

INFRASTRUCTURE GRIDS AND NETWORKS

THE CHALLENGES AHEAD, AMID SECURITY AND EFFICIENCY

edited by **Carlo Secchi** and **Alessandro Gili**

with the knowledge partnership of

**McKinsey
& Company**



ISPI

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Via Antonio Boselli, 10 – 20136 Milan – Italy
www.ledizioni.it
info@ledizioni.it

INFRASTRUCTURE GRIDS AND NETWORKS. THE CHALLENGES AHEAD, AMID
SECURITY AND EFFICIENCY

Edited by Carlo Secchi and Alessandro Gili
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Introduction

In recent years, the pace of geopolitical and economic upheavals, alongside the frequency of climate-related disasters, has accelerated significantly. Adding to this instability is the uncertainty surrounding the policy direction of a second Trump administration, which has further strained international relations – particularly the transatlantic alliance.

However, long before Trump's return to the political stage, concerns over de-risking and economic security had already become central to the European agenda and to the strategies of major global economies. These priorities have driven the development of redundancy measures, the creation of new trade corridors and logistical networks, and the expansion of energy infrastructure, including electricity grids and pipelines.

This report delves into the pivotal role of critical infrastructure networks and grids as the backbone of today's global economy and as essential foundations for achieving the primary objectives of economic growth, competitiveness, and energy and digital transitions. From highways and railways to subsea electricity grids, digital undersea networks, and the interconnected global network of ports and airports, these systems serve as vital enablers of economic growth, innovation, and sustainable development. By highlighting their significance, this analysis emphasizes how these interconnected grids and networks drive progress and resilience in modern economies, which are increasingly exposed to a variety of risks.

The critical importance of infrastructure brings into focus the pressing question of its safety and security. Enhancing security is essential, particularly in an era marked by geopolitical instability, hybrid threats, sabotage, and escalating international tensions. Protecting critical infrastructure from harmful actions by hostile or third-party actors is vital to ensuring the smooth and efficient operation of the essential assets that underpin modern societies. To this end, both national and international measures are being implemented to bolster defense and cybersecurity, reducing the risks and impacts of potential attacks and disruptions.

There is a growing consensus that actions once known as “disaster recovery plans” – which gained global prominence following the September 11, 2001 attacks on the Twin Towers – can only serve as a starting point for more effective measures to enhance both security and safety.

In the energy sector, security extends beyond protection to encompass the diversification of supply chains. For instance, avoiding strategic dependencies, such as Europe’s previous reliance on Russian natural gas, is a priority. New pipelines and LNG terminals are pivotal in achieving diversification. Similarly, the establishment of electricity grids spanning regions and countries is crucial for fostering integrated electricity markets and linking renewable energy production with major centers of consumption. The Mediterranean basin, in particular, offers a promising model for a new strategy of interconnected grids and networks, forging mutually beneficial partnerships between energy-producing and consuming nations.

Closely related to security is the concept of safety, which focuses on minimizing and preventing unintentional damage – whether from natural disasters or human error – to critical grids and networks. Safety is inherently tied to resilience, emphasizing the capacity to withstand and recover from disruptions. This topic was extensively discussed in the 2023 ISPI Report, which focused on strengthening infrastructure resilience, an issue clearly linked with infrastructure safety.

Finally, the issue of dual-use is increasingly significant, especially for mobility networks. Amid growing international tensions, military mobility is becoming an integral consideration in the design and adaptation of core transportation systems, as highlighted in the 2024 revision of the EU TEN-T Network Regulation. As a matter of fact, the issue of military mobility has become increasingly important after the outbreak of the Russian aggression against Ukraine, and this Country was well covered by the new layout of the European transport corridors. On another front, the concept of dual-use also encompasses the ability of transport infrastructure to accommodate other grids and pipelines, such as digital, electricity, and natural gas networks, thereby promoting cross-regional and cross-national interconnectivity (for example, by enabling the installation of electricity or digital cables within a transport tunnel infrastructure). Moreover, dual use also implies that critical infrastructure, such as ports, can serve additional purposes, including evolving into key energy hubs over time. However, dual-use infrastructure may also introduce additional threats – such as those related to military mobility – which must be considered when planning, reinforcing, and adapting the infrastructure involved. In fact, designating these infrastructures as critical assets for military mobility may make them increasingly attractive targets for hostile actors.

In the digital realm, undersea cables form the backbone of global internet connectivity, carrying approximately 97-99% of worldwide data traffic. They are also crucial for facilitating nearly all international economic and financial transactions. However, recent events have highlighted their vulnerability to both intentional and unintentional damage. Geopolitical attacks, as well as natural disasters such as earthquakes and volcanic eruptions, pose significant threats to the integrity and functionality of these critical international digital networks.

To mitigate these risks and prevent major disruptions to global and regional connectivity, strategies focusing on redundancy and enhanced defense measures are being actively

pursued. These include increased surveillance and deterrence efforts aimed at protecting this vital infrastructure from potential harm.

On the other hand, the prospects for alternative forms of digital and internet connectivity are growing, with satellite internet constellations gaining traction. While these systems do not yet match the latency, speed, and reliability of cable connections, they are making significant strides. For example, Elon Musk's Starlink constellation is increasingly enabling internet access in remote areas and supporting military or governmental operations. However, this advancement introduces additional security risks, such as safeguarding critical data and addressing concerns over the potential monopoly position of Starlink. To mitigate this latter risk, several countries are developing their own satellite internet constellations. Notable initiatives include China's Thousand Sails mega constellation and the EU's IRIS² project, both aimed at diversifying the market and enhancing global connectivity options. There is an emerging situation of overcrowding of satellites in low orbit, which moreover have an overall short life cycle and therefore by producing space debris reduce the space available for other satellites.

Increasing the security and safety of network and grid infrastructure inevitably raises the overall costs associated with their design, construction, operation, and maintenance. Factors such as climate change, escalating international conflicts, and rising geopolitical tensions further exacerbate these costs. These challenges make the trade-off between security and efficiency more pressing than ever. As global networks become increasingly interconnected, the need for robust security measures to protect against both physical and cyber threats intensifies, often at the expense of operational efficiency. At the same time, the urgency of addressing climate-related risks, such as extreme weather events, places additional strain on resources. However, new technologies and AI can offer cost-effective security and safety solutions for grids and networks, especially when compared to past approaches. AI can amplify the potential benefits of

certain technological developments currently under study or nearing deployment – such as the use of data from cyber tyres to help prevent security and safety issues in both urban and long-distance road transportation. In addition, AI can prove to be a useful support in the deployment of ERTMS to improve railway mobility and interoperability.

The cross-border and international nature of grids and networks – particularly electric grids, gas pipelines, and digital cables, which often span across international waters and special economic zones – requires the strengthening of international laws in this area. This is especially important when addressing the issue of liability for damages caused to these infrastructures. As these critical networks connect multiple nations and regions, establishing clear frameworks for responsibility and accountability becomes essential to ensure fair resolution in case of accidents, disruptions, or environmental harm, as well as concerning the route of laying these cables. Moreover, as the global reliance on these systems continues to grow, there is an increasing need for collaboration among international regulatory bodies to ensure that legal standards are updated to address emerging challenges, such as cyber threats, climate-related risks, and technological advancements.

This report will address the topics outlined above. The first section will examine the geopolitical rationale behind infrastructure investments in new transport corridors and seaports, as well as their impact on competitiveness. It will also consider the technological opportunities that support the energy transition and the digitalization of transport infrastructure.

Next, the report will explore the evolving strategies and growing investments in digital networks and electricity grids – both of which are crucial for technological advancement and enhanced economic competitiveness. It will also assess whether satellite communications could serve as a viable alternative to undersea digital networks, potentially strengthening redundancy and reducing the risk of disruptions to global digital connectivity.

The financial dimension of cross-border connectivity – particularly within the European Union – will also be analyzed, along with strategies to improve the security of critical connectivity infrastructure. This includes consideration of the increasing role of military mobility in safeguarding such assets.

Finally, the first section of the Report will focus on the international legal framework governing undersea digital cables and submarine power grids. It will review the regulations surrounding their deployment, protection against threats, and protocols for response in the event of an attack or disruption.

The second part of the report will adopt a geographical perspective, analyzing the main transport and energy corridors emerging at the international level, such as the India-Middle East-Europe Corridor (IMEC) and the Middle Corridor. In line with ISPI's traditional areas of focus, Mediterranean transport and energy connectivity will also be examined, with the analysis expanded to include the broader contexts of Africa and the Middle East.

Significant attention will be devoted to the Americas, exploring the impact of Trump-era policies on transport and energy infrastructure in the United States, as well as the growing investments in connectivity infrastructure across Latin America.

Finally, the report will turn to Asia and China in particular, where investment in railway infrastructure – both domestically and with neighboring countries – has surged over the past decade. China is also emerging as a leader in the development of new electricity grids and is increasingly competing with the United States in the domain of digital undersea cables. Could this leadership be challenged by rising debt levels, as well as by the protectionist and economic security measures adopted by China's main trading partners, such as the US and the EU?

The trade-off between security and efficiency – sharpened by increasingly strained international relations – seems to be here to stay. Governments and economic actors alike are now more willing to absorb higher costs to ensure the resilience

and security of their supply chains, energy sources, and communications networks.

While building redundancy undeniably comes at a price, it may ultimately prevent far greater economic losses in the event of disruptions or targeted attacks. The same logic applies to climate resilience: preparing for and adapting to extreme weather events is becoming a critical component of long-term planning.

In this rapidly evolving global landscape, economic decisions will be increasingly shaped by considerations of risk and uncertainty. Only time will reveal where the balance in this trade-off between security/resilience and efficiency will ultimately lie.

Carlo Secchi, Alessandro Gili

SAFETY AND SECURITY: DISTINCT YET INTERCONNECTED CONCEPTS

The terms *safety* and *security* are often used interchangeably in everyday language, but they refer to different concepts with distinct meanings.

Safety relates to resilience and robustness – the ability of a system, structure, or process to withstand events of a natural or accidental nature, not caused by deliberate human actions. It is a critical requirement for any operation or initiative. However, safety comes with a cost, presenting a classic trade-off: the greater the desired level of robustness, the higher the financial investment required (e.g., building railroad tracks out of gold would enhance durability, but at a significantly higher cost).

Security, on the other hand, refers to the capacity to withstand or prevent harm caused by intentional acts. These may range from acts of war or terrorism to more economically motivated behaviors, such as cyberattacks designed to gain financial advantage or inflict economic damage. As with safety, maintaining security involves costs, and decisions must be made regarding how much to invest based on the expected benefits – a balance between risk and reward.

Importantly, both safety and security levels are not static. They can change over time due to new threats or evolving conditions. Security, in particular, is often influenced by changes in human behavior or geopolitical dynamics. Safety risks may also increase as a result of emerging and unprecedented natural challenges, such as those linked to climate change, which demand proactive resilience strategies.

1. The Redrawing of the Global Connectivity Map. What's Next?

Alessandro Gili, Roberto Italia

What does connectivity mean in an era of permacrisis where strategic interdependencies are increasingly weaponized? Answering this question has become more complex amid accelerating geopolitical shifts that are shaking the foundations of global order. These changes challenge not only the scope but also the economic rationale behind national and cross-border critical infrastructure networks.

The era in which economic efficiency was the primary and sole driver for developing such infrastructure is over. Today, critical connectivity must also serve a broader strategic purpose: ensuring national resilience, safeguarding economic sovereignty, and preventing the emergence of dependencies that could compromise security. Infrastructure decisions are no longer just technical or economic – they are increasingly political, shaped by concerns over power, influence, and vulnerability.¹

As global competition intensifies, connectivity becomes a strategic asset, not just a utility. The Nord Stream 1 and 2 pipelines – linking Germany with Russia through the Baltic Sea – offer a striking example of how strategic energy infrastructure can both connect markets and create dangerous dependencies. Initially, these pipelines served as powerful tools for economic integration, linking a fossil fuel-rich Russia with

¹ M. Bridges, [Infrastructure Is Remaking Geopolitics](#), *Foreign Affairs*, 10 May 2024.

Germany, Europe's largest manufacturing powerhouse in need of cheap energy. However, they also demonstrated how such infrastructure can be turned into instruments of coercion, enabling the weaponization of interdependence to influence political decisions.

By early 2022, Nord Stream 1 was carrying natural gas that accounted for approximately 55% of Germany's total natural gas imports. The situation could have been even more critical had Nord Stream 2 become operational. That outcome was ultimately averted when the German government halted the project and imposed sanctions on Russia just days before the full-scale invasion of Ukraine in February 2022. Later, in September 2022, a series of underwater explosions severely damaged both pipelines, causing massive gas leaks and rendering them inoperable.²

The Nord Stream case illustrates a broader lesson: economic linkages – whether they take the form of energy pipelines, digital cables, or transport corridors – can facilitate prosperity, but they can also be exploited to build and exert strategic dependencies. In the case of Nord Stream, what once supplied Germany with affordable energy for its industries and households also became a geopolitical liability.

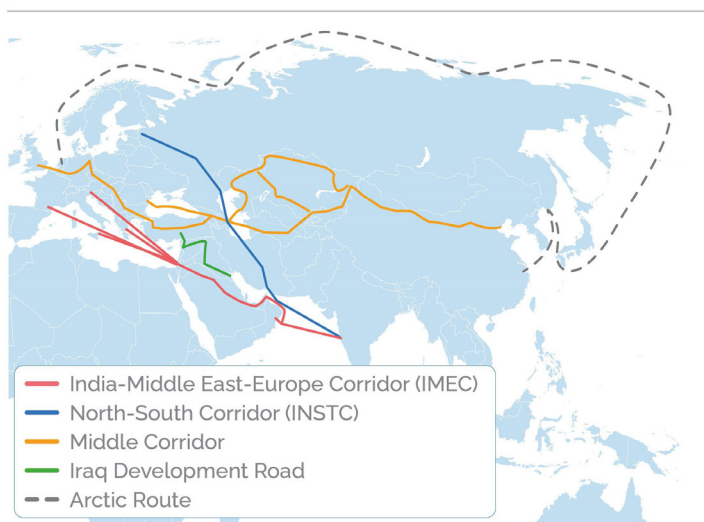
The Covid-19 pandemic, followed by geopolitical upheaval driven by the war in Ukraine, the ongoing conflict in the Middle East, and, more recently, the global trade disruption triggered by the second US Trump administration, is rapidly reshaping global connectivity priorities.

At the same time, major economies are implementing industrial policies aimed at reclaiming manufacturing capacity and leading the transition to green and digital technologies. These efforts are redrawing global flows of goods, commodities, energy, and data.

² N. Adomaitis and J. Ahlander, “[Nord Stream: What’s known about the mystery pipeline explosions?](#)”, *Reuters*, 7 February 2024.

As a result, the demand for transport infrastructure, logistics networks, electricity grids, and energy pipelines is undergoing significant transformation. In essence, geopolitics and geoeconomics are reshaping the global connectivity landscape – or, to borrow Parag Khanna’s term, the world’s “connectography”.³ The new guiding principle for global corridors, grids, and networks has increasingly become diversification and redundancy, as reflected in numerous policy strategies over the past two years focused on transport, energy, and digital connectivity.

FIG. 1.1 - THE RACE FOR NEW STRATEGIC ROUTES



Source: ISPI elaborations

³ P. Khanna, *Connectography: Mapping the Global Network Revolution*, W&N, 16 April 2016.

In the field of transport and logistics connectivity, as highlighted in the 2024 ISPI Infrastructure Report on global logistics, trade routes have been shifting due to both short-term disruptions and long-term structural changes.⁴

New industrial policies – such as the US Inflation Reduction Act, various EU initiatives, and the growing prominence of clean and high-tech manufacturing hubs in Asia (including China, India, Japan, and other South Asian countries) – have begun to reshape global value chains. This trend has been further accelerated by efforts from the US and EU to reduce strategic dependencies on China, particularly in critical sectors. Even before the return of the Trump administration, these shifts had already led to an increased use of export controls, economic security measures, and restrictions on foreign direct investment. These actions have contributed to the fragmentation of global value chains and the re-routing of international trade flows.⁵

Processes such as reshoring, nearshoring, and friendshoring have also gained momentum, pointing to the rise of new economic connectors – countries like Vietnam, Mexico, and Morocco – which are emerging as key bridges between geopolitical blocs. This is taking place alongside a broader reorganization of trade and logistics networks among like-minded nations, signalling a new phase in globalisation.⁶

⁴ C. Secchi and A. Gili, *Logistics in Transition. Exploring Geopolitical, Economic, and Technological Trends*, ISPI-McKinsey Report, Milan, Ledizioni, May 2024.

⁵ F. Chimits, C. McCaffrey, J. Mejino Lopez, N. Poitiers, V. Vicard, and P. Wibaux, *European Economic Security: Current practices and further development, In-Depth Analysis*, European Parliament, April 2024. See also F. Fasulo and A. Gili, *The Rise of Fragmentation. A New Economic Security Era?*, ISPI Report, Milan, Ledizioni, September 2024; E. Fabry, N. Köhler-Suzuki, P. Lamy, and M. Sibona, “Shields Up: How China, Europe, Japan and the United States Shape the World through Economic Security”, Policy Paper no. 297, Jacques Delors Institute, February 2024.

⁶ S. Zhengxi Wu, “China and the US both want to ‘friendshore’ in Vietnam”, Atlantic Council, 26 June 2024. See also A. Kateb, “Morocco’s Long Road Toward Economic Transformation”, Carnegie Middle East Center, 20 September 2024.

However, the return of Donald Trump to the White House has reshuffled the deck. The new US administration has adopted a more confrontational stance toward the rest of the world, “friends” and “foes” alike, in line with its 2025 Trade Policy Agenda. The document, released last March, asserts that “the United States must have an economy focused on production”, which means a high-wage economy that fosters job creation, drives innovation, and strengthens national defence.⁷ From 20 January through early June 2025, the White House has implemented several historic tariff measures, invoking new legal foundations (e.g. the International Emergency Economic Powers Act – IEEPA of 1977) beyond the statutes used during Trump’s first term.⁸

Below are the measures taken so far:

1. IEEPA tariffs to address the northern and southern border security issues and the fentanyl crisis, i.e. two successive rounds of a 10% tariff on all imports from China; a 25% on those goods from Mexico and Canada (except for potash and Canadian energy, which receive a lower 10% rate) that do not qualify for duty-free treatment under the US-Mexico-Canada Agreement (USMCA);
2. Section 232 tariffs, i.e. two successive rounds of a 25% tariff on imports of steel and aluminium, including derivative metal products based on the value of their steel and aluminium content, with no country exemptions; 3 a 25% tariff also on imports of automobiles and certain automobile parts;
3. Section 232 investigations to assess whether imports of copper, timber and lumber, semiconductors, pharmaceuticals, medium and heavy-duty trucks, processed

⁷ Office of the United States Trade Representative, [The President’s 2025 Trade Policy Agenda](#), 3 March 2025.

⁸ Section 232 of the Trade Expansion Act of 1962 to protect national security, Section 201 of the Trade Act of 1974 to safeguard domestic industries, Section 301 of the Trade Act of 1974 to address trade agreement violations and unfair trade practices.

critical minerals and derivative products, commercial aircraft and jet engines pose a threat to US national security;

4. finally, on April 2, the so-called “Liberation Day”, Trump announced the IEEPA “reciprocal” tariffs to reduce the large and persistent US goods trade deficit, which has been “caused in substantial part by a lack of reciprocity” from foreign countries according to the current US administration: a 10% “baseline” rate on most trade partners; a set of higher, country-specific “reciprocal” rates on 57 counterparts (e.g. a 20% tariff on EU goods) with which the United States has bilateral goods trade deficits. Products that are already subject to, or may be targeted in the future by, specific Section 232 tariffs, energy/energy products, and imports from Canada and Mexico (at least temporarily) are exempt from this round of duties.⁹

At the time of writing in early June, Trump’s trade policy is still in flux. First, several goods may soon be targeted by product-specific tariffs under Section 232. Second, the country-specific “reciprocal” tariffs have been suspended for all 57 trading partners, including China and the EU, with only the 10% rate currently in effect following Trump’s decision to grant a 90-day pause.

Third, checks and balances have added a fresh layer of uncertainty. On May 28, the US Court of International Trade voted in a 3-0 opinion that all of Trump’s IEEPA tariffs (thus, the ones to address the northern and southern border security issues and the fentanyl crisis, and the “Liberation Day” tariffs) were unlawful because IEEPA does not grant such unbounded authority to the President.¹⁰ The court permanently enjoined

⁹ The White House, [Executive Order: Regulating Imports with a Reciprocal Tariff to Rectify Trade Practices that Contribute to Large and Persistent Annual United States Goods Trade Deficits](#), 2 April 2025.

¹⁰ In a separate case, the US District Court for the District of Columbia ruled

these tariffs, but the government immediately appealed.¹¹ The very next day the US Court of Appeals for the Federal Circuit allowed the IEEPA tariffs to continue being collected while the case is under appeal. If higher courts uphold the initial ruling, potentially culminating in a Supreme Court decision, these tariffs will be lifted, and importers could receive refunds for duties already paid.

Despite the legal and procedural uncertainty surrounding this key pillar of the administration's trade agenda, US tariffs have already risen compared to 2024. Such a spike, never seen in a century in the country, could prove counterproductive for American interests and, in the case of the transatlantic relationship, could even spark the (cautious) redefinition of the relationship between the EU and China. A path fraught with obstacles, just considering the split of the EU Member States on how to cope with the imports of battery electric vehicles from China last year.

Moreover, Trump's actions push the EU to be bolder in its de-risking agenda, notably by leveraging the largest network of trade agreements in the world. In fact, Brussels has accelerated negotiations for comprehensive and modernized trade agreements with emerging economies. Currently, trade negotiations are ongoing with countries such as India, the Philippines and Thailand. The European Commission officially concluded negotiations on a comprehensive agreement with Mercosur (after 25 years) in December 2024 and updated a previous agreement with Mexico (after 9 years) in January 2025, although the complex ratification process lies ahead. Since free trade is not experiencing its brightest season, the EU has been working on other channels of cooperation: the

that IEEPA does not authorize tariffs at all.

¹¹ The US Court of International Trade is part of the nation's federal court system and was created by Congress to handle specialized disputes around trade, including tariffs. Decisions are appealed on the same track as rulings from district courts, meaning a challenge would go to a federal appeals court and then the US Supreme Court.

EU-India Trade and Technology Council (on the model of the TTC with the US); bilateral partnerships on strategic raw materials (e.g. with Canada, Australia or Namibia) and the Minerals Security Partnership (regardless of what its leading partner, the US, decides to do in the future); digital trade agreements with Singapore and South Korea as well as digital trade partnerships with both countries plus Japan and Canada; the High Level Economic Dialogue with Japan; and last but not least, the Global Gateway initiative, which seeks to reduce reliance on China and enhance EU-Africa transport integration and value chains, particularly through 12 strategic multimodal corridors.¹²

In this rapidly changing strategic and economic landscape, ongoing military conflicts are placing additional pressure on already strained and volatile international economic relations and global value chains. Since December 2023, Houthi attacks on container and energy vessels transiting the Red Sea have severely disrupted traffic through the Suez Canal, resulting in a 50% decline in 2024. This disruption has led to increased costs and longer shipping times, as more vessels are forced to reroute via the Cape of Good Hope – a detour that is increasingly becoming a structural alternative. This shift is also beginning to affect maritime traffic within the Mediterranean basin, further altering traditional trade dynamics.¹³

Against this backdrop, the transport corridors connecting Asia and Europe are experiencing a revival. The Middle Corridor (or Trans-Caspian International Transport Route) – established in 2017 – has assumed a critical role, especially following Russia's invasion of Ukraine and the subsequent exclusion of the traditional Northern Route, which passed

¹² European Commission, [EU-Africa: Global Gateway Investment Package - Strategic Corridors](#), October 2023.

¹³ I. Lahiri, "Egypt's Suez Canal revenue fell sharply in 2024 on regional tensions", *Euronews*, 17 April 2025. See also SRM, *Italian Maritime Economy. Le nuove sfide dei porti dell'area euro-mediterranea. La crisi nel Mar Rosso e le trasformazioni imposte dai modelli green*, 11° Rapporto Annuale, 2024.

through Russian territory and was widely used by European operators.¹⁴ By 2024, traffic along the Middle Corridor had increased more than fourfold compared to 2021, with a remarkable 63% growth in 2024 alone.¹⁵ This surge has been supported by substantial infrastructure investments in both ports and railways. Key developments include upgrades to ports on the Caspian Sea – such as Aktau in Kazakhstan, Turkmenbashi in Turkmenistan, and Anaklia in Georgia (with rising Chinese investments) – as well as improvements to the Kazakh and Uzbek railway networks and increased capacity on the Baku-Tbilisi-Kars (BTK) railway line.¹⁶

The European Union has reaffirmed its commitment to enhancing connectivity with Central Asia. At the first EU-Central Asia summit in April 2025, the partnership was elevated to a strategic level. The EU also pledged to mobilize up to €12 billion through the Global Gateway framework to support sustainable transport infrastructure and logistics networks in Central Asia – particularly the Middle Corridor. This initiative aims to reduce regulatory and technical bottlenecks and ultimately integrate the Corridor into the EU's Trans-European Transport Network (TEN-T).¹⁷

¹⁴ A. Dayar, “22 Days from Japan to Europe: East Asia’s Middle Corridor Milestone”, Caspian Policy Center, 27 March 2025. See also World Bank, “Middle Trade and Transport Corridor: Policies and Investments to Triple Freight Volumes and Halve Travel Time by 2030”, November 2023; OECD, “Realising the Potential of the Middle Corridor”, 2023.

¹⁵ S. Sakenova, “Cargo Transport via Middle Corridor Surges to 4.1 Million Tons in 11 Months”, *The Astana Times*, 18 December 2024.

¹⁶ G. Hajiyeva, “Baku-Tbilisi-Kars Railway Celebrates Seven Years of Transforming Regional Connectivity”, *Caspian News*, 31 October 2024. See also I. Nechepurenko, “Plans for a Chinese Port Roil the Politics of a Former Soviet Nation”, *New York Times*, 13 March 2025.

¹⁷ Council of the European Union, [Joint press release following the first EU-Central Asia summit](#), Press Release, 4 April 2025. See also J. Vakhobov, and A. Komilov, “The EU and Central Asia Can Forge a Strategic Partnership Through Connectivity”, *The Diplomat*, 3 April 2025.

Meanwhile, China has shown renewed interest in the Middle Corridor. At the 8th International Silk Road Expo in Xi'an in September 2024, Beijing announced its formal participation in the initiative through the China Railway Container Transport Corporation (CRTC).¹⁸ Additionally, a third rail crossing between China and Kazakhstan is currently under construction and is expected to be completed by 2027. This new link will further boost trade between the two countries and enhance the overall capacity of the Middle Corridor.¹⁹

Another emerging global transport network with significant future potential is the India-Middle East-Europe Economic Corridor (IMEC), officially launched in September 2023 on the sidelines of the G20 Summit in New Delhi. The initiative brings together the European Union (particularly France, Germany, and Italy), India, the United States, Israel, Jordan, Saudi Arabia, and the United Arab Emirates.²⁰

India is making major investments in maritime infrastructure, including the \$9 billion Vadhavan Port in northwest India – a deep-sea facility expected to become one of the world's largest container ports by 2035.²¹ The country is also working to connect its major international ports with key national industrial centers by developing railway and logistics infrastructure, as well as advancing 11 industrial corridor projects.²²

¹⁸ R.M. Cutler, “China Officially Joins the Middle Corridor”, *The Times of Central Asia*, 2 October 2024.

¹⁹ Railway Supply, “Kazakhstan-China Rail Crossing to Open in 2027, Expanding Trade Routes”, 30 September 2024.

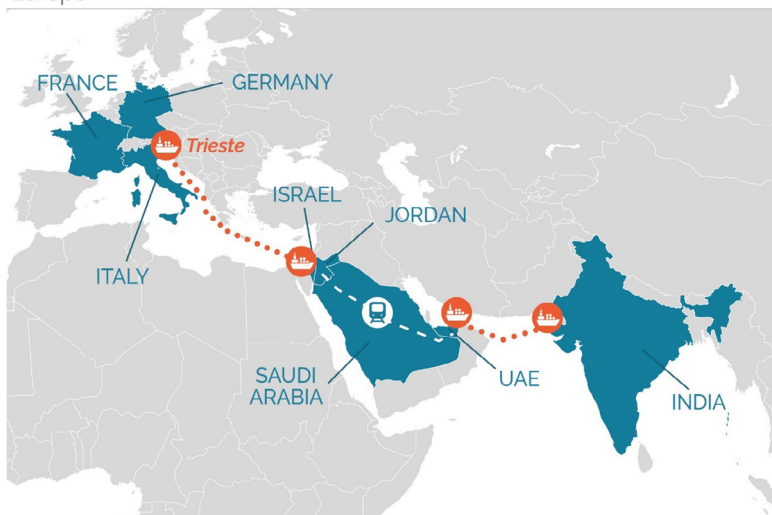
²⁰ The White House, *Memorandum of Understanding on the Principles of an India – Middle East – Europe Economic Corridor*, Press Release, 9 September 2023.

²¹ D. Peri, “Vadhavan port will be a game changer for India”, *The Hindu*, 2 December 2024. See also S. Patel, “India approves \$9-billion port to boost trade with Europe”, *Reuters*, 19 June 2024.

²² A. Delivorias and D. Falkenberg, *India's Connectivity Initiatives. A multi-faceted strategy*, European Parliamentary Research Service, October 2024.

FIG. 1.2 – IMEC: INDIA-MIDDLE EAST-EUROPE
ECONOMIC CORRIDOR

The economic corridor project linking India to the Middle East and Europe



Source: ISPI elaborations

On the land segment through the Gulf region, the Gulf Railway Project appears to have regained momentum. Originally launched in 2009 but stalled multiple times due to regional geopolitical instability, the 2,100 km railway – intended to connect all six Gulf Cooperation Council (GCC) countries – is now back on track. Relaunched in 2024 with planned investments of up to \$250 billion, the project is scheduled for completion by 2030 and is set to become the backbone of IMEC’s Gulf land segment. The Gulf Railway Project could indeed be functional to connect the UAE’s landing point to Saudi Arabia, Jordan, and Israel.²³ Additionally, a new railway connecting key

²³ H. Cameron, “[Momentum Builds for \\$250 Billion Mega Railway Project](#)”, *Newsweek*, 17 October 2024. See also [Railway Supply](#), [GCC Railways Project](#):

Omani ports with the UAE is under development, potentially expanding IMEC's geographical reach in the Arab region to include Oman's strategic ports.²⁴

The project has reaffirmed its strategic relevance to the new Trump administration, which views IMEC as a key tool to counter and isolate China's growing influence across the Indo-Pacific, the Middle East, and Europe. While it remains uncertain how the land route will connect to Israel's Mediterranean ports given the ongoing regional conflict, President Trump reiterated during a meeting with Indian Prime Minister Modi in February 2025 that IMEC could play a pivotal role in fostering economic integration among participating countries. He also emphasized its potential to support the normalization of political relations in the region – an objective previously pursued through the Abraham Accords during his first administration.²⁵ For the United States, IMEC represents not only a strategic infrastructure alternative but also a critical mechanism to “de-risk” from China and contain the expansion of Beijing's Belt and Road Initiative (BRI) across the region.²⁶

The situation on the European segment of the project remains unclear and is still evolving. A key question is whether the landing point should be located in Greece, Italy, or France.

The Port of Piraeus in Greece presents some challenges, particularly due to its control by COSCO, a Chinese state-owned multinational marine transportation conglomerate. Additionally, Greece has limited integration into the core TEN-T (Trans-European Transport Network) corridors. However, the 2024 revision of the TEN-T Regulation is

[Connecting Gulf Nations with a Unified Railway Network by 2030](#), 9 November 2024.

²⁴ D. van der Laan, “[Oman – UAE Hafeet Rail project awards major contracts](#)”, Rail Freight, 12 February 2025.

²⁵ The White House, [United States – India Joint Leaders' Statement](#), 13 February 2025.

²⁶ W.F. Wechsler, “[The continent-spanning win Trump can secure with Modi](#)”, Atlantic Council, 10 February 2025.

expected to enhance long-term connectivity in the Western Balkans, potentially improving links between Greece and Central Europe, thus strengthening Greece's strategic role in the Mediterranean.²⁷

France has recently designated Marseille as the European landing point for IMEC. In early 2024, the French government also appointed a special envoy for IMEC to help shape the project and secure France's involvement. Despite these steps, the final decision regarding the European entry point remains open.²⁸

Italy has been working to catch up. In April 2025, it appointed a special envoy for IMEC and proposed Trieste as another potential European hub.²⁹ The Adriatic deep-sea port of Trieste offers several advantages, including a special tax regime and robust infrastructure, particularly strong rail connections to Central Europe. The city and its port are part of two EU TEN-T corridors: the Mediterranean and the Adriatic-Baltic.³⁰ Germany is Trieste's top trading partner by rail traffic, accounting for around 30% of total rail movements.³¹ Furthermore, Trieste is a major supplier of oil to Central European countries such as Germany and the Czech Republic, primarily via the Transalpine Pipeline (TAL).³²

²⁷ D. Gavalas and G. Dikaïos, "Connecting Opportunities: Greece's Strategic Role in the India-Middle East-Europe Economic Corridor", ELIAMEP, Policy Brief 194/2025, 22 January 2025.

²⁸ Ministère de l'Europe et des Affaires étrangères, *Visit of Gérard Mestrallet to India*, 18 September 2024.

²⁹ E. Rossi, "L'Italia nomina l'ambasciatore Talò come inviato per Imec", *Formiche*, 2 April 2025.

³⁰ G. Terzi di Sant'Agata and V. Shenoy, "Trieste as pillar of IMEC for Europe could create a new Golden Road for India", *The Economic Times*, 10 February 2025. See also F. Parisi, "Corridoio indo-mediterraneo: «Trieste porto gateway per Europa»", *AdriaPorts*, 6 March 2025.

³¹ *AdriaPorts*, "Porto di Trieste, Germania primo «cliente» per traffico ferroviario", 12 May 2023.

³² J. Lopatka, "Czechs to start oil imports through upgraded TAL pipeline in April", *Reuters*, 27 March 2025.

It is important to note that Marseille and Trieste should not necessarily be viewed as competitors. They could instead serve different markets, and IMEC could be designed as a multi-point network rather than a single point-to-point corridor. Such a configuration could improve the corridor's efficiency and economic rationale, while also reducing the risk of emerging competition.³³

Indeed, Turkey has expressed opposition to the IMEC corridor. President Erdoğan has asserted that no new corridor should be built without Turkey's involvement. In response, Turkey is promoting the \$17 billion Iraqi Development Road Project – a 1,200-km road and rail corridor linking the port of Faw in Basra to Faysh Khabur on the Iraq-Turkey border and further connecting to Turkey's rail and road networks. This route would provide access to the Mediterranean via the port of Mersin and allow road access to Europe through Istanbul.³⁴

Finally, a multi-point corridor approach could also support the EU's broader strategy under its Global Gateway and Investment Package for Africa and Italy's investment and strategic priorities in the Mediterranean and Africa under the Mattei Plan.³⁵ Egypt, backed by France, has signalled its interest to be involved in the IMEC initiative.³⁶ During a state visit by King Salman of Saudi Arabia to Cairo, the two countries reaffirmed their commitment to strengthening ties by constructing a bridge linking Saudi Arabia to the Sinai Peninsula across the Red Sea.³⁷

³³ See A. Rizzi, [“The infinite connection: How to make the India-Middle East-Europe economic corridor happen”](#), European Council on Foreign Relations (ECFR), 23 April 2024.

³⁴ A. Samson, [“Turkey floats alternative to G20's India-Middle East trade corridor plan”](#), *Financial Times*, 17 September 2023.

³⁵ European Commission, [EU-Africa: Global Gateway Investment Package](#).

³⁶ *Africa Intelligence*, [“Cairo aims to graft itself on to IMEC economic corridor”](#), 16 April 2025.

³⁷ *The Arab Weekly*, [“Egypt to build bridge to Saudi Arabia, integrate railways into Asia-Europe trade”](#), 26 May 2025.

Climate change may also open up new maritime corridors in the future. As Arctic ice continues to melt, previously inaccessible routes – such as the Northern Sea Route (NSR) – are becoming increasingly navigable. This particular route offers significant advantages, including a reduction in travel time and operational costs on the Europe-Asia corridor. For instance, it is approximately 6,400 km shorter than the traditional Shanghai-Rotterdam route via the Suez Canal, cutting transit time from 48 to around 35 days. In 2024, the route recorded transit traffic of more than 3 million tons, an increase of about 50%, with vessels carrying crude oil dominating.³⁸ However, several challenges remain. Operational costs are still high, due in part to the need for icebreakers, which are expensive to operate. Additionally, the NSR is limited by its seasonality and underdeveloped infrastructure. Some shipowners will only consider using the route if it proves profitable, which currently limits its viability; some others will avoid it for environmental reasons. The NSR is not suitable for all types of vessels; it is generally accessible only to smaller ships. That said, it could benefit sectors such as agribusiness, where the naturally low temperatures help preserve food and reduce refrigeration costs.³⁹

There are also significant geopolitical considerations. Russia maintains military infrastructure along the NSR and requires foreign ships to obtain permits to pass through waters it claims as part of its Exclusive Economic Zone – an assertion that conflicts with international maritime law. China, which describes itself as a “near-Arctic state” has also expressed strong interest in the route, viewing it as a strategic alternative to diversify its trade routes with Europe.⁴⁰

³⁸ Eurasian Rail Alliance Index, [The Northern Sea Route as a key Russian transport corridor: strategic importance and development prospects](#), 31 March 2025.

³⁹ E. Peschiera, “Alternativa o illusione? La Northern Sea Route secondo Alessandro Panaro”, *Osservatorio Artico*, 17 March 2025.

⁴⁰ A. Dagaev, “The Arctic Is Testing the Limits of the Sino-Russian Partnership”, *Carnegie Politika*, 18 February 2025.

In the United States, the strategic importance of maritime connectivity was underscored by a new Executive Order (EO) issued by President Trump in April 2024. Aimed at restoring “America’s Maritime Dominance”, the EO highlights the deep interconnection between the maritime industry and control over international shipping routes. In addition, it acknowledges China’s overwhelming dominance in the global maritime sector, noting that approximately 80% of the world’s ships and ship-to-shore cranes, as well as 96% of shipping containers, are manufactured by China. In contrast, the US currently lacks significant production capabilities in these critical segments. To address this imbalance, the order introduces a Maritime Action Plan (MAP) designed to revitalize American maritime industries, counter China’s dominance, and strengthen the resilience of the US supply chain. It emphasizes that maritime transport is essential to American economic security and the unrestricted flow of global trade.⁴¹

Beginning October 14, Chinese-built and owned vessels will be subject to a fee of \$50 per net ton, with an annual increase of \$30 over the next three years. Chinese-built vessels owned by non-Chinese entities will be charged \$18 per net ton, with a \$5 annual increase over the same period. This policy marks a clear shift in the US stance on international maritime connectivity.⁴²

President Trump has also expressed a desire to regain influence over the Panama Canal, where the two main ports – Balboa and Cristobal – are currently operated by the Chinese company Hutchison Ports.⁴³ At the time of writing, the Swiss-Italian MSC Group, in partnership with American investment

⁴¹ The White House, [Fact Sheet: President Donald J. Trump Restores America’s Maritime Dominance](#), 9 April 2025.

⁴² K. Magramo and A. Cooban, [“The US wants to charge Chinese ships to dock at American ports”](#), CNN, 18 April 2025.

⁴³ S. Camacho, [“The Crisis Trump Is Causing in Panama Will Reach Far Into Latin America”](#), Carnegie Endowment for International Peace, 19 February 2025. See also S. Waldenberg and M. Rios, [“Trump reiterates threat to retake Panama Canal ‘or something very powerful’ will happen”](#), CNN, 2 February 2025.

firm BlackRock, is nearing completion of a €17.5 billion deal to acquire an 80% stake in Hutchison Ports. The acquisition includes the two key Panama Canal ports and 40 other terminals across 23 countries, many located in Africa and Asia.⁴⁴

The Panama Canal remains indeed strategically vital for the US, particularly because the nation's largest container ports are on the East Coast. A significant share of US trade with Asia passes through these ports and thus through the Panama Canal. This dependency is further intensified by the lack of new investment of rail infrastructure to transport goods between industrial hubs in the East Coast and Rust Belt to the West Coast.⁴⁵

Besides the global corridors, connectivity is also a cornerstone of internal competitiveness. The Trans-European Transport Network (TEN-T) has been envisioned as the backbone for advancing the integration of the EU's internal market by establishing an efficient, multimodal, and high-quality transport infrastructure across the Union. The network encompasses railways, inland waterways, short sea shipping routes, and roads that link urban nodes, maritime and inland ports, airports, and terminals. Its objective is to facilitate the efficient movement of people and goods, ensure access to jobs and services, and promote trade and economic growth.⁴⁶ The 2024 revision of the TEN-T Regulation updates the maps of both the core and comprehensive corridors. It also reflects new geopolitical realities by incorporating Ukraine, Moldova, and the Western Balkans into the network, while removing Russia and Belarus.⁴⁷ Moreover, the rapidly evolving geopolitical

⁴⁴ A. Migliaccio and T. Patel, "Italy's Secretive Shipping Tycoon Has Been Thrust Into Spotlight With New Port Deal", *Bloomberg*, 14 April 2025.

⁴⁵ US Department of Transportation, Bureau of Transportation Statistics, [Port Performance Freight Statistics 2025](#).

⁴⁶ European Commission, DG Move, [Trans-European Transport Network \(TEN-T\)](#).

⁴⁷ European Union, [REGULATION \(EU\) 2024/1679 of The European Parliament and of The Council of 13 June 2024 on Union guidelines for the development of the trans-European transport network, amending Regulations](#)

landscape and emerging threats are reflected in the increased emphasis on military mobility in the 2024 TEN-T revision. In line with the EU Action Plan on Military Mobility 2.0, the new provisions aim to ensure the swift and seamless movement of military personnel, equipment, and assets – both at short notice and on a large scale – within and beyond the EU. As such, the trans-European transport network must be capable of serving dual purposes: both military and civilian.⁴⁸

Against this backdrop, two key projects exemplify the strategic importance of the TEN-T network in enhancing connectivity and boosting Europe's competitiveness.

The first is Rail Baltica, a €15.3 billion high-speed railway project currently under development, spanning 870 km across Estonia, Latvia, and Lithuania. Initially designed to enhance economic competitiveness, it has taken on new strategic and political significance in light of Russian threats in Eastern Europe. The project aims to provide a direct rail connection between the Baltic States and Poland, linking them more closely with the EU's core infrastructure – something that currently does not exist.⁴⁹

The second major project is the Fehmarnbelt Link, a €7.4 billion tunnel under construction that will connect Denmark and Germany. The tunnel will feature two-lane highways in both directions, as well as two electrified rail lines. When completed – expected in 2029 – it will reduce travel time from the current 45-minute ferry crossing to just seven minutes by train. Once opened, it will be the world's longest combined road and rail tunnel, as well as the longest immersed tunnel

(EU) 2021/1153 and (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013, Official Journal of the European Union, 28 June 2024.

⁴⁸ European Commission, [Trans-European Transport Network \(TEN-T\)](#), DG Move. See also European Commission, [Action Plan on Military Mobility 2.0](#), DG DEFIS, 10 November 2022.

⁴⁹ F. O'Sullivan, [“Ambitious High-Speed Rail Plans Advance in the Baltic Region”](#), *Bloomberg*, 9 January 2025; see also L. Louis, [“In Russia's shadow: The Baltics wait for Europe's strategic new railway”](#), *BBC News*, 10 November 2024.

globally. This project is not only part of the TEN-T network but is also recognized as an Important Project of Common European Interest (IPCEI).⁵⁰

Lastly, in April 2025, Germany approved a massive €500 billion infrastructure investment plan spanning 12 years. Including defense spending, the total investment rises to €1 trillion. This initiative is expected to play a key role in modernizing Germany's ageing infrastructure and revitalizing the country's competitiveness.⁵¹ As part of the plan, €150 billion will be allocated to strengthen and relaunch the national railway network, with €80 billion dedicated specifically to urgent repairs and upgrades across the existing system.⁵²

Europe is not the only player working to develop an extensive rail network to boost internal competitiveness. Since 2008, China has been building a high-speed rail system from scratch, aiming to connect the country's major industrial and urban centers while improving both national and international logistics. By 2025, the high-speed network is expected to reach 50,000 km (triple of the EU) – accounting for 30% of the country's total railway operating mileage of 162,000 km.⁵³

China is also expanding its railway network beyond its borders. In February 2025, the Vietnamese Parliament approved the construction of a new \$8.3 billion railway linking northern Vietnam to China, partially financed through Chinese loans. The 391 km line will further integrate northern Vietnam – a region with a booming manufacturing sector and significant rare earth and critical minerals reserves – with southern

⁵⁰ A. Symons, "Underwater rail tunnel linking Denmark and Germany to replace 45-minute ferry with 7-minute train", *Euronews*, 19 June 2024; see also M. Knight, "A vast undersea tunnel is being built that will change the road and rail map of Europe", *CNN*, 12 March 2025.

⁵¹ M. Martinez, "What is the huge German spending plan agreed by parties?", *Reuters*, 18 March 2025.

⁵² Railway Supply, *Germany Plans Massive €150 Billion Investment in Railways*, 18 April 2025.

⁵³ H. Huifeng, "China's high-speed rail network on track to breach 50,000km milestone in 2025", *South China Morning Post*, 2 January 2025.

China. This project aligns with broader efforts to establish a Pan-Asian railway network, building on the Laos-China high-speed railway completed in 2021 and its planned extension into Thailand.⁵⁴ Additionally, Vietnam has announced plans to begin construction of a \$67 billion north-south high-speed railway by December 2026. The 1,541 km line will connect Hanoi and Ho Chi Minh City, passing through 20 localities. The project aims to enhance Vietnam's competitiveness and strengthen its position as an economic connector between the United States and China.⁵⁵

In North America, Canada has announced the launch of its first high-speed rail line – the Toronto-Quebec City High-Speed Rail Network – which will operate at speeds of up to 200 km/h. With a \$2.7 billion investment, it represents the largest infrastructure project in the country's history. Spanning 1,000 km and connecting major cities such as Ottawa and Montreal, the line aims to boost economic productivity while addressing critical connectivity and mobility needs.⁵⁶

In terms of internal connectivity, the United States presents a mixed picture. On the one hand, rail transport plays a significant role in the country's logistics system, particularly for long-distance hauls between the Atlantic and Pacific coasts. However, the rail network is in need of significant investment for maintenance and modernisation. Rail accounts for approximately one-quarter of all freight movement, including intermodal transport. It handles about 25% of grain shipments and up to 70% of coal transport. Following decades of consolidation, the rail logistics sector is now predominantly privately owned, with a handful of freight companies controlling most of the network. These companies are responsible for

⁵⁴ S. Strangio, "[Vietnam's National Assembly Approves \\$8B Rail Link to China](#)", *The Diplomat*, 21 February 2025.

⁵⁵ D. Loan, "[Vietnam to begin construction of \\$67B high-speed railway in December 2026](#)", *VnExpress International*, 24 April 2025.

⁵⁶ Railway Technology, "[Cadence Consortium to develop Alto high-speed rail project in Canada](#)", 20 February 2025.

maintaining and upgrading infrastructure, having invested a total of \$700 billion over the past 30 years. The seven largest railroad companies generate 94% of the industry's total revenue, contribute roughly 1% to the US GDP, and employ around one million people.⁵⁷

The situation is markedly different when it comes to passenger transportation. This service is primarily operated by Amtrak (the National Railroad Passenger Corporation), a federally owned company established in 1971. Since its inception, Amtrak has never operated profitably without public subsidies. Several factors contribute to this, including the limited reach of the rail network, outdated infrastructure and technology, Americans' long-standing preference for private vehicles, and a strong reliance on air travel for long-distance trips between cities. As a result, passenger rail ridership remains low, with only 28.6 million users recorded in 2023. Over the years – particularly under Democratic administrations – there have been repeated efforts to modernize and expand passenger rail. The most significant recent initiative came through the Infrastructure Investment and Jobs Act of 2021 (IIJA, also known as the Bipartisan Infrastructure Law), which allocated \$102 billion to rail transport – the highest federal investment in the sector since 1980.⁵⁸

The development of a high-speed rail network remains a contentious issue in the broader debate over American infrastructure. So far, high-speed rail initiatives have been funded only at the state level, with limited efforts to connect a few major cities. Currently, the largest and only active high-speed line is the Acela Express, which operates along the Northeast Corridor between Boston and Washington, D.C. In Florida, the private company Brightline operates a passenger rail service

⁵⁷ N. Berman, "[How the U.S. Rail System Works](#)", Council on Foreign Relations, 3 April 2023.

⁵⁸ US Department of Transportation, [Federal Railroad Administration, Infrastructure Investment and Jobs Act Information from FRA](#), last updated 5 March 2025.

between Miami and Orlando, offering high-speed service on the segment between Orlando and Cocoa. Meanwhile, in California, planning for a high-speed rail line connecting Los Angeles and San Francisco began in 2008. Construction did not start until late 2015, and the first operational segment is now projected for completion no earlier than 2033 – well behind the original target of 2020. Estimated costs have also ballooned, rising from \$33 billion in the initial design to \$128 billion today. Overall, the debate is shaped by two opposing viewpoints. Proponents argue that high-speed rail offers substantial economic and environmental benefits, claiming that every dollar invested yields a \$4 return and contributes to sustainable national connectivity. Critics, however, question the feasibility of a nationwide network, citing the vast distances between major cities, demographic challenges, and prohibitive costs – estimated to reach as much as \$3 trillion.⁵⁹

The Energy Transition Requires New Grids, Pipelines and Interconnections

In the age of electrification, electricity grids are becoming the backbone of efforts to meet growing energy demand and to ensure an effective balance between supply and demand. Both international and national energy networks are being reshaped by two major trends: the rise of renewable energy sources and the need for new interconnections, as well as a shifting geopolitical landscape that challenges traditional models based on economic efficiency, which have historically guided the design, planning, and construction of grids and pipelines. Today, in addition to economic efficiency and cost reduction for consumers and businesses, energy systems must also prioritize security and resilience. They need the capability to reverse energy flows quickly in response to evolving geopolitical

⁵⁹ A. Nazaryan, “[After a Slow Start, High-Speed Rail Might Finally Arrive in America](#)”, *New York Times*, 1 April 2025.

developments. Diversification and redundancy have become essential features of modern energy infrastructure.

In Europe, the phasing out of Russian gas is changing traditional supply routes, with growing imports now arriving from the West (Spanish LNG terminals), the North (Norwegian natural gas), and the South (Algeria). Liquefied Natural Gas (LNG), in particular, has played a crucial role in enabling Europe to reduce its dependence on Russian gas. This has been achieved by utilizing previously underused LNG facilities, constructing new infrastructure, and deploying floating storage and regasification units (FSRUs).⁶⁰

Ukraine stands as a key example of these transformations. In March 2022, the country synchronized its electricity grid with that of the European Union.⁶¹ In January 2025, Kyiv ended the gas transit agreements that allowed Russian natural gas to pass through Ukrainian territory, prompting Central European countries to compensate for the shortfall with increased deliveries from Germany and Italy.⁶²

Finally, in February 2025, the Baltic States – Estonia, Latvia, and Lithuania – successfully de-synchronized from the Russian and Belarusian electricity grids. They fully integrated into the EU internal energy market by connecting to the European continental network through Poland.⁶³

The second key factor behind the growing importance of electricity grids is the energy transition, which will demand

⁶⁰ U. Keliauskaitė, S. Tagliapietra, and G. Zachmann, “[Europe urgently needs a common strategy on Russian gas](#)”, Bruegel, 2 April 2025.

⁶¹ European Commission, [2 years since Ukraine and Moldova synchronised electricity grids with EU](#), DG ENER, 15 March 2024.

⁶² European Commission, [End of transit via Ukraine – Information from the conclusions of the Commission’s assessment](#), DG ENER. See also J. Sharples, “[The End of Russian Gas Transit via Ukraine: Immediate Impact and Implications for the European Gas Market in 2025](#)”, Oxford Institute for Energy Studies, January 2025.

⁶³ European Commission, [Baltic States join the European continental electricity grid after fully disconnecting from Russian and Belarussian networks](#), Press Release, 9 February 2025.

more electricity and significantly increased investment in grid infrastructure. As highlighted in the Letta and Draghi Reports, and more recently in the EU Clean Industrial Deal, the lack of sufficient interconnections and grid infrastructure – along with limited energy system integration and flexibility – continues to hinder the integration of more affordable, decarbonized energy sources and weakens the EU’s resilience to emerging threats.⁶⁴

In the past, power generation centres were typically located close to consumption hubs. However, the energy transition is reshaping this architecture, with offshore and distributed generation increasingly integrated into the grid. As a result, substantial investments in local, national, and cross-border electricity infrastructure are essential to keep pace with the rapid growth of renewables and electricity demand – wind capacity is expected to double and solar photovoltaic capacity to triple by 2030. Several EU Member States are already facing delays in connecting renewable energy projects to the grid due to limited capacity. Cross-border interconnections, in particular, play a crucial role in supporting market integration, supply security, system flexibility, price stability, and overall competitiveness.⁶⁵

In Europe, significant investments in electricity grids are underway to support the energy transition and increase the share of renewables in the energy mix.

In Germany, 9,600 km of high-voltage lines are being built to support the growing demand for renewable energy and decarbonization. Among these, the A-Nord power link – approved in April – is designed to enhance the transmission of wind power from northern to southern Germany and is expected to be operational by 2027.⁶⁶

⁶⁴ European Commission, *The Clean Industrial Deal: A Joint Roadmap for Competitiveness and Decarbonisation*, COM (2025) 85 final, 26 February 2025.

⁶⁵ ACER – European Union Agency for the Cooperation of Energy Regulators, *Electricity Infrastructure Development to Support a Competitive and Sustainable Energy System. 2024 Monitoring Report*, 16 December 2024.

⁶⁶ V. Eckert, “New north-south German power line expected in mid-2027”, *Reuters*, 15 April 2025.

In Northern Europe, the 600 km NordLink interconnector between Germany and Norway was inaugurated in 2021. When Germany experiences low electricity generation, Norwegian hydropower can compensate for the shortfall. Conversely, the direct link allows Norway to import German wind power during peak demand, preserving its hydropower reserves.⁶⁷

In Italy, grid operator Terna plans to invest over €23 billion over the next decade to integrate renewable energy sources and boost the transmission capacity of the national grid. By 2030, several strategic interconnections are expected to be online, including the Tyrrhenian Link, the Adriatic Link, the connection between Sardinia, Corsica, and Tuscany, and the Italy-Tunisia energy bridge. In May 2025, Greece and Italy signed a Memorandum of Understanding to establish a 1,000 MW undersea power link between the two countries.⁶⁸ In 2023, a new 1.2 GW interconnection between Italy and France went live: it is the longest direct current (DC) cable power line in the world installed along motorway infrastructure.⁶⁹

In the Mediterranean, interconnection projects such as ElMed (between Italy and Tunisia), the Euro-Africa Interconnector (between Egypt, Cyprus and Greece), and the planned South H2Med green hydrogen pipeline are designed to leverage regional advantages and support the creation of a Euro-Mediterranean renewable energy market. Most of these projects are included in the EU's Projects of Common Interest (PCI) list.⁷⁰

These developments align with the 2022 Trans-European Networks for Energy (TEN-E) Regulation, which promotes

⁶⁷ Deutsche Bundesregierung, [New cable links Germany and Norway](#), 27 May 2021.

⁶⁸ Terna, [“Terna: presentato il Piano di Sviluppo 2025 della rete elettrica nazionale”](#), 14 March 2025. See also Terna, [“New Italy-Greece interconnection \(GR.ITA 2\)”](#).

⁶⁹ Terna, [Italy - France interconnection](#).

⁷⁰ G. Semeraro and F. Landini, [“Italy, Germany, Austria, Tunisia and Algeria back hydrogen grid project”](#), *Reuters*, 21 January 2025.

stronger grid interconnections across Europe. The regulation aims to build an integrated energy market, lower electricity prices, and balance intermittent renewable supply with continental demand.⁷¹

Despite ongoing progress, Europe still needs new interconnections to support its energy goals. Through the TEN-E Regulation, the EU has identified over 100 electricity Projects of Common Interest (PCIs) and supported their permitting, construction, and financing – particularly via the Connecting Europe Facility (CEF). These efforts have helped to develop a physical power infrastructure aligned with the goals of a unified Single Market and have contributed to progress toward the EU's target of achieving 15% electricity interconnection capacity by 2030. However, the European Commission estimates that €584 billion in investments will be needed for electricity grids across the EU by the end of this decade. The 2023 Action Plan for Grids further emphasizes that cross-border transmission capacity must reach 64 GW by 2030 to accommodate increasing demand and the growth of renewables.⁷²

In line with this, the 2025 Action Plan for Affordable Energy highlights the economic benefits that integrated electricity markets already provide to European consumers – estimated at approximately €34 billion annually. Deeper market integration could raise these benefits to €40–43 billion per year. From a regional perspective, the Action Plan calls for: the development of an integrated offshore grid in the Northern Seas; strengthening the physical integration of the Baltic States with Central and Northern Europe, following the Baltic synchronization; increasing the interconnection capacity of the Iberian Peninsula with the rest of Europe – an issue

⁷¹ European Commission, [Trans-European Networks for Energy](#), 15 December 2022. See also European Commission, [Grids, the missing link - An EU Action Plan for Grids](#), COM(2023) 757 final, 28 November 2023.

⁷² European Commission, [Grids, the missing link - An EU Action Plan for Grids](#), COM (2023) 757 final, 28 November 2023.

highlighted by recent blackouts; enhancing connectivity and market integration between Southeast and Central Europe.⁷³

The upcoming European Grids Package is expected to further accelerate grid upgrades and expansions, streamline permitting procedures, and support rapid electrification – all with the broader objective of enhancing Europe’s competitiveness in a decarbonizing global economy.⁷⁴

Globally, demand for electricity grid infrastructure is steadily increasing. According to the International Energy Agency (IEA), annual investment in electricity grids will need to exceed \$200 billion by the mid-2030s to meet growing electricity demand. The IEA also highlights that inadequate transmission capacity remains a major barrier to power system development, electrification, and energy security. In particular, grid infrastructure has not kept pace with the rapid expansion of renewable energy sources being integrated into the system.⁷⁵

China is investing \$800 billion over six years to address strains on its energy system caused by the rapid expansion of renewable capacity. These grid investments include more than 500,000 km of transmission lines connecting the country’s western and northern provinces – which are rich in renewable energy resources – to the major demand centres in the east.⁷⁶ In 2025 alone, China’s State Grid plans to invest \$88.7 billion in the national grid.⁷⁷

In the US, renewed support for fossil fuels under the second Trump administration has introduced uncertainties regarding

⁷³ European Commission, [Action Plan for Affordable Energy](#), COM(2025) 79 final, 26 February 2025.

⁷⁴ European Commission, [Commission collects views in preparation of the European Grids Package](#), DG ENER, 13 May 2025.

⁷⁵ International Energy Agency, [Building the Future Transmission Grid](#), February 2025.

⁷⁶ E. White and W. Ding, “[Gridlock in China: huge spending on network in shift to green energy](#)”, *Financial Times*, 9 July 2024. See also N. Stylianou, J. Tauschinski, and E. White, “[How Xi sparked China’s electricity revolution](#)”, *Financial Times*, 12 May 2025.

⁷⁷ C. Howe, “[China’s State Grid outlays record \\$88.7 bln investment for 2025](#)”, *Reuters*, 15 January 2025.

grid investments and development, following a surge in spending on new electricity infrastructure driven by Biden's Inflation Reduction Act and the Bipartisan Infrastructure Law. Nevertheless, Trump has committed to easing permitting hurdles for power transmission and pipeline projects. In 2024, US utilities invested over \$50 billion in new distribution grids.⁷⁸

On a global scale, new international submarine power cables are expanding rapidly and are set to play an increasingly important role in enhancing grid reliability, diversity, and security of supply. One of the most ambitious projects is the Xlinks Power Project, which aims to connect Morocco to the United Kingdom. This \$30 billion initiative plans to develop 11.5 GW of renewable generation, 22.5 GWh of battery storage, and a 3.6 GW high-voltage direct current (HVDC) link between the two countries. Once operational, it will supply energy to 7 million homes – approximately 8% of the UK's current electricity demand.⁷⁹

Following this, as part of a broader \$40 billion deal between Italy and the UAE spanning several sectors,⁸⁰ a new submarine cable interconnection agreement was signed by Italy, Albania, and the UAE for the Italy-Albania segment. This marks the first step in IMEC's energy connectivity framework.⁸¹ This interconnection also supports India's One Sun, One World, One Grid (OSOWOG) initiative, which aims to link the power grids of Europe, Asia, the Gulf, and Africa. The goal is to create an international energy market where supply and demand can be balanced, leveraging the different time zones of participating countries to optimize peak consumption. Such integration

⁷⁸ E. García, “US grid investments take off as power demand hikes”, *Reuters*, 28 January 2025.

⁷⁹ A. Faouzi, “UK-Morocco Power Link Seeks Political Support to Unlock \$29.9 Billion Green Project”, *Morocco World News*, 1 February 2025.

⁸⁰ G. Fonte and A. Armellini, “Italy's Meloni bags UAE investment pledge worth \$40 billion”, *Reuters*, 24 February 2025.

⁸¹ F. Maccioni, “Italy, Albania, UAE sign deal for Adriatic energy link”, *Reuters*, 15 January 2025.

would help mitigate the intermittency challenges of renewables and reduce the costs and requirements associated with energy storage.⁸² Similar undersea interconnections are also being developed between India and Gulf countries under the IMEC and OSOWOG frameworks.⁸³

Finally, in East Asia, Singapore's Energy Market Authority approved the SunCable Australia-Asia PowerLink project in late 2024. This \$13.5 billion initiative will build a 4,300 km undersea power cable to transmit solar-generated electricity from Australia's Northern Territory to Singapore, with a 3 GW transmission capacity. The project will also supply electricity to Darwin, the capital of the Northern Territory, by 2030.⁸⁴

The New Digital Domain.

The Geopolitical Race for Digital Undersea Cables

As is widely known, digital submarine cables form the backbone of global internet connectivity, carrying approximately 97-99% of the world's digital communications. Today, over 600 cables are either operational or planned, spanning roughly 1.2 million kilometers. Currently, only ten countries possess the capacity to build and operate this critical infrastructure. Prior to 2008, the submarine cable industry was dominated primarily by companies from advanced economies such as the United States, Japan, and France. However, increased government investment by China led to the entry of Huawei Marine Networks Co. Ltd.

⁸² D. Sharma, "One Sun, One World, One Grid: Empowering Sustainability", *Invest India*, 10 January 2024.

⁸³ HVDC World, "Proposed UAE-India HVDC Interconnection. Turning a Cross-Border Power Grid Vision into Reality", 22 April 2025. See also S. Anand, "India in talks with Gulf Asia Nations for cross-border power grid links under OSOWOG", *The Economic Times*, 6 November 2024.

⁸⁴ L. Jackson, "Singapore approves import of solar energy from Australia via undersea cable", *Reuters*, 22 October 2024. See also A. Hancock, "Singapore looks to Australian outback to power shift to sustainable energy", *VOA News*, 29 October 2024.

(acquired by Hengtong in 2020), transforming the industry into a strategic arena of geopolitical and security concerns. The launch of the Digital Silk Road in 2015 – two years after the Belt and Road Initiative (BRI) – marked the beginning of a new phase of global competition over digital submarine connectivity. As part of its “Made in China 2025” strategy, Beijing set an ambitious target to capture 60% of the global submarine cable market by 2025. However, due in part to US efforts to reduce reliance on critical Chinese technologies, China’s market share in the submarine cable sector has stalled at around 15–18%. Against this backdrop, major tech companies such as Google, Facebook (Meta), Amazon, and Microsoft have significantly ramped up their investments in submarine cable projects in recent years. As of 2023, these companies were estimated to control about 70% of the global market for submarine cable construction and maintenance.⁸⁵ Google alone, which owns extensive digital infrastructure worldwide, invested \$1 billion in new cable systems in 2024. In February 2025, Meta announced plans to build the world’s longest submarine cable – spanning 50,000 kilometers – that will encircle the globe and establish three new oceanic digital corridors.⁸⁶

In the context just described, the geopolitical implications of the challenges surrounding submarine cables are multifaceted. We are witnessing a process of de-risking in digital communications through submarine cables. Similar to trends observed in transportation, energy, and especially technology, there is a clear movement toward securitization and risk reduction. This has led to the gradual emergence of two rival blocs: Western countries on one side, and China along with its major allies on the other. This division results in reduced overall efficiency and increased costs, ultimately fragmenting the global tech ecosystem and forcing states and companies to make strategic decisions about the hardware and components they

⁸⁵ A. Capri, “The new geopolitics of undersea cables”, Hinrich Foundation, April 2024.

⁸⁶ A. Desmarais, “Meta to build ‘ambitious’ 50,000 km subsea cable around the world”, *Euronews*, 18 February 2025.

use. These dynamics also significantly influence key decisions regarding cable routes, as well as who builds and owns these infrastructures – all of which are increasingly scrutinized under national security frameworks, positioning digital undersea cables as critical infrastructure and instruments of geopolitical power.⁸⁷ More importantly, this situation drives redundancy strategies aimed at creating alternative connections to mitigate geopolitical and accidental risks while ensuring that each state and region has access to multiple submarine cable links.⁸⁸

The increasing technology de-risking between China and the US led to the Trump administration's intervention in 2019 to block the direct connection between the US and Hong Kong via the Pacific Light Cable Network. Originally designed in 2016 by Facebook and Google, the network now terminates in the Philippines and Taiwan but excludes Hong Kong.⁸⁹ The US government's primary concern was the involvement of a Chinese company in the construction consortium and the potential risk of espionage if the cable connected directly to Chinese territory. This case illustrates Washington's view of major tech companies as strategic assets, demonstrating its willingness to intervene when their economic interests conflict with national security objectives. Even more emblematic is the Hong Kong-America cable system (HKA), intended to connect Hong Kong to California, with both Chinese investors (including China Telecom) and American investors (including Meta). Launched in 2018, the project came to a halt in 2021 when the international consortium withdrew its application for a US license, despite over 85% of the cable already being laid.⁹⁰

⁸⁷ A. Gross, A. Heal, C. Campbell, D. Clark, I. Bott, and I. de la Torre Arenas, "How the US is pushing China out of the internet's plumbing", *Financial Times*, 13 June 2023.

⁸⁸ J. Brock, "U.S. and China wage war beneath the waves – over internet cables", *Reuters*, 24 March 2023.

⁸⁹ Submarine Cable Networks, PLCN.

⁹⁰ W. Qiu, *HKA Consortium Withdraws Application for Submarine Cable Landing License in the US*, Submarine Cables, 12 March 2021. See also A. Gross et al., "How the US is pushing China out of the Internet's plumbing", *Financial*

This approach was ultimately reinforced by new US legislation: the Undersea Cable Control Act. In early 2023, the House of Representatives passed a bill aimed at safeguarding US dominance in undersea cable capabilities, with a particular focus on curbing China's technological, economic, and military advancements in this domain. The Act specifically mandates that the US government develop a strategy to restrict China's access to goods and technologies that could be used in the production of submarine cables.⁹¹

In this context, the main Western countries and their allies in Asia are attempting to coordinate efforts to contain Beijing's growing role as a key player in regional connectivity. The Quad countries – comprising Australia, the United States, Japan, and India – established the *Quad Partnership for Cable Connectivity and Resilience* in May 2023. The initiative aims to pool expertise on submarine cables and build an alternative to Chinese-led projects.⁹² To this end, in July 2024, Australia launched the new *Cable Connectivity and Resilience Centre* to enhance connectivity, strengthen security, and support the region's digital growth.⁹³ Finally, the Quad members have committed to connecting all major Pacific islands via submarine data cables by 2025, allocating over \$140 million toward this goal.⁹⁴

In Europe, the European Commission and the High Representative issued a Joint Communication aimed at strengthening the security and resilience of submarine cables. The document outlines a series of actions to prevent, detect, respond to, repair, and deter threats. It also places particular

Times, 13 June 2023.

⁹¹ Congress of the United States of America, “H.R.1189 – Undersea Cable Control Act”, 28 March 2023.

⁹² A. Hemrajani, “[The Quad Partnership for Cable Connectivity and Resilience](#)”, RSIS Commentary, no. 166, 17 November 2023.

⁹³ Australia's Ministry for Foreign Affairs, [Launch of the Cable Connectivity and Resilience Centre](#), Media Release, 29 July 2024.

⁹⁴ Japan Ministry of Foreign Affairs, [The Wilmington Declaration. Joint Statement from the Leaders of Australia, India, Japan, and the United States](#), 21 September 2024.

emphasis on the need for increased investment in new cables to address the infrastructure gap the EU has accumulated in recent years.⁹⁵

The Commission will also develop an investment framework for undersea infrastructure with the goal of enhancing its safety and resilience. Under the Connecting Europe Facility – Digital program, which supports digital communications infrastructure, €420 million has already been allocated to 51 projects. An additional €520 million is set to be invested between 2025 and 2027, specifically for so-called “strategic cables of European interest” (IPCEIs). These are projects co-financed by the private sector and the governments of participating Member States under concessional terms. To facilitate the implementation of these strategic projects, the Commission has committed to fostering dialogue with private sector stakeholders, the European Investment Bank, and national development banks to explore new forms of co-financing.⁹⁶

The new submarine cables will primarily aim to enhance global connectivity between Europe and regions such as Africa, the Middle East (e.g., the BlueMed East project and Sparkle’s Raman cable to India, which will be crucial for the IMEC Corridor), and Asia (notably through Arctic routes). They will also strengthen connections among EU Member States across the Mediterranean, the Atlantic, the Baltic Sea, and continental Europe, while supporting connectivity in the EU’s Outermost Regions and Overseas Countries and Territories.⁹⁷

⁹⁵ European Commission, [Joint Communication to the European Parliament And The Council on an Eu Action Plan on Cable Security](#), JOIN(2025) 9 final, 21 February 2025.

⁹⁶ European Commission, [Commission Recommendation on Secure and Resilient Submarine Cable Infrastructures](#), C(2024) 1181 final, 26 February 2024. See also A. Deruda, “Sicurezza in mare: l’UE difende i suoi cavi”, *Commentary*, ISPI, 21 March 2025.

⁹⁷ European Commission, [New projects signed under CEF Digital to enhance and strengthen submarine cable infrastructure across and to the EU](#), 5 December 2024.

Moreover, digital undersea cables have been identified as key components of the EU's External Action in the European Union's International Digital Strategy, published in June 2025. According to the new strategy, the Global Gateway will serve as the primary instrument for achieving the EU's strategic international connectivity objectives in cooperation with like-minded partners. The BELLA cable to South America, the MEDUSA submarine cable, and Sparkle's Blue-Raman undersea cable along the IMEC corridor have all been highlighted as critical segments of the EU's future international digital connectivity backbone.⁹⁸

Not to forget, in the broader context of geopolitics, economics, and technology, these infrastructures are closely tied to the dynamics of data centres, whose geographic locations are largely influenced by the layout of undersea digital cables. In this arena, Asia is playing an increasingly significant role, while Europe – particularly cities like Genoa, Marseille, and regions like Sicily – continues to play a crucial part.⁹⁹

A Fast-Evolving Landscape

The connectivity explored in this chapter underscores the pivotal role of networks in advancing broader political and economic agendas. By design, networks are strategic instruments that both reflect and reinforce geopolitical alliances. Cross-border interconnections often signal closer ties between nations – but as recent European events demonstrate, they can also create strategic dependencies, exposing vulnerabilities in economic security and national resilience. Geopolitical and hybrid risks and threats require State and non-State actors to adapt by strengthening resilience and security, including through the adoption of redundancy strategies.

⁹⁸ European Commission, *An International Digital Strategy for the European Union*, JOIN(2025) 140 final, 5 June 2025.

⁹⁹ A.Capri, “The geopolitics of modern data centers”, Hinrich Foundation, 14 May 2024.

The accelerating pace of global geopolitical shifts is redrawing the map of required infrastructure and reshaping alliances in this space. The uncertain posture of the new US administration casts doubts on America's long-term commitment to multilateral Western initiatives on infrastructure connectivity, such as the Partnership for Global Infrastructure and Investment (PGII) – once seen as a key alternative to China's Belt and Road Initiative (BRI).

As transatlantic relations show signs of strain, including the recurring threat of new tariffs, there is growing pressure to rethink the derisking strategy between European and Chinese economies. Still, while geopolitical tensions may complicate progress, they are unlikely to halt the momentum toward deeper connectivity – an imperative for both the energy transition and the digital transformation. These shifts demand an ever-denser web of networks and interconnections.

The central challenge now lies in building these systems at scale while avoiding geopolitical overlapping and inefficiency. Failing to do so risks undermining not just the economic viability of these projects, but their strategic value as well.

2. The Tech Opportunity to Enable the Energy Transition and Digitise Transport Infrastructures¹

Luca Milani, Stefano Napoletano, Andrea Ricotti, Nicola Sandri

Growth in the European Union has been slowing in the past decades, driven by weakening productivity growth, calling into question Europe's ability to meet its ambitions. Indeed, EU persistently grew at a slower pace than US over the past two decades, while China has been rapidly catching up. The EU-US gap in the level of GDP at 2015 prices has gradually widened from slightly more than 15% in 2002 to 30% in 2023. The main driver of these diverging developments has been productivity, which is responsible for 70% of the gap with US in per capita GDP at Purchasing Power Parity (PPP). Additionally, slower productivity growth has in turn been associated with slower income growth and weaker domestic demand in Europe: on a per capita basis, real disposable income has grown almost twice as much in the US as in the EU since 2000. Raising the EU's competitiveness is necessary to reignite productivity and sustain growth in this changing world.²

In this context, development and modernisation of existing transport infrastructures will play a key role in the relaunch

¹ Confidential and proprietary. Any use of this material without specific permission of McKinsey & Company is strictly prohibited.

² European Commission, *The Future of European competitiveness*, September 2024.

of European economy. Investing in infrastructure creates immediate economic benefits through job creation in the short term and long-term competitiveness gains:

- In the short term, infrastructure projects create jobs in construction, engineering, manufacturing, and related industries, providing an immediate boost to employment and income levels. These jobs, directly and indirectly created, stimulate local economies by increasing demand for materials, services and goods.
- In the long term, new and improved infrastructures enhance productivity and efficiency. Well-developed transport networks, reliable energy systems, and digital connectivity reduce costs and delays and create new business links and opportunities. In addition, by reducing bottlenecks and creating new sources of supplies, infrastructure contributes to sustainable economic growth and supports businesses and economies remain competitive.

Quantitatively, the multiplier effect of infrastructure is remarkable: spending 1 additional dollar in infrastructure increases GDP with a multiplying effect of 0.81.

While it is undoubtedly true that investing in transport infrastructure will play a fundamental role in relaunching the economy, it is also worth to remember that the transport sector is one of the largest sources of greenhouse gas emissions in the European Union, accounting for 25%, with road transport responsible for more than 70% of transport activity. The European Climate Law sets out a legal commitment for Europe to achieve climate neutrality by 2050 and reducing GHG emissions is necessary in all sectors of Europe's economy.³

Various stakeholders expect transport infrastructure operators to embrace sustainable and technologically advanced practices, while investing into new construction and modernisation:

³ European Environmental Agency.

- Investors: ESG Assets Under Management of private equity and infrastructure funds could surpass \$40 trillion by 2030, with a CAGR of 3.5%. This is expected to constitute more than 25% of total Assets Under Management of \$140 trillion.
- Regulatory bodies and institutions: nearly 50,000 EU companies will have to disclose their impact on the environment to help consumers and investors make sustainable choices, according to the Corporate Sustainability Reporting Directive (CSRD), adopted by the European Commission in November 2022.
- Consumers and transport infrastructure users: sustainability has been evolving from just a trend to a standard consideration, which influence consumer behaviours, with >70% of consumers viewing this aspect a crucial factor when making purchases.
- Employees: in a survey of 2,000 employees in United States, 76% of respondents indicated that they want to work for a company that is trying to have a positive impact on the world. Almost two thirds, however, said that current efforts by businesses to tackle environmental and societal challenges do not go far enough.⁴

This dual transition – encompassing both environmental sustainability and digital innovation – seeks to significantly improve operational efficiency, reduce environmental footprints, and align transport infrastructure with broader policy objectives addressing climate change and digital transformation. By integrating cutting-edge technologies and sustainable practices, transport infrastructure operators can enhance resilience, optimise resource utilisation, and meet evolving regulatory and societal expectations.

⁴ Expert interviews, press clippings on public sources, McKinsey.

FIG. 2.1 – INTEGRATING SUSTAINABLE AND TECHNOLOGICALLY ADVANCED PRACTICES IS ESSENTIAL WHEN INVESTING IN NEW CONSTRUCTION AND INFRASTRUCTURE MODERNISATION

Investors	ESG AUM of private equity and infrastructure funds accounting for 40 USD trillion by 2030, reporting a CAG of 3.5% p.a., and constituting >25% of total AUM
Regulatory bodies and institutions	50,000 EU companies need to disclose their impact on the environment to help consumers and investors make sustainable choices, according to the Corporate Sustainability Reporting Directive (CSRD)
Consumers and transport infrastructure users	>70% consumers considers sustainability as a crucial factor when making purchases
Employees	>75% people indicates that they want to work for a company that is trying to have a positive impact on the world, with two thirds, saying that current efforts by businesses to tackle environmental and societal challenges do not go far enough

Source: expert interviews, press clippings on public source, McKinsey analysis

The environmental aspect of this transition involves adopting low-carbon technologies, increasing energy efficiency, and implementing circular economy principles. Strategies such as electrification, the use of alternative fuels, and green construction materials are becoming standard across the sector. Additionally, policies promoting carbon neutrality and biodiversity protection are reshaping how transport networks are developed and maintained.

Simultaneously, digital transformation is revolutionizing the industry through smart infrastructure, automation, and data-driven decision-making. Innovations such as predictive maintenance, intelligent traffic management, and AI-powered analytics are optimising performance and improving user experiences. The convergence of these environmental and digital shifts is driving the evolution of transport infrastructure toward a more efficient, resilient, and sustainable future.

The following sections explore the latest technologies to enable the energy transition and digitise infrastructure across different transport infrastructure asset classes, including railways, roads, airports, and ports. Each category presents

unique challenges and opportunities, with operators leveraging innovative approaches to meet sustainability goals while enhancing service efficiency and reliability.

Deep Dive on Technologies to Enable the Energy Transition in Railways, Roads, Airports and Ports

As far as energy transition is concerned, below are some of the most significant technologies and use cases recently adopted by leading transport infrastructure operators. These initiatives reflect the industry's ongoing efforts to enhance sustainability, efficiency, and resilience in response to evolving environmental challenges and requirements. The following examples highlight key strategies that have been successfully applied across various transport sectors, showcasing how forward-thinking approaches can drive long-term improvements in operational effectiveness and environmental responsibility.

In **railways**, best practices and use cases worth to highlight concern:

- Diversification of energy sources using renewable energy. Powering the fleet exclusively with renewable sources (such as wind energy) or biofuels to reduce environmental footprint and CO₂ emissions. For instance, increasing blends of biofuels can help decrease GHG emissions by up to 25%.
- Reuse of energy produced or recycled in various processes. Converting the energy generated during train braking into electricity that is fed back into the railway grid. This leads to energy savings for all trains operating on the electric network, as accelerating trains can utilise the energy produced by those that are braking. Savings of 17%, and less wear on friction braking components, can be achieved thanks to these practices.
- Adoption of technologies and practices to reduce CO₂ and other pollutant emissions. Implementing low-global-warming-potential refrigerants in trains and

using LNG-powered trains to minimise emissions from train air-conditioning systems and improve air quality in areas served by non-electrified rail lines. In regions where electrification is not feasible, utilising LNG as a locomotive fuel can lead to a 20% reduction in CO₂ emissions and a 70% reduction in sulphur dioxide emissions.

- Interventions to reduce noise pollution from railway activities. Equipping train carriages with noise-reducing brake pads and installing sound-absorbing barriers to lower noise pollution from the fleet. Using composite brake blocks can result in a 50% reduction in perceived noise.

In **roads**, best practices and use cases worth to highlight concern:

- Installation of on-the-move charging systems. Inductive charging technology integrated directly into the roadway, enabling contactless energy transfer to move or stationary vehicles. This helps reduce both emissions and noise pollution. Studies estimate that global CO₂ emissions can be reduced by 1% year-on-year with wireless EV charging technology.
- Adoption of SBTi standards. Commitment to setting and pursuing science-based greenhouse gas emission reduction targets to lower greenhouse gas emissions.
- Introduction of dual pricing for fares and services. Systematic use of digital tools that allow dual pricing in terms of both € and CO₂ for services used, raising customer awareness of the importance of sustainability.
- Tools to guide the design, construction, and maintenance of projects. Adoption of biodiversity assessment tools during the design, construction, and maintenance phases to minimise environmental impact and promote a balance between infrastructure development and conservation.

- Electrification of corporate fleets. Promotion of fully electric vehicles for employees, offering hybrids as an alternative option while completely excluding gasoline or diesel cars to encourage a more sustainable transportation system.
- Rainwater harvesting using the highway surface. Collecting rainwater that falls on highways in dedicated reservoirs, making it available for industrial and agricultural use, helping to mitigate water shortages during drought periods.

In **airports**, best practices and use cases worth to highlight include:

- Reduction of noise pollution. Restricting access for the noisiest airplanes to lower sound emissions, improving residents' quality of life and urban transit. Disturbance for people living close to the airport can be reduced by 20%, by cutting the number of flights.
- Efficient management of energy sources. Installing a solar system for renewable energy generation and storage to achieve energy self-sufficiency, leading to cost savings and lower emissions from electricity consumption. These solar farms can reduce CO₂ emissions by more than 11,000 tons per year, with an investment of €50 million.
- Reduction, reuse, and recycle waste and water. Implementation of rainwater harvesting systems collecting water from the roofs of the terminals and re-use it for toilet flushing, watering plants, and cleaning the air conditioning system. Implementing such system can save approximately 1 million cubic metres of water per year for an area of 27k sqm.
- Promotion of the use of sustainable aviation fuels (SAF). Introducing reduced landing fees for airlines using sustainable fuels, helping to cut CO₂ emissions by up to 70% compared to traditional jet fuel.

- Protection of natural habitats and resident species. Participation in reforestation initiatives to offset unavoidable emissions, enhancing the environmental impact on the surrounding territory.

In **ports**, among best practices and use cases worth to highlight:

- Electrification of docks and port equipment. Installation of a cold-ironing system to supply electricity to docked ships, reducing CO₂ emissions from port operations by using electric power instead of fossil fuels. Ships can reduce annual CO₂ emissions by up to 30%, with financial savings of up to 25% per call.
- Adoption of sustainable fuels. Construction of biofuel production facilities to generate biomethane and other green fuels, improving the ecological footprint of port operations by reducing carbon emissions. More than 800,000 tons of carbon dioxide annually can be reduced with an investment of approximately \$1.3 billion.
- Environmental monitoring. Deployment of sensors and advanced technologies to monitor water and air quality, helping to control and mitigate the environmental impact of port activities. Some ports have cut emissions by up to 25% using AI solutions to track emissions, optimise scheduling, and reduce waste.
- Implementation of circular economy programs. Production of sustainable methanol and recycling of materials for the chemical industry to minimise waste and lower disposal costs.

FIG. 2.2 - TECHNOLOGIES TO ENABLE THE ENERGY TRANSITION
IN RAILWAYS, ROADS, AIRPORTS AND PORTS

				
Asset class	Railways	Roads	Airports	Ports
Use cases and best practices	• Diversification of energy sources using renewable energy • Reuse of energy produced or recycled in various processes • Adoption of technologies and practices to reduce CO₂ and other pollutant emissions • Interventions to reduce noise pollution from railway activities	• Installation of on-the-move charging systems • Adoption of SBTi standards • Introduction of dual pricing for fares and services • Tools to guide the design, construction, and maintenance of projects • Electrification of corporate fleets • Rainwater harvesting using the highway surface	• Reduction of noise pollution • Efficient management of energy sources • Reduction, reuse, and recycle waste and water • Promotion of the use of sustainable aviation fuels (SAF) • Protection of natural habitats and resident species	• Electrification of docks and port equipment • Adoption of sustainable fuels • Environmental monitoring • Implementation of circular economy programs

Source: Expert interviews, press search on industry articles and latest companies publications, McKinsey analysis

Deep Dive on Technologies to Enable Transport Infrastructures' Digitalisation in Railways, Roads, Airports and Ports

As digital transformation accelerates across the transport sector, leading infrastructure operators are adopting innovative solutions to enhance efficiency, connectivity, and resilience. The following best practices and use cases highlight some of the most impactful technologies recently implemented in railways, roads, airports, and ports. These examples showcase how digitalisation – through technologies such as AI, IoT, and advanced analytics – is revolutionising operations, optimising resource management, and improving overall service quality.

By leveraging cutting-edge digital tools, the industry is not only enhancing performance but also paving the way for smarter, more sustainable, and future-ready infrastructure.

In **rail**, best practices and use cases worth to highlight include:

- Use of technologies to increase revenue. Algorithms to analyse historical trends, consumer demand, and pricing to identify optimal sales strategies and increase revenue through better forecasts of future demand and personalised offers. A potential +3-8% in revenues can be achieved through these technologies.
- Use of algorithms to improve operational efficiency. Employing AI tools and machine learning to predict demand spikes on trains and at stations, enabling timely interventions and capacity optimisation, ultimately enhancing passenger experience and operational efficiency. These innovations can lead to +5% revenue increase.
- Advanced monitoring and control systems. Introducing “computer vision” systems and predictive algorithms for fraud prevention, improving the passenger travel experience. These systems can enable a reduction in security costs by 10%.
- Technologies for predictive maintenance. Adopting IT systems that collect and analyse real-time data for preventive maintenance, reducing maintenance costs and increasing service reliability. These innovations can reduce unplanned downtime by 15-25%, cut maintenance costs by 15-30% and delays per service by 20%.

In **roads**, best practices and use cases worth to highlight concern:

- Digital Twins. Development of a digital replica to monitor and optimise road operations in real-time by integrating data from IoT sensors, Building Information

Modeling (BIM), and Geographic Information System (GIS) models. This aims to enhance infrastructure efficiency, safety, and sustainability. Digital Twins to better manage traffic incidents resulted in an increase of incident detection of 160%, leading to a 30% reduction in secondary crashes.

- Technologies for predictive maintenance. Adoption of digital platforms that provide all the necessary tools to manage O&M (Operations & Maintenance) activities throughout the infrastructure lifecycle. This improves infrastructure management, increases operational efficiency, and reduces costs. Predictively managing infrastructure maintenance can reduce repair costs by 20% and improve response time by 30%.
- Advanced smart tolling systems. Implementation of barrier-free toll systems that allow vehicles to pass through without stopping, improving traffic flow and reducing travel times. Crashes at toll plazas can be reduced by up to 40% due to removal of barrier tollbooths.
- GenAI tools to support employees. Provision of GenAI-powered virtual assistants to help employees with text generation, information analysis, document summarisation, and translation. These tools simplify repetitive tasks, allowing employees to focus on higher-value activities.

In **airports**, among best practices and use cases worth to highlight:

- Adoption of digital tools to increase revenue. Introduction of machine learning models to analyse and optimise airport gate occupancy, identifying underutilised gates. For instance, airport gating with machine learning can cut gate-planning time by 90% and reduce annual fuel consumption.
- Biometrics. Implementation of advanced biometric

systems to support various operations (e.g., self-service check-in, self-service baggage drop-off, e-gates for immigration), enabling boarding processes to be completed in 3 seconds and check-in within 10 minutes.

- Smart baggage management. Use of automated and digital solutions to track and manage baggage, simplifying screening processes, reducing wait times while maintaining high quality and security standards. Automated baggage tracking systems can reduce handling times by around 20-30% through smart batching and efficient processing.
- Security technologies. Deployment of autonomous robots equipped with sensors and cameras to monitor terminals, detect security breaches, and alert personnel when necessary. This enhances security through continuous monitoring, reduces human error, and improves operational efficiency.
- Technologies to enhance customer experience. Deployment of digital departure boards capable of displaying personalised flight information to multiple travellers simultaneously, improving the overall passenger experience. These boards can display personalised information to 100 people at the same time using AI and facial recognition technology.
- AI in mobile apps. A GenAI-powered mobile app plugin that enhance passenger experience through personalised recommendations and promoting airport services and offers. For instance, more than 40% of travellers state they would be interested in using personalised, curated itinerary driven by AI.
- Technologies to optimise operations. Implementation of advanced air traffic management technologies for optimised arrival sequencing. Additionally, robotic deployment to assist cleaning staff by covering large surface areas and collecting useful data to improve workforce efficiency.

In **ports**, best practices and use cases worth to highlight concern:

- Optimization of maritime traffic and routes. Implementation of a digital platform that centralises authorisations and procedures, simplifying port operations, optimising routes, and reducing ship waiting times. According to some estimates, vessels wait more than 45 minutes before leaving the quay after cargo handling at the terminal has been completed.
- Technologies for operations management. Implementation of IT systems to manage the loading and unloading of vehicles and goods arriving and departing from the port, reducing transit times and streamlining document management. Ports using AI tools to allocate berths based on ship size, arrival time, and cargo needs can reduce wait times by up to 30%.
- Port infrastructure Digital Twin. Collection of sensor data, analysis, and simulations (Digital Twin) for real-time port monitoring. This increases the ability to anticipate and mitigate potential risks while optimising traffic flows. Ports report potential 20% boosts in efficiency using digital twins.
- Drones for monitoring and security. Deployment of drones equipped with high-resolution cameras and advanced sensors to inspect infrastructure and patrol port areas. These innovations reduce infrastructure downtime by increasing the speed and accuracy of inspections while enhancing port security.
- Promoting innovation and competitiveness through competitions. Organisation of a competition among tech startups to select and implement the best project, fostering continuous innovation in port areas.

FIG. 2.3 – TECHNOLOGIES TO ENABLE TRANSPORT INFRASTRUCTURES’ DIGITALISATION IN RAILWAYS, ROADS, AIRPORTS AND PORTS

				
Asset class	Railways	Roads	Airports	Ports
Use cases and best practices	• Use of technologies to increase revenue • Use of algorithms to predictive maintenance improve operational • Advanced monitoring and control systems • Technologies for predictive maintenance	• Digital Twins • Technologies for predictive maintenance • Advanced smart tolling systems • GenAI tools to support employees	• Adoption of digital tools to increase revenue • Biometrics • Smart baggage management • Security technologies • Technologies to enhance customer experience • AI in mobile apps • Technologies to optimize operations	• Optimization of maritime traffic and routes • Technologies for operations management • Port infrastructure Digital Twin • Drones for monitoring and security • Promoting innovation and competitiveness through competitions

Source: Expert interviews, press search on industry articles and latest companies publications, McKinsey analysis

Conclusion

Modernising existing infrastructure and constructing new systems with a strong focus on energy transition and digitalisation is crucial for building a resilient and sustainable transport network. Achieving this transformation requires a coordinated effort among various stakeholders, including governments, private sector entities, financial institutions, and research organizations. To successfully implement this shift, several key factors should be considered:

- **Implementation of Public-Private Partnerships (PPP):** Encouraging private sector investment in infrastructure is essential for mobilising capital and accelerating project development. This can be achieved through well-structured incentives, tax benefits,

transparent legal frameworks, and strategic shareholding participation. Effective PPP models foster collaboration between public and private entities, ensuring efficient resource allocation and long-term sustainability.

- **Establishment of Centres of Excellence (CoE):** Creating dedicated hubs for innovation, training, research, and knowledge-sharing is critical for advancing sustainable transportation solutions. These centres can serve as incubators for new technologies, facilitate interdisciplinary collaboration, and develop expertise in emerging areas such as smart mobility, electrification, and predictive maintenance powered by digital tools.
- **Strengthening of financial markets to attract private capital:** Traditionally, large-scale infrastructure projects have been primarily funded through public sector investments. However, to accelerate development and bridge funding gaps, it is crucial to enhance financial markets to make infrastructure projects more attractive to private investors. This includes introducing innovative financing instruments, such as green bonds and infrastructure investment funds, as well as ensuring regulatory stability to build investor confidence.

By fostering collaboration, innovation, and investment in energy transition and digitalisation, the transportation sector can evolve into a more sustainable, efficient, and future-ready ecosystem.

3. Investing in Connectivity: The European Investment Bank and Cross-Border Infrastructure

Gelsomina Vigliotti, Laura Piovesan

Critical infrastructure is the backbone of the global economy. Roads, railways, electricity and gas grids, and digital networks enable economic growth and are key drivers of competitiveness and innovation. These systems bolster resilience and security while facilitating transition in the energy and digital sectors. While most infrastructure projects are developed by individual nation-states to meet domestic needs, cross-border infrastructure plays an indispensable role in enabling the seamless movement of goods, services, and people across borders, thus driving regional connectivity and growth.

In 2021, the G20 Development Working Group¹ identified regional connectivity as a key priority. Previously, the OECD² had highlighted a significant investment gap, emphasising that spending on transport connectivity in developing countries must double to meet the Sustainable Development Goals. More recently, the 2024 Draghi report³ emphasises the importance of cross-border infrastructure for the European Union's overall

¹ REFERENCE GUIDE, [Connectivity Across Borders: Global practices for cross-border infrastructure projects](#), February 2021

² OECD, [Enhancing Connectivity through Transport Infrastructure](#), 31 August 2018.

³ European Commission, [The future of European competitiveness](#), September 2024.

competitiveness, and reports by Nordregio^{4,5} and the Asian Development Bank (ADB)⁶ provide concrete insights into the critical role played by such initiatives in regional integration.

Cross-border infrastructure projects require large-scale investments that physically or digitally connect two or more countries. However, the international scope of these projects introduces complex challenges beyond those encountered in national infrastructure developments. Fragmented markets, differing legal and regulatory frameworks, and the scale of financing often present significant barriers to investment.

Despite the high costs and complexity, cross-border infrastructure is vital to completing the European Union's internal market and Energy Union. Furthermore, as deglobalisation trends reshape global supply chains, an increase in demand for improved connectivity, both within the EU and beyond is expected. The European Investment Bank (EIB) plays a central role in facilitating the development of such infrastructure. In the past 15 years, the Bank has provided financing of €20 billion to over 100 cross-border infrastructure projects, supporting total investments of approximately €60 billion globally. Furthermore, the EIB's contribution goes far beyond financial support. Drawing on its wide range of expertise, the Bank offers technical advisory services and assists in policy development to guide and encourage investment in this sector.

This chapter explores the EIB's contributions to cross-border infrastructure development, the challenges these projects face, and their future in a rapidly evolving global economy.

⁴ Nordregio is an international research institute focused on regional development, policy and planning in the Nordic region.

⁵ <https://pub.nordregio.org/r-2024-15-strengthening-cross-border-cooperation-in-nordics/1-introduction.html>

⁶ Asian Development Bank, [Asian Economic Integration Report 2025](#).

Specific Challenges of Cross-Border Infrastructure Projects

Cross-border infrastructure projects face several unique and critical challenges that can impede their successful implementation:

1. **Regulatory Complexity:** Differing laws, standards, and regulations across countries create significant hurdles in project planning and implementation. These challenges are often compounded by language and cultural barriers, making coordination between stakeholders more difficult. Projects must comply with the legal requirements of each jurisdiction involved, which can lead to delays and increased costs.
2. **Financial and Investment Risks:** Cross-border infrastructure projects typically require large upfront investments and can be prone to unpredictable returns. For example, when constructing tunnels, geological studies often cannot provide full certainty about the characteristics of the terrain, introducing unforeseen risks. Similarly, for energy interconnectors, long development timelines create difficulties in accurately assessing costs and benefits, as market conditions and energy prices can fluctuate over time. Stakeholders may disagree on market conditions or project outcomes, leading to disputes over cost allocation. Such challenges may delay projects, increase costs, and make financing more complex. In some cases, public intervention or the formation of joint ventures between competitors may be necessary to ensure that these projects move forward.
3. **Coordination Challenges:** Aligning priorities across multiple governments, private sector players, and financiers is another significant challenge. Effective and continued regional coordination is necessary to ensure that projects progress through the planning, preparation, and implementation phases. For example, rail and motorway

projects may face difficulties at the project preparation level, particularly when new infrastructure needs to be aligned with existing networks. Similarly, digital inter-connectors often require careful coordination of contracts and payments to ensure timely implementation. Differences in national regulations – such as network tariffs – can further complicate cross-border energy projects.

4. **Longer Approval Processes:** Due to the complexity of cross-border projects, obtaining the necessary permits and approvals can take many years. The more parties involved, the longer these processes typically take. In addition, environmental and social impact assessments may further delay projects, especially when multiple jurisdictions are involved. Coordinating the various stakeholders – both national and EU-level institutions – becomes crucial to overcoming these delays.
5. **Political and Economic Asymmetry:** Obtaining the political backing of multiple governments is often essential for the realisation of cross-border infrastructure projects. If the costs and benefits of a project are unevenly distributed between countries, some governments may place less emphasis on its importance, particularly if they already have sufficient domestic infrastructure. For example, a country with well-established energy infrastructure may not prioritise cross-border projects if it perceives minimal domestic benefits. While EU grants, such as those from the Connecting Europe Facility, help to mitigate this issue, political and economic disparities still pose significant challenges.
6. **Difficult Physical Terrain:** Cross-border areas often span challenging terrains such as mountains, rivers, or seas, which present significant difficulties for construction, maintenance, and security. For instance, building tunnels or bridges over such terrains increases both the project costs and the risks, making investors hesitant to fund such projects.

To bridge these gaps, public financial institutions like the EIB play a vital role in overcoming these barriers through its financial support, advisory services, and alignment with policy frameworks that facilitate cross-border infrastructure development.

EIB's Role in Cross-Border Infrastructure Lending

As the world's largest multilateral development bank, the EIB plays a pivotal role in addressing investment gaps in sectors like cross-border infrastructure, where market conditions alone may not lead to the successful implementation of projects. The Bank's involvement is not limited to lending. Its participation in a project attracts additional financing from other sources, thereby maximising the impact of the Bank's financial contributions.

Since 2010, the EIB has signed approximately €20 billion in loans for over 100 cross-border infrastructure projects, with a significant portion of these projects focused on energy and transport infrastructure. Of these loans, 65% have been allocated to projects within the EU, with many also involving collaboration between EU Member states and neighbouring countries. Additionally, the EIB has extended its support to projects in Africa and Asia, reinforcing economic ties and enhancing trade between continents. The Bank's ongoing involvement in such initiatives reflects its long-standing expertise in managing the complexities of cross-border infrastructure development.

Cross-Border Infrastructure Projects by Sector

In the past the 15 years, the EIB's financial contributions to cross-border infrastructure have largely focused on energy and transport, with substantial investments in both sectors.

1. **Energy:** The EIB has allocated over €10 billion to projects that improve energy security, supply diversification,

and the integration of energy markets. By enhancing energy security and supporting the transition to cleaner energy sources, these projects contribute to the EU's broader energy policy objectives.

2. **Transportation (Rail and Road):** The EIB has invested approximately €9 billion in cross-border transport projects, particularly focusing on transnational highways, tunnels, and railway corridors. These projects not only enhance mobility and foster economic growth by facilitating business and tourism but also contribute to reducing emissions and improving safety.
3. **Telecommunications:** While digital connectivity has received a smaller share of EIB lending (€0.3 billion), the Bank's investments in this area have significantly improved internet and data-sharing capabilities across borders, contributing to a smoother flow of information.

EIB's Added Value

The EIB's contributions to cross-border infrastructure development go beyond financial support. The Bank's deep expertise in technical, administrative, regulatory, and political aspects of infrastructure projects enables it to add significant value through its advisory services and policy development efforts. The Bank has become a trusted and valued partner both for project promoters and policy makers:

1. **Technical advisory:** The EIB offers a wide range of advisory services to help entities involved in cross-border infrastructure projects. These services include assisting with the preparation of bankable projects, helping project promoters navigate regulatory requirements, and advising on how to meet EU sustainability standards. Through its advisory support, the EIB helps ensure that projects are feasible, structured correctly, and compliant with EU regulations. This technical expertise has been particularly impactful in the energy and transport

sectors, where multiple regulatory frameworks and risk factors often lead to delays and complications. In what can become a highly politicised and conflictual project landscape, the EIB's neutral stance backed up by knowledge acquired over many years of experience is a key ingredient of success.

2. **Policy development:** The success of cross-border infrastructure projects depends not only on financial and technical support but also on a strong policy framework that encourages investment. The EIB has worked closely with the European Commission and national governments to shape policies that facilitate cross-border infrastructure development. The Bank has been instrumental in the development of key frameworks such as the Trans-European Networks (TEN-T and TEN-E) and the EU Energy Union, which provide strategic guidance for the development of transport and energy infrastructure across the EU. Through its active involvement in these policy discussions, the EIB helps ensure that projects funded by the Bank align with the broader objectives of European integration and solidarity.

EIB Cross-Border Infrastructure on the Ground

The following case studies illustrate the importance of the EIB's role in the success of cross-border infrastructure projects:

1. **Oresund Bridge (Sweden, Denmark):** This iconic TEN-T project links Malmö in Sweden with Copenhagen in Denmark and has significantly improved regional integration. The bridge supports daily cross-border travel for 75,000 people and over 50% of the freight traffic between the two countries. The EIB provided almost half the finance required for the bridge's construction which, since its completion, has generated approximately €8.4 billion in economic benefits for both Sweden and Denmark, highlighting the

profound impact that cross-border infrastructure can have on regional economies.

2. **Motorway Modernisation A32 (France, Italy):** The A32 motorway, connecting north-western Italy with France through the Fréjus tunnel, is a vital artery for business and tourism in the region. The motorway, which traverses difficult mountain terrain, has been modernised with EIB support to improve safety and resilience, particularly in light of risks such as earthquakes and extreme weather events. These upgrades enhance connectivity and help mitigate the effects of climate change on infrastructure.
3. **Medusa Submarine Cable System (North Africa, Southern Europe):** The Medusa submarine cable system, a state-of-the-art digital connectivity project, spans 7,100 km and connects North Africa with Southern Europe, with landing points in Cyprus, France, Italy, Portugal, Spain, Algeria, Egypt, Morocco, and Tunisia. The cable improves the collaboration between national research and education networks, offering ultra-high-capacity, resilient, and cyber-secure digital connectivity. The EIB's support has been crucial in coordinating the multiple stakeholders involved and securing additional funding for the project's non-commercial components.
4. **Celtic Interconnector (Ireland, France):** The Celtic Interconnector is a high-voltage submarine power cable spanning the 575 km between the coasts of southern Ireland and north-west France. It is the first direct electricity connection between Ireland and continental Europe and will play a key role in Ireland's decarbonisation strategy. The cable will facilitate the integration of the Irish electricity market into the EU market, increase Ireland's use of renewable electricity and boost the grid's resilience and security. The EIB's financial contribution will be pivotal in raising the additional long-term finance which is vital to cross-border infrastructure.

5. **Moldova Rail Infrastructure (Moldova, Ukraine):**

The rehabilitation of a key freight railway line between Moldova and Ukraine has been particularly significant since the outbreak of the war in Ukraine. The line provides access to crucial ports and has become an important route for trade and logistics. The EIB's involvement has helped overcome long-standing administrative barriers and fostered cooperation between the two countries' railway administrations, improving the efficiency and reliability of cross-border transport.

Outlook

As global trade and energy landscapes shift, cross-border infrastructure is poised to become even more critical. The expansion of energy interconnectors, low-carbon gas pipelines, and high-speed digital networks will drive Europe's connectivity and sustainability ambitions. At the same time, enhanced railway corridors and modernized transport links will be essential to boosting economic resilience and climate action.

With global initiatives like the EU's Global Gateway the role of public financial institutions like the EIB has never been more vital. By bridging investment gaps, fostering policy alignment, and providing expert guidance, the EIB remains a cornerstone of Europe's commitment to seamless, sustainable, and future-ready connectivity.

Investing in cross-border infrastructure is more than just an economic imperative – it's a commitment to a more integrated, resilient, and connected future.

4. The Unbearable Weakness of Efficiency? Military Power, Globalisation and Critical Infrastructures Protection

Andrea Gilli, Danilo Mattera Trimonti

Critical infrastructures have drawn increasing attention in recent years. Two decades of globalisation, technological innovation, and energy transition have deepened societal and economic reliance on systems for producing, storing, and transporting goods, data, people, and financial resources – encompassing railways, seaports, data centres, cables, pipelines and hospitals, among others.¹ As this dependence has intensified, however, vulnerabilities have also expanded and threats have escalated: technological advances have lowered the barriers to physical attacks, digitalisation heightens cyber risks, and the resurgence of great-power rivalries alongside militant non-state actors makes critical infrastructures prime targets, for denial, disruption and punishment.² This chapter is divided in two parts. First, it examines the concept, importance and vulnerabilities of critical infrastructures, highlighting the challenges related to their protection. Next, the chapter explores military protection of critical infrastructure across land, sea, air, and space domains,

¹ A.H. Cordesman, *Cyber-threats, Information Warfare, and Critical Infrastructure Protection*, London, Bloomsbury Publishing, 2001.

² B.R. Kane et al., *Threats to Critical Infrastructure: A Survey*, Santa Monica, CA, RAND Corporation, 2024.

highlighting recent European efforts, focusing on NATO and EU initiatives like the “Baltic Sentry” operation – launched in January 2025 to secure Baltic Sea infrastructure – and the Trans-European Transport Network (TEN-T). The chapter concludes stressing the progress as well as the recurrent challenge of protecting critical infrastructures.

Critical Infrastructures

This section discusses what are critical infrastructures, their roles and vulnerabilities.

Logic. The modern world is built around technology.³ Technological change, historically, increases productivity, thus fostering economic growth. Not all technologies, however, are alike.⁴ While some technologies enable an increase in the output, others permit these very technologies to operate: in this sense, they work as complements.⁵ Trains required rails, electricity needs grids and the internet calls for cables. Complementary technologies and assets are hence historically contingent: their relevance is related to the dominant technology of each era.⁶ Current complementary assets and technologies may thus see their centrality wane as new technologies emerge. Cables are central for sharing digital information, however the age of distributed satellite communications may alter this picture. Additionally, as countries around the world pursue different

³ V. Smil, *Creating the Twentieth Century: Technical Innovations of 1867-1914 and Their Lasting Impact*, Oxford, Oxford University Press, 2005.

⁴ T.F. Bresnahan and M. Trajtenberg, “General purpose technologies ‘Engines of growth’?”, *Journal of Econometrics*, vol. 65, no. 1, January 1995, pp. 83-108.

⁵ R. Adner and R. Kapoor, “Value Creation in Innovation Ecosystems: How the Structure of Technological Interdependence Affects Firm Performance in New Technology Generations”, *Strategic Management Journal*, vol. 31, no. 3, March 2010, pp. 306-28.

⁶ A.D. Lambert, *The Last Sailing Battlefleet: Maintaining Naval Mastery 1815-1850*, London, Conway Maritime Press, 1991; P.M. Kennedy, *The Rise and Fall of British Naval Mastery*, London, Penguin Books, 1976.

policies, they will assign different levels of importance to various critical infrastructures. For instance, seaports and railways are relevant because of globalisation which, however, different trends like reshoring of manufacturing and 3D printing may put into question in the years ahead.

In recent years, critical infrastructures have attracted attention not just due to their prominent economic role but also because of their vulnerabilities, especially from malign actors. In this perspective, it is worth bringing to the fore that strategy scholars have long highlighted these issues. Bernard Brodie, for instance, noted that the transition from sailing ships to steamships increased the relevance of seaports for accessing coal and thus powering the second industrial revolution.⁷ Similarly, a few decades later, Albert Wohlstetter famously noted how the vulnerability of U.S. Air Force's bases undermined the nuclear deterrence, forcing the Pentagon to undergo a massive investment in hardening and dispersion.⁸ This is not surprising as strategy is about exploiting vulnerabilities and complicating adversaries' calculus.⁹

Concept. Globalisation, technological innovation, and the energy transition have rendered, over the past three decades, our economies and societies more interconnected and interdependent than ever before. Highways and railways enable the swift movement of goods and people, supporting trade and military mobility; seaports act as gateways for global commerce, handling over 80% of the world's trade by volume; hospitals ensure public health and resilience during crises; and financial institutions manage the flow of capital, with daily transactions worth trillions of dollars reliant on secure digital networks.

⁷ B. Brodie, *Seapower in the First Machine Age*, Princeton, NJ, Princeton University Press, 1941.

⁸ F.M. Kaplan, *The Wizards of Armageddon*, Palo Alto, CA, Stanford University Press, 1983.

⁹ A. Gilli, M. Gilli, and N. Petrelli, "Before Vegetius: Critical Questions for European Defense", Policy Brief, Milan, Institute for European Policy-Making, 2024.

In modern days' parlance these complementary assets are called critical infrastructures which, according to the U.S. Department of Homeland Security, refer to "the assets, systems, and networks, whether physical or virtual, so vital (...) that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof".¹⁰ This definition highlights the slippery nature of the concept which, on the one hand, does not clearly permit to divide what is a critical infrastructure and what is not.¹¹ On the other, it does not permit to determine where do they start and where to they end.¹² For instance, are the raw materials used to produce pipelines, the electronics constituting data centres or the software used in hospitals and banks part of critical infrastructures? Concepts are never perfect, but they are useful.¹³ The concept of critical infrastructure is useful because it sheds light on a central but vulnerable element of our socio-economic systems, although these conceptual issues leave some open some daunting challenges – as we will discuss later.

Vulnerabilities, threats and challenges. Critical infrastructures are important because of their central geo-economic role but also for their vulnerabilities which may not only, accidentally,

¹⁰ U.S. Department of Homeland Security, *National Infrastructure Protection Plan: Partnering for Critical Infrastructure Security and Resilience*, Washington, DC, DHS, 2013; Council of the European Union, "Council Directive 2008/114/EC on the Identification and Designation of European Critical Infrastructures and the Assessment of the Need to Improve Their Protection", *Official Journal of the European Union*, L345/75, 8 December 2008; NATO, *Baseline Requirements for National Resilience*, Brussels, NATO Headquarters, 2019.

¹¹ D.E. Streusand, "Geopolitics versus Globalization", in S.J. Tancredi (ed.), *Globalization and Maritime Power*, Washington, DC, National Defense University, 2002, pp. 41-56.

¹² C. Gallais and E. Filiol, "Critical Infrastructure: Where Do We Stand Today? A Comprehensive and Comparative Study of the Definitions of a Critical Infrastructure", *Journal of Information Warfare*, vol. 16, no. 1, Winter 2017, pp. 64-87.

¹³ G. Sartori, "Concept Misformation in Comparative Politics", *American Political Science Review*, vol. 64, no. 4, 1970, pp. 1033-53.

lead to major socio-economic paralyses but also be exploited by malign actors. In this respect, three considerations are in order. First of all, Western countries' critical infrastructure represent an appealing target for competitors, adversaries and enemies who have an inherent incentive in attacking this type of easier-to-disrupt target, especially *vis-à-vis* traditional military installation – given Western countries' military superiority.¹⁴ China or North Korea have in fact developed, over the past decades, strategic cyber weapons precisely to hold hostage their adversaries in order to compensate for their military inferiority at the conventional and nuclear level.¹⁵ Along the same lines, both state actors like Russia or terrorist groups and criminal organizations may eye critical infrastructures due to the lower costs either for carry out an attack or related to the consequences. Additionally, technological change has lowered the entry barriers for attacking critical infrastructures: a simple drone may halt traffic in a major airport, online information may provide would-be attackers with all the intelligence to conduct an attack, and the emergence of cyber weapons have put at risk financial institutions and satellites.

Second, and related, critical infrastructures are difficult to defended effectively or efficiently: their extension makes them difficult-to-impossible to defend comprehensively, also because as some receive more protection, adversaries may strategically focus on others.¹⁶ Critical infrastructures have, also, often a transnational dimension which makes their protection harder to design or execute. For instance, country can perfectly

¹⁴ A. Gilli and M. Gilli, "The Spread of Military Innovations: Adoption Capacity Theory, Tactical Incentives, and the Case of Suicide Terrorism", *Security Studies*, vol. 23, no. 3, 2014, pp. 513-47; A. Gilli and M. Gilli, "Why China Has Not Caught Up Yet: Military-Technological Superiority and the Limits of Imitation, Reverse Engineering, and Cyber Espionage", *International Security*, vol. 43, no. 3, Winter 2019, pp. 141-89.

¹⁵ F.S. Cunningham, *Under the Nuclear Shadow: China's Information-Age Weapons in International Security*, Princeton, NJ, Princeton University Press, 2025.

¹⁶ R. Powell, "Defending against Terrorist Attacks with Limited Resources", *American Political Science Review*, vol. 101, no. 3, 2007, pp. 527-41.

protect an undersea cable within its territorial waters. However, if its neighbour does not, the physical infrastructure will not be secure. A governance problem thus emerges which can be complicated by technological challenges, economic costs and coordination problems.¹⁷

Finally, but related, critical infrastructures not only need to be protected from various types of attacks, including accident, sabotage, kinetic as well as non-kinetic (electronic or cyber) but, more importantly, they are not traditionally the core focus of armed forces. As a result, while armed forces possess some of the key capabilities to defend certain critical infrastructures, the very military is not designed, culturally and organisationally, to protect them. This tension can undermine effectiveness, as happened in World War I when the Royal Navy was not able to protect the country's maritime trade.¹⁸

Military Protection of Critical Infrastructures: Land, Sea, Air, and Space

This section examines how armed forces protect critical across land, sea, air, space and cyber domains, revealing a paradox: while militaries bring unmatched technological and operational prowess, their efficiency falters against the scale, diversity, and transnational nature of the task. Each domain underscores unique roles, challenges, and strategic trade-offs, however a constant feature characterises them all: armed forces may protect either critical infrastructure to support civilian activities or for their role in military missions.

Land: Mobility, Connectivity and Vulnerability. Land-based critical infrastructures can be divided between hubs related to transportations (train stations and airports), energy (power

¹⁷ A.A. Stein, "Coordination and collaboration: regimes in an anarchic world", *International Organization*, vol. 36, no. 2, 1982, pp. 299-324.

¹⁸ G. Mukunda, "We Cannot Go On: Disruptive Innovation and The First World War Royal Navy", *Security Studies*, vol. 19, no. 1, 2010, pp. 124-59.

plants) and communications (data centres and servers) as well networks (railways and highways, fibre cables, the electric grid). Military forces have worked, over the past two decades, to protect these critical infrastructures for two main purposes: preserving societal cohesion, political stability and economic activity as well as safeguarding civilian assets which would play a critical role in a military emergency. After 9/11, several civilian targets have been hardened or protected by military forces. Military cyber expertise has been provided in support of cyber security. Military transport equipment has been used in civilian emergencies, including during the Covid-19 pandemic, for delivering medical devices. With respect to current policies, three main considerations are in order.

First, in Europe, a cornerstone policy related to transportation is TEN-T which integrated highways, railways, and inland waterways into a cohesive transport network spanning 27 Member states. Designed to enhance economic connectivity, TEN-T corridors – such as the North Sea-Baltic route – also play a strategy role for military mobility. Since 2013, the EU has invested over €30 billion in TEN-T projects, with recent updates prioritising resilience against sabotage and climate impacts. The 2024 revision of the TEN-T regulation explicitly states that the trans-European transport network is intended for dual use – both civilian and military. In particular, military mobility should enable the rapid and seamless movement of personnel, equipment, and assets – both on short notice and on a large scale – within and beyond the EU.¹⁹ The TEN-T revision aligns with the objectives outlined in the 2022 Strategic Compass for Security and Defence, as well as the Action Plan for Military Mobility 2.0. Both strategies emphasise the need to enhance military mobility and call for increased investment

¹⁹ [Regulation \(EU\) 2024/1679](#) of The European Parliament and of the Council of 13 June 2024 on Union guidelines for the development of the trans-European transport network, amending Regulations (EU) 2021/1153 and (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013, Official Journal of the European Union, 28 June 2024.

to achieve this goal.²⁰ However, NATO is not directly involved and only a few years ago, the EU had even reduced the funding of military mobility – although being fundamental for NATO deterrence and defence posture, especially in its deterrence by reinforcement in the Eastern Front.²¹ In this respect, NATO's Eastern Flank exercises like Defender Europe 2023 entailed rapid-response units and drones patrolling TEN-T corridors to counter sabotage, ensuring troop mobility against a resurgent Russia.

Second, after the cyberattack Estonia suffered in 2007 which disrupted its banking system – and more generally after Russia's 2014 annexation of Crimea – NATO made societal resilience a key element of its deterrence and defence posture.²² The working assumption was that it was imperative to preserve the functioning of the societies in case of attack, in order to guarantee the effectiveness of the Alliance. A 2022 cyberattack on Deutsche Bahn's signalling system, halting trains for hours, exposed once again the salience of hybrid threats – which Russia has been mounting for the past two decades.²³

Finally, data centres and servers represent a vital organ for the global digitalised economy. While cloud computing companies try to obviate physical threats, a simultaneous attack against multiple sites could have systemic disruptive effects. Their physical protection is and will be growing in importance in the future – at least until big data remains the paradigm of artificial intelligence.²⁴

²⁰ European Commission, *Action Plan on Military Mobility 2.0*, JOIN(2022) 48 final, 10 November 2022. See also European Union, *A Strategic Compass for Security and Defence*, 24 March 2022.

²¹ S. Monaghan, “Resetting NATO's Defense and Deterrence: The Sword and the Shield Redux”, CSIS Brief, Center for Strategic and International Studies, 2022.

²² E.H. Christie and K. Berzina, “NATO and Societal Resilience: All Hands on Deck in an Age of War”, Policy Brief, German Marshall Fund of the United States, 2022.

²³ S.G. Jones, “Russia's Shadow War Against the West”, CSIS Brief, Center for Strategic and International Studies, 2025.

²⁴ G. Presidente, “The Technological Paradigm, Stupid”, Policy Brief, no. 33,

Sea: Power Projection Meets Fragility. There are three main types of sea-based critical infrastructures: seaports, undersea cables as well as pipelines and oil and gas rigs. In theory, maritime routes could also be included as maritime trade represents the central element of globalisation.²⁵ Beside highlighting the conceptual problems discussed at the beginning, this aspect can be kept aside because, historically, naval forces have also protected maritime trade.²⁶ Three considerations are in order. First, naval forces have, by default, historically fulfilled humanitarian assistance disaster relief (HADR) missions: the fact that the bulk of the world population lives relatively close to the shores and, in emergencies, land routes and airports are often inaccessible, make them extremely relevant for this task.²⁷ Second, ports represent a weak link in global security governance due to the volume, intensity and extension of maritime traffic – this explains why criminal organisations extensively rely on maritime traffic for drug smuggling and arms traffic. Over the past few years, several initiatives have been launched aiming at port security. Among others, NATO Defence Innovation Accelerator for the North Atlantic (DIANA) in 2023 launched its challenges for would-be start-ups and one included seaport security against a wide array of threats – electromagnetic, kinetic and cyber (as demonstrated by the 2021 Rotterdam seaport hack).

The vulnerability of undersea cables and pipelines have been repeatedly highlighted in recent years, especially as Europe became more dependent on gas pipelines for energy supplies and digitalisation drove a dramatic expansion in worldwide digital traffic. After the 2022 Nord Stream pipeline sabotage

Institute for European Policy-Making, 2025.

²⁵ Tancredi (ed.), *Globalization and Maritime Power*.

²⁶ W.P. Hughes and J.M. Richardson, *Fleet Tactics and Naval Operations*, Annapolis, MD, Naval Institute Press, 2018.

²⁷ B. Barry, with contributions from S. Fetzek and Lieutenant Colonel C. Emmett, “Green Defence: the defence and military implications of climate change for Europe”, International Institute for Strategic Studies, 8 February 2022.

and several accidents to undersea cables in the North and Baltic Seas, NATO launched “Baltic Sentry” in 2025 through which German and Danish frigates, armed with sonar and drones, patrol Baltic waters to deter Russian hybrid threats.²⁸

Oil rigs have observed tension in the past due to disputes about maritime waters, for instance when Türkiye threatened Italian ships in the Eastern Mediterranean.²⁹ The growing competition for natural resources coupled with technological progress are currently opening a new domain, the seabed – which in turn could lead both to military competition as well as to threats to critical infrastructures in the near future.³⁰

Air and Space: Dual-Use Dilemma. This section discusses protection of critical infrastructures in the air, space and cyber domains. The three domains are distinct but closely intertwined, this is why they are treated together.

In the air, fighter jets and missile defences shield hubs like Frankfurt, a TEN-T node, from kinetic threats. However, airports face a growing array of subtle challenges, including man-portable air-defense systems (MANPADS) and drones which can threaten airplanes and ground control stations. In 2018 a drone swarm at the London Gatwick airport grounded 1,000 flights. Cyber attacks, as evidenced by the 2020 Eurocontrol breach, also represent an insidious threat as well as nearby accidents, like the 2025 fire near the London Heathrow airport which paralysed air traffic around the world for a day. Airports, due to high volume of passengers, their widespread origins and destinations as well as the close and dense environments, also represent a soft target for chemical, biological, radiological and nuclear threats.

²⁸ “NATO launches ‘Baltic Sentry’ to increase critical infrastructure security”, *NATO*, Brussels, NATO HQ, 2025.

²⁹ S. Jewkes, “Turkish blockade of ship off Cyprus is out of Eni’s control: CEO”, *Reuters*, 16 February 2018.

³⁰ D.R. Strachan, “Forward...from the Seabed?”, *CIMSEC*, 13 March 2018.

Space is playing a bigger economic and societal role as well as becoming more contested.³¹ NATO's 2019 space doctrine and the U.S. Space Force's orbital sensors track threats like Russia's 2021 anti-satellite (ASAT) tests, which littered orbit with debris endangering Galileo satellites. Europe, reliant on defensive Space situation awareness (SSA), lags in counter-ASAT options, leaving it vulnerable to adversaries. In recent years, jamming of geolocation signals have occurred in the Baltic regions,³² thus threatening air traffic while cyberattacks against satellites have also increased.³³

Conclusion

This short summary of the military protection of critical infrastructures leads to three final considerations. First of all, critical infrastructures vary across time and space. Defining also where a critical infrastructure starts and end is not easy both in theory and in practice. Insofar as European countries will maintain a military superiority, its adversaries will try to exploit the vulnerabilities of their critical infrastructures. European countries, in recent years, have undertaken different initiatives aimed at protecting their critical infrastructures. However, governance issues as well as varying priorities have affected their effectiveness. Last, but not least, this is also due to the fact that new threats emerge and European countries had to face other emergencies, from the financial crisis to terrorism, from the Covid-19 pandemic to Russia's war against Ukraine.

³¹ T. Harrison, *Building an Enduring Advantage in the Third Space Age*, Washington, DC, American Enterprise Institute, 2024.

³² K. Eggert, "GPS jamming in the Baltic region: Is Russia responsible?", *Deutsche Welle*, 5 May 2024.

³³ C. Poirier, "The War in Ukraine from a Space Cybersecurity Perspective", *Report*, no. 84, Vienna, European Space Policy Institute, 2022.

5. Geopolitics on Steroids: Opportunity or Mayhem for Seaports?

Theo Notteboom, Hercules Haralambides

Given the morphology of our planet, trade would have been impossible without shipping seaports. In a globalised ecosystem of liberal economics, seaports thrive when the international macro-environment avoids conflict, promotes trade, and supports the development of efficient and extensive global supply chains. In recent years, however, cross-border tensions and disruptions are increasingly influencing the dynamics of international trade and shipping networks. The importance of energy and transport infrastructure during trade and related frictions brings ports to the forefront, given their role both in stimulating growth and development, as well as in disrupting commercial and military logistics. A case in point is the March 2025 temporary truce deal in the Russia-Ukraine war, reached by presidents Trump and Putin, albeit applying only to attacks on energy infrastructures. This makes seaports important focal points in geopolitical considerations, potentially allowing them to act as geopolitical agents, able influence and shape geopolitical debates and actions.

This contribution focuses on how and to what extent growing geopolitical tensions impact seaports. To that effect, we distinguish between three geopolitical themes directly or indirectly affecting ports: (1) Ports as nodes in geopolitically sensitive corridors and networks; (2) Ports and the Geopolitics of trade; (3) The geopolitics of investment and ownership in

ports. We conclude with thoughts on the future role of ports in the current geopolitical scene. Do geopolitics and *global economic uncertainty* present opportunities for ports, or are they causing mayhem?

Ports as Nodes in Corridors and Networks

The expansion of international trade, as well as competition among nations, have led to efforts to create trade corridors and new trade routes and trade agreements.¹ Examples include the International North-South Transport Corridor (INSTC); the Al-Faw Turkey-Iraq Multimodal Corridor; the India-Middle East-Europe Economic Corridor (IMEC); the China-Pakistan Economic Corridor (CPEC); the China-Myanmar Economic Corridor (CMEC); the Trans-European Transport Network (T-TEN); the Pan-American Highway; the Shanghai Cooperation Organization (SCO); QUAD (Quadrilateral Security Dialogue) and more.²

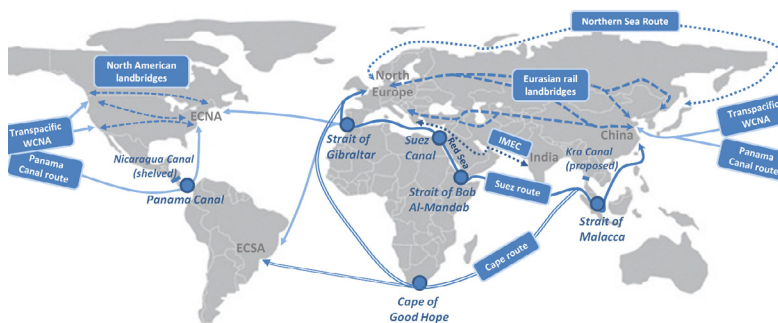
A maritime (or overland) corridor consists of a relatively narrow geographical area, attracting trade flows due to shorter distances, superior infrastructure and/or trade agreements among lateral states. Metaphorically, maritime corridors could be seen as the arteries of international trade. Strategic points along maritime conduits such as the Panama Canal, the Suez Canal, the Straits of Malacca and the Straits of Gibraltar function as important turntables in the global shipping network. Maritime corridors and networks are complemented by land-based networks. A good example is the (overland) “belt” and the (maritime) “road” in China’s Belt and Road Initiative (BRI). In past decades, post-Panamax mega-ship developments, port development and the dynamics in logistics networks have

¹ M.E. Porter, *The competitive advantage of nations*, New York, NY, Free Press, 1990.

² T. Notteboom, H. Haralambides, and K. Cullinane, “The Red Sea Crisis: ramifications for vessel operations, shipping networks, and maritime supply chains”, *Maritime Economics & Logistics*, vol. 26, no. 1, 2024, pp. 1-20.

created the right conditions for the large-scale development of long-distance inland corridors such as the rail land-bridges in North America, or the rail corridors between China, Central Asia and Europe, part of China's BRI. At the same time, new maritime routes emerged as exemplified by the Northern Sea Route (NSR), promoted by Russia and China (Figure 5.1).

FIG.5.1 - ROUTING ALTERNATIVES ON THE ASIA-NORTH EUROPE TRADE AND ASIA-AMERICAS TRADE



Source: Notteboom et al. (2024)

Vessels navigate through maritime lanes and interoceanic passages according to the *international law of the sea* and various treaties that ensure free passage. Transit fees are occasionally charged by government agencies, such as the Panama Canal Authority, the Suez Canal Authority, and the various Russian controlling stations along the NSR. However, geopolitical tensions can make nations “nervous” when it comes to using these critical routes. Seaports located in strategic chokepoints, such as the Strait of Hormuz, the South China Sea, the Red Sea/Suez Canal area, and the ports at the entrances of the Panama Canal, are especially susceptible to such tensions. For example, in early 2025, as soon as the newly elected US president Donald Trump aired his intention to reclaim the Panama Canal, CK Hutchinson sold most of its port assets, apart from those in mainland China, to a US consortium, led by the BlackRock

asset manager. Countries may seek to secure control over essential maritime trade routes, to minimise risks posed by external actors. As a result, concerns are growing about the safety and costs associated with vessels passing through these maritime chokepoints.

The Red Sea crisis³ shows that it is no longer unthinkable that a key maritime artery in the global shipping network gets severely disrupted and even cut off, despite international treaties guaranteeing free passage. Geopolitical factors play an important role here. Automatic Identification System (AIS) data on ship movements shows that the Red Sea passage remained open for the maritime interests of certain geopolitically allied countries or companies that were willing to pay the Houthi militia for safe passage. Anecdotal evidence has raised such safe passage fees to amounts in excess of €2 billion a year, but the Houthi have always refuted such allegations. Nonetheless, adversarial nations and vessel operators incurred substantial additional supply chain costs by having to sail around the Cape of Good Hope to avoid being attacked by the Houthi.

In the current geopolitical climate, states are motivated to preserve or control critical maritime infrastructure or, at the very least, ensure access to it. Geopolitical conflict affecting a specific route or passage makes the affected governments and supply chain actors search for alternative routes. Recent examples include controversial statements by US President Donald Trump in early 2025 about reasserting US control over the Panama Canal; China's claims over islands in the South China Sea; and the Nicaragua Canal⁴ and Kra Canal⁵ projects, as leverage to secure access to routes such as the Panama Canal and the Straits of Malacca, respectively.

³ For a detailed analysis see Notteboom et al. (2024).

⁴ J. Chen, T. Notteboom, X. Liu, H. Yu, N. Nikitakos, and C. Yang, "The Nicaragua Canal: potential impact on international shipping and its attendant challenges", *Maritime Economics & Logistics*, vol. 21, 2019, pp. 79-98.

⁵ R.S. Sulong, "The Kra Canal and Southeast Asian Relations", *Journal of Current Southeast Asian Affairs*, vol. 31, no. 4, 2012, pp. 109-25.

Growing security issues are leading to renewed attention and investments in defence. The role of seaports in this context is also receiving increased attention. Many ports are assigned a more pronounced military role and become indispensable to national defence planning. Their infrastructure, location, and operational capacity can make them a cornerstone of a nation's defense strategy, as well as attractive bases for the projection of foreign naval power, especially in times of conflict or geopolitical tension. Ports located near *critical trade routes* can serve as hubs of naval and other operations, aimed at securing international shipping lanes against threats like piracy and terrorism.

Many commercial ports have become ports of "dual use" in nature, housing a naval base next to their commercial activities. They can be found at critical military locations near maritime chokepoints (e.g., Djibouti near the Red Sea and the Gulf of Aden; Gwadar, at the entrance of the Pakistan-China corridor; Souda Bay in Greece) or at domestic ports (e.g., San Diego and Norfolk as homeports for the US naval fleet at the US West Coast and US East Coast respectively). Stationing advanced warships at a port in a geopolitically tense region can send a message of military readiness. Ports can act as *command hubs* for the coordination and monitoring of defence operations, and house *electronic warfare capabilities* to intercept and jam enemy communications. Ports equipped with dry docks and maintenance facilities can play a role in constructing, repairing, and overhauling military and dual-use vessels.

In today's geopolitical context, port terminals might be asked to adopt a *logistical role in facilitating (large-scale) military operations and exercises*. For example, in response to a perceived Russian threat, the European Union committed to reinforcing the military transport infrastructure needed to move troops and material. Some EU ports are planned play a key role in the creation of *defense corridors*, primarily linking deep-water North Sea ports to Europe's eastern borders.

Ports and the Geopolitics of Trade

In the 1950s, the concept of “World Peace through World Trade” became the foundation of post-war trade liberalisation. The thinking was simple, marvellously propounded by Frédéric Bastiat one hundred years before (1850): “economic interdependence through trade and foreign investment makes war unprofitable”.⁶ The same principle underlies President Xi Jinping’s grandiose concept of the BRI: “the melding of cultures through economic interdependence expunges war and leads to a safer planet”.⁷

Globalisation was promoted by the developed world not so much because it truly believed in its merits, but out of necessity: countries in the developed world had become “mature” economies and “affluent societies” with a car in every garage and a television set in every living room;⁸ how much more could consumers buy? Production in the developed world exceeded demand, so it had to be sold beyond its borders. And production had to be on a large scale in order to enjoy economies of scale and international competitiveness, following the successful example of post-war Japan. So, opening up foreign markets through free trade and globalisation was the solution to sustaining massive production. And here was the capital error: the developed world was not producing “inside” to sell “outside” but produced “outside” through Foreign Direct Investment (FDI) and relied on reimporting these products back home. The effects of this on employment, tax revenues and the unravelling of the “welfare state” were all too obvious.

With the financial crisis of 2009, a trend of deglobalisation or *slowbalisation*⁹ began to emerge and disdain for cheap

⁶ F. Bastiat, *The Law*, Foundation for Economic Education, 1998. *La Loi* (the law) was first published in Paris in 1850 by Librairie De Guillaumin et Co.

⁷ Both quotations, of Bastiat and Xi, are paraphrases of similar expressions of Bastiat and Xi, attempted here by the authors of this chapter.

⁸ J.K. Galbraith, *The Affluent Society*, London, Hamish Hamilton Ltd., 1958.

⁹ *The Economist*, “Slowbalisation: The Future of Global Commerce”, 24 January 2019.

consumerism, friendshoring, nearshoring, shorter supply chains, 3D printing, and *global economic uncertainty* started to become visible. The international political consensus that supported the universal economic benefits of globalisation, which characterised much of the XX and early XXI centuries, had begun to erode. A multipolar world emerged where nations compete for economic, political, and military positioning. The emergence of China, as the leader of the global South, is now challenging the hegemony of the United States. Some other governments and political groups too have started to question the free trade model, seeking to rebalance or redefine its meaning and practical implementation. The role and function of trading blocs is also being scrutinised, as seen with Brexit and similar misgivings of certain EU members. The structural developments that boosted trade in the past – falling transportation costs, trade liberalisation, expanding global production chains and financial deepening – do not seem to support trade to the same extent as before. At present, we seem to be returning to the protectionist pre-WWII era, marked by high tariffs, conflict, trade wars, weakening trade ties, and competition among great powers; an era where defence spending becomes the means for explicit projection of power and global dominance.

Economic power shifts among nations reshape trade networks, leading to new dependencies and rivalries. Geopolitical tensions between major economies can lead to *trade decoupling and realignment*. This means countries may reduce their dependence on rival nations, fostering or strengthening new trade alliances. The forces toward trade decoupling and realignment are the strongest in critical sectors such as energy, rare earth materials and high-tech goods. For example, the war in Ukraine has resulted in an increasing disconnection between Russia and Western countries in both political and economic terms, coupled by a wide array of mostly ineffective sanctions.¹⁰ Starting in 2022, this situation has brought about

¹⁰ For an overview see R. Griffin, R. Perkins, M. Gordon, J. Holman, and A.

abrupt changes in traffic volumes with Russia in many EU ports. Growing tensions between China and the US are causing similar effects in the medium term, with Europe remaining indecisive about the merits of an equidistant stance between the two, in spite of the frequent friendly nods of China, which is being visibly westernised exactly for this purpose.

In a possible return to protectionism, tools that governments have at their disposal, in addition to reciprocal tariffs, include quotas, import licensing, tighter customs procedures, sanctions, trade defence measures, and the favourable treatment of domestic business. Additional trade remedy actions consist of antidumping, countervailing, and safeguard measures.¹¹ With the new US Administration and President Trump's "America First" policy, mostly pursued through import tariffs (or threats thereof), ports will soon start to feel the full impact of the situation. At the time of writing, a good example of this happening is the imposition of steep tariffs by the US and EU on the imports of Chinese electric vehicles (EV), in order to address an alleged "unfair and unbalanced trade",¹² and the "unfairly subsidised" China-made electric vehicles.¹³ As a result, EV manufacturing is likely to shift even more to countries not liable to such tariffs like Thailand, Indonesia, Vietnam, Hungary, Turkey, Brazil, etc. Together with this, global trade patterns and shipping networks are realigned. It is expected here that similar will be the results of the announced US tariffs on Canadian and Mexican exports, planned to take effect in early March 2025 after the initial implementation date was postponed for a month.

Critchlow, [Infographic: Sanctions on Russian commodities tracker](#), S&P Global, 27 February 2024.

¹¹ [Temporary Trade Barriers Database](#), World Bank Group, Washington D.C., 2 March 2021

¹² The White House, [America First Trade Policy](#), Washington D.C., 20 January 2025.

¹³ European Commission, [EU imposes duties on unfairly subsidised electric vehicles from China while discussions on price undertakings continue](#), EC Press Release, Brussels, 29 October 2024.

At this juncture, we would be amiss not to mention that for tariffs to be effective, demand for imports must be elastic; otherwise, inflation and high interest rates would ensue, hurting the imposer, and hindering growth and development in his own country. Moreover, tariffs overvalue the imposer's currency, hurting its own exports which would be hurt anyway by the countervailing tariffs of the affected countries. Tariffs thus become a boomerang. In addition, inflation and interest rate uncertainty lead to volatility in financial markets and supply chains, again impacting trade and shipping patterns.

The push for selective trade decoupling and realignment is evident in the geopolitics of *strategic autonomy*. In general terms, strategic autonomy policies seek to enable a nation or region to make independent decisions and act autonomously in critical areas, thereby reducing excessive dependence on other countries. These policies reflect a desire to safeguard sovereignty, in an increasingly globalised and interdependent world, while minimising vulnerability to external pressures. Key economic components of these policies include diversifying trading partners, reducing reliance on single suppliers or nations for critical goods (e.g., rare earth minerals, food, energy, or medical supplies), and enhancing production in strategically vital sectors, such as semiconductors, pharmaceuticals, renewable energy technologies, agriculture, and military equipment. Geopolitics and technological leadership play a crucial role in this endeavour.

The pursuit of strategic autonomy necessitates policies that, to the extent possible, balance partnerships with global powers while preserving the ability to act independently. Often, this is easier said than done and can be quite challenging, as exemplified by the European Union's strategic autonomy efforts,¹⁴ aiming to reduce dependency (e.g., on NATO) while maintaining cooperative ties with (most) non-EU nations. At the time of reckoning, however, such efforts become null, and

¹⁴ EU strategic autonomy 2013-2023: from concept to capacity, EU Strategic Autonomy Monitor Brief, European Parliamentary Research Service (EPRS), July 2022.

void and “sides” must be taken. When designing such policies, policymakers must consider that achieving full autonomy is extremely difficult (if not impossible) in a highly interconnected global economy characterised by strongly intertwined global supply chains. For example, a full economic decoupling from China is unthinkable and undesirable by any country, given China’s dominance in many industrial manufacturing sectors.¹⁵ Moreover, considerable financial resources and time are needed to develop strategic autonomy capabilities, while expressing intentions related to strategic autonomy may provoke retaliatory actions or trade responses from other nations, even those considered friendly.

Strategic autonomy has a significant *maritime dimension*. It encourages states to reduce their dependence on fleets owned or operated by rival nations, especially those that are geopolitically distant. To accomplish this, a government may adopt protectionist measures to further develop, strengthen and safeguard its own *national fleet*, or impose restrictions on domestic businesses regarding the use of certain foreign flags. A recent example of this is the decision of the US Department of Defence, in early January 2025, to add China’s state shipping company China COSCO Shipping to a blacklist of companies allegedly supporting the Chinese military.¹⁶ By prioritising the development of their own merchant fleets, countries aim to ensure that critical goods can be transported under national “oversight”, during crises or geopolitical tensions. This approach also helps guarantee the transport of essential goods, such as energy resources and food, without excessive reliance on foreign-flagged vessels, thereby safeguarding energy and food security. However, developing and maintaining an *own* fleet comes at a cost, demanding substantial investments, skilled labour, and

¹⁵ Global economic fracturing and shifting investment patterns - A diagnostic of 10 FDI trends and their development implications, UN Trade and Development UNCTAD, Geneva, DIAE/2024/1, 2024.

¹⁶ E. Yep, “US blacklists China’s state shipping company COSCO, CNOOC’s global oil trading arm”, S&P Global, 7 January 2025.

expertise. Haralambides (1986) has shown that whatever a country earns as freight revenue of its own fleet is annulled by losses in the trade account of its balance of payments.¹⁷

Second, strategic autonomy is often focused on maintaining a domestic shipbuilding industry whose commercial activity is not driven by efficiency or cost, but by the need for shipyards to continue building naval vessels; again, this is the case in the US. It is interesting to note that US Aid and an ever-growing list of “strategic” cargoes, ranging from energy products to wheat, rice and soybeans, must be carried on a US-flagged vessel. The latter must be financed and built in the US and manned by American citizens whose high wage costs are subsidised to bring them in line with crews from other countries.

Governments may offer subsidies, tax incentives, or low-interest financing to encourage shipping companies to procure domestically-built vessels and strengthen national fleets. China, for example, in an attempt to support and expand its massive shipbuilding industry, currently the largest in the world,¹⁸ subsidises the early retirement (scrapping) of its vessels.¹⁹

Finally, in a tense geopolitical environment, governments may specifically target shipbuilding facilities in rival countries that have military connections and are involved in the construction of *dual-use ships*. These are designed to serve commercial purposes during peacetime and fulfill military or emergency roles during crises.²⁰

¹⁷ H.E. Haralambides, “Investment in shipping and the balance of payments short-run equilibrium freight rate”, *International Journal of Transport Economics*, vol. XIII, no. 3, 1986.

¹⁸ See UNCTAD, *Review of Maritime Transport*, UNCTAD, Geneva, 2024 for a detailed overview of the world shipping and shipbuilding industries.

¹⁹ Z. Yang, Z. Jiang, T. Notteboom, and H. Haralambides, “The impact of ship scrapping subsidies on fleet renewal decisions in dry bulk shipping”, *Transportation Research Part E: Logistics and Transportation Review*, vol. 126, June 2019, pp. 177-89.

²⁰ D.Y. Coulter, “Maritime security and dual-use vessels: The role of commercial shipping in military operations”, *Naval War College Review*, vol. 59, no. 1, 2006.

Investment and Ownership in Ports

Trade decoupling and realignment processes, caused by geopolitical dynamics, can have serious ramifications for seaports, although, in most cases, ports are not the prime or first-in-line target of geoeconomic decisions. However, geopolitical tensions can also result in policy decisions directly aimed at ports as prime targets. In particular, as such tensions rise, *ownership and investment in port areas come increasingly with (geopolitical) strings attached*, affecting a port authority's ability to welcome the investors or operators of its choice.

The entry of global players into the local terminal operator industry does not always imply an infusion of private capital by the foreign state-owned terminal operators who move in. Examples include global investments by DP World (part of Dubai World) and PSA (part of Temasek Holdings), or the large Chinese state-owned firms Cosco Shipping Ports and China Merchants Holding. The moves of these operating groups can, rightfully or not, stir geopolitical controversy as exemplified by the take-over of P&O Ports by DP World, or the investment spree of COSCO and China Merchants around the world. As a result, the European Commission introduced its 2019 “critical infrastructure” framework for screening foreign direct investments to safeguard security and public order. Opposite to the binding nature of similar screening steps of the US Senate, however, the EU makes mere recommendations, leaving the decision to accept or not the FDI to the Member state.

The investment orgy of state-owned global terminal operators remains controversial to many who assume, often purposely wrongly, that investments are aligned with the geo-economic ambitions of the parent state-holding.²¹ As geopolitical sensitivities have become much more pronounced in recent years, often refuting the principle of *comparative advantage*,

²¹ J. Chen, Y. Fei, P.T.W. Lee, and X. Tao, “Overseas port investment policy for China's central and local governments in the Belt and Road Initiative”, *Journal of Contemporary China*, vol. 28, no. 116, 2019, pp. 196-215.

foreign involvement in port investments is increasingly seen as a direct security risk, particularly in case commercial objectives in a port are combined with military and geopolitical motives.²² Therefore, commercial strategies pursued by terminal operators can become important national policy issues. This is exemplified by the 24.99% minority shareholding of COSCO Shipping Ports in HHLA's Container Terminal Tollerort (CTT) in Hamburg. When COSCO and HHLA announced the proposed deal in 2022 (initially involving a 35% shareholding), political controversy erupted in Germany, also with strong opposition from labour unions (such as Verdi). The Berlin government and the European Commission screened the proposed transaction, with the latter recommending against approval. In the end, Chancellor Olaf Scholz pushed the deal through in 2023.²³ CTT was officially declared "critical infrastructure" in 2023, but this did not change the situation on the ground.

Often, such opposition to FDI isn't but concealed protectionism with the blessings of trade unions which are in this way also protecting the employment of their members. A notable recent example (2024) was the strong opposition of the International Longshoremen's Association (ILA) of the US²⁴ against automation and foreign ownership, citing threats to job security and potential national security risks. In summary,

²² O. Merk, "Geopolitics and commercial seaports", *Revue Internationale et Stratégique*, vol. 107, no. 3, 2017, pp. 73-83; J. Devermont, A. Cheatham, and C. Chiang, "Assessing the risks of Chinese investment in Sub-Saharan African ports", Washington DC, Center for Strategic and International Studies, June 2019; Office of the U.S. Trade Representative, *Report on China's Targeting of the Maritime, Logistics and Shipbuilding Sectors for Dominance*, Section 301 Investigation, 16 January 2025.

²³ F. Ghiretti et al., *Chinese Investments in European Maritime Infrastructure*, Policy Department for Structural and Cohesion Policies Directorate-General for Internal Policies PE 747.278, September 2023; F. Doppen, T. Notteboom, and D. De Bievre, "In the Eye of a Geopolitical Storm: Responses of Port Management Bodies to Investment Screening in the EU", IAME 2025 Conference, International Association of Maritime Economists, Valencia, 25-28 June 2024.

²⁴ ILA represents dockworkers along the US East- and Gulf Coasts.

any foreign state-linked investment and ownership in port terminals can raise, justifiably or not, several geopolitical concerns prompting action.

First, there might be concerns about the market power of the foreign entities, particularly when there is a *high risk of alignment of these firms with foreign geopolitical interests*. Investments by foreign terminal operators can be controversial since their hold onto strategic port facilities may imply a loss of sovereignty, going against long-term national interests.

Second, some geopolitical agents might voice their concern about foreign terminal operators being able to *extract sensitive trade data or might acquire access to key technologies and information flows*. Opponents of specific foreign investments or ownership in ports might argue that, when shared with foreign government agencies, such data can be used to design (hostile) trade policies or used in the battle for technological superiority. To counter any reasonably plausible arguments and to protect data sovereignty, governments are increasingly implementing policies to ensure national or regional control over data, data confidentiality, and data transfer.

Third, geopolitical agents might want to reduce the risks of a *drain of economic surplus toward powerful foreign state-linked players*. Local and national policymakers might want to ensure that the local community is getting its fair share of the economic surplus enjoyed by the foreign terminal operator as a result of its often exclusive entitlement to operate the terminal. Experience in the drafting of concession agreements has addressed many of such qualms although, as always, the devil is in the detail and attention is required. This is especially true of concessions in developing countries where, often, considerable *information asymmetry* exists between the global terminal operator and the local port authority awarding the concession.

Fourth, some geopolitical agents may voice concerns to the effect that foreign state-linked entities might use their entry into ports as a stepping stone to increase their *control and influence in the hinterland* through infrastructure investments (such as

rail), and the implementation of a vertical integration strategy of the port operating company to include land transportation or distribution facilities. While such concerns are yet to be supported by empirical evidence, particularly smaller ports could worry that such a geopolitically-backed strategy reduces port user choice and lowers competition levels in a port's hinterland connectivity.

Given the above, governments might impose restrictions on who can invest and operate terminals, and related hinterland infrastructure and services, and stipulate strict institutional and operational conditions foreign state-linked entities should adhere to. In this context, *FDI screening mechanisms* are gaining momentum. Countries often require stringent reviews of foreign investments in critical infrastructure, like that of the US Committee on Foreign Investment (CFIUS) process. In Europe, Regulation (EU) 2019/452 established a framework for EU cooperation on incoming FDI based on standards for investment screening and the establishment of a network for information sharing across the EU. The regulation aims to better equip the EU to identify, assess and mitigate potential risks certain FDI – particularly those in critical infrastructure and advanced technology sectors – pose to the security or public order of the EU or its Member states.

In the past, most EU Member states have amended existing national investment screening mechanisms, or have developed new ones, while the EU is revising its 2019 FDI Screening Regulation.²⁵ In the case of the latter regulation, it emerged that the European “north” was in favour of stricter screening while the capital hungry “south” was much more lenient and accommodating. Such differences in approach, often well justified, make an EU-wide policy on screening mechanisms rather challenging in the case of terminal FDI (and not only). Doppen et al. (2024)²⁶ demonstrated that the investment

²⁵ European Commission, Third Annual Report on the screening of foreign direct investments into the Union, COM(2023) 590 final, 19 October 2023.

²⁶ Doppen et al. (2024).

screening mechanisms in EU Member states have elicited different responses from port authorities across the EU. FDI screening frameworks and their applicability in ports might differ between nations, and only a few practical experiences have been gained on how to deploy FDI screening mechanisms in a meaningful way in the context of terminal concessions or terminal acquisition processes.

Next to providing port services via state-owned or state-linked terminal operators, foreign states can also exert geopolitical influence on ports in other ways.²⁷ First, they can directly or indirectly provide financial support for port construction using national state-owned banks or other strategic investment vehicles, or by granting subsidies or technical assistance. Such support, although in principle welcome, often comes with certain conditions. Deals are typically negotiated and closed bilaterally at government level. It has occasionally been argued that deals might involve pressure aiming at geopolitical “alignment” of the receiving country. In other words, port finance, it has been claimed, can be used as a tool of economic diplomacy, fostering dependencies that can translate into political influence. Recriminations of this sort have often been directed towards China, including “debt trap” accusations. However, no investigation to date, even in highly debated cases such as investments in the Sri Lankan Hambantota port, or the Mombasa-Nairobi railway in Kenya, has shown “sinister” motivations.

Second, state-owned construction companies might be mobilised for port construction, maintenance, and operations. For example, Yang et al. (2020)²⁸ analyse how Chinese state-owned companies such as China Merchants Holdings

²⁷ Merk (2017); D. Yang, L. Li, and T. Notteboom “Chinese investment in overseas container terminals: The role of investor attributes in achieving a higher port competitiveness”, *Transport Policy*, vol. 118, March 2022, pp.112-22.

²⁸ Z. Yang, Y. He, H. Zhu, and T. Notteboom, “China’s Investment in African Ports: Spatial Distribution, Entry Modes and Investor Profile”, *Research in Transportation Business & Management*, vol. 37, no. 100571, December 2020.

International (CMHI), China State Construction (CSC), China Harbour (CHEC) and China Road and Bridge (CRBC) are involved in port investments, construction and operations in African ports using a multitude of business modes ranging from EPC (Engineering Procurement Construction), EPC+F+I (EPC + Finance + Invest) and BOT (Build, Operate, Transfer) to other Public Private Partnership arrangements.

Conclusions: Opportunity or Mayhem for Ports?

Seaports face significant vulnerabilities in today's geopolitical climate due to their critical role in global trade and their susceptibility to physical, cyber, and economic threats. Our chapter has hopefully shown that the current geopolitical context for ports is multifaceted and highly complex. Given this complexity, one might ask whether the geopolitical tense environment brings opportunities rather than mayhem to ports. The answer to this question urges us to reflect on the ramifications of the geopolitical issues discussed above.

The geo-economic and geopolitical landscape has a major impact on seaports, which have limited control over these external factors. Geopolitical objectives and policies also have a significant impact on the strategies and operational decisions of port users. We believe that seaports should not merely endure these developments but proactively adapt to them. Shifting trade patterns, driven by processes such as friendshoring, trading with friends and strategic autonomy ambitions, present new opportunities for ports. These trends can help ports attract business and further develop into industrial-logistics turntables. Geopolitical shocks and disruptions often lead to greater fluctuations in cargo volumes and affect the geographical distribution of incoming and outgoing cargo flows. To effectively manage these challenges, it is essential to develop a high degree of commercial resilience and operational agility, enabling ports to respond swiftly to disruptions within their value chains. The volatility of the geopolitical climate

complicates the ability to predict future developments, underscoring the need for a stronger focus on risk and resilience management, scenario-based approaches for long-term port planning, and flexible strategies in port operations. For many ports around Europe, particularly in the European South, the above is easier said than done, given the presence of a stifling bureaucracy and the overarching central government control over ports and the degree of their autonomy.

Seaports have a crucial role to play in enhancing the strategic autonomy of a country or region. As vital components of industrial and logistics ecosystems and energy hubs, ports are well-positioned to provide the land, infrastructure, and resources necessary for processing critical and strategic materials. They also facilitate the production, storage, stockpiling, and transportation of both fossil and alternative energy sources, as well as the development of circular economies focused on recycling and upcycling materials. Additionally, national or allied foreign seaports can serve as key locations for building national or regional shipbuilding capabilities and can act as home ports for the national commercial and naval fleets.

We have demonstrated that ownership and foreign investment in port areas increasingly come with geopolitical strings attached, impacting a port authority's ability to welcome specific investors or operators of its choice. While investment screening mechanisms are on the rise, their content and applicability in ports varies significantly from country to country. As governments increasingly scrutinise foreign port technology and equipment deployed in national ports in the context of geopolitical strategy, terminal operators are challenged to demonstrate that their port equipment and technology do not pose backdoor security vulnerability or undermine the integrity of national port operations.

Port authorities are not in principle involved in the geopolitical positions and strategies of their respective governments. However, this does not mean that they should remain passive. Port authorities might have good reason to

oppose or challenge geopolitical actions affecting them, if such (arbitrary) actions seriously undermine their ability for effective value creation and service delivery for their customer base, or if they involve an unfounded and undocumented act of favouritism. Governments, port authorities, and the wider port and logistics community should engage in dialogue on how to assess and mitigate possible negative impacts that a justified government-led geopolitical action/measure could have on the commercial environment of the port. Frequent unannounced and uncoordinated geopolitical activism by a national government creates an unfavourable investment climate in ports.

Ports are key nodes in maritime corridors and networks that are becoming increasingly vulnerable. They are drawn into geopolitical contests focused on crucial maritime chokepoints and shipping lanes, whether they like it or not. Many commercial ports are effectively transitioning to a dual-use profile by hosting naval bases, acting as hubs for naval operations aimed at securing international shipping lanes or playing a logistical role in facilitating large-scale military operations and exercises.

Ports play a critical role in trade and defence, but their vulnerability to attacks makes them significant candidates for geopolitical disruptions and direct attacks. However, they are high-value assets and agents in a precarious geopolitical environment. To mitigate risks, it is essential to implement proactive measures such as diversifying trade routes, enhancing port security, building port resilience, and fostering international and stakeholder cooperation. Ports should ensure they are equipped with the capabilities to participate in debates about the balance of power, shape economic dependencies, and act as pivotal assets in protecting a nation's strategic and economic interests on the global stage.

6. Mediterranean Ports: Disruption, Competition, and Emerging Operational Models

Massimo Deandreis, Alessandro Panaro

In the current global economic and maritime context, it is extremely complex to outline all the challenges ports face in their day-to-day operations. This chapter will primarily focus on container traffic, since this sector is widely regarded as the one that most broadly affects global trade and whose trends serve as an indicator of the state of manufacturing goods flows and supply chains.

The wars in the Black Sea and the Red Sea have had a significant impact on strategic maritime routes, disrupting the flow of goods. Even today, the Suez Canal – a critical chokepoint for European import-export – presents a highly disrupted scenario. Final data for 2024 indicate a 50% decline in vessel transits compared to 2023, and a 65.4% decrease in the volume of goods transported. Container ships have been the most likely to divert around the Cape of Good Hope, with access to the canal down by 70%. However, other types of vessels have also opted to avoid the Egyptian hub, contributing to a total estimated loss of \$7 billion in toll revenue.

The diversions towards South Africa have now become structural and it is no longer appropriate to consider this option merely as an alternative route. Thus, the main container carriers have incorporated re-routing into their regular service schedules, and the additional transit time is no longer regarded as a delay.

The Mediterranean, for its part, does not appear to have recorded a decline in the total volume of goods transiting through the region in 2024, as evidenced by data from the basin’s most important ports. As shown in the table below, few ports experienced significant decreases in 2024. Instead, there has been a shift in traffic distribution: ports in the Eastern Mediterranean (e.g., Piraeus and Port Said) showed declines – though not substantial – while ports in the Western Mediterranean (e.g., Tanger Med and Valencia) recorded double-digit increases.

TAB. 6.1 - CONTAINER TRAFFIC – PANEL OF MEDITERRANEAN PORTS

MED Ports	MTeus 2024	Var % on 2023
Tanger Med	10.2	+18.8
Valencia	5.5	+14.2
Piraeus	4.8	-6.1
Algeciras	4.7	-0.6
Port Said	4.3	-1.8
Gioia Tauro	3.9	+11
Barcelona	3.9	+18.5
Marsaxlokk	2.9	+2
Genoa	2.8	+2.9

Source: SRM on Port Authorities

In addition to the crises mentioned above, ports now face further challenges. The United States has announced a series of global tariffs that will inevitably prompt reactions from shipping companies and have repercussions on maritime transport.

The full impact of these measures will only become measurable once the final list of taxed products is confirmed. However, it is reasonable to anticipate complex scenarios in which each country will be affected based on its volume of imports and exports to the United States. Italy, for example, exported nearly €30 billion worth of goods to the US in the first nine months of 2024, primarily in the mechanical engineering, transportation and agri-food sectors. It is clear that these sectors will be the most directly impacted by new tariffs. The overall effects, however, are more debatable, as Italy tends to export high-end goods that are generally less sensitive to tariff increases.

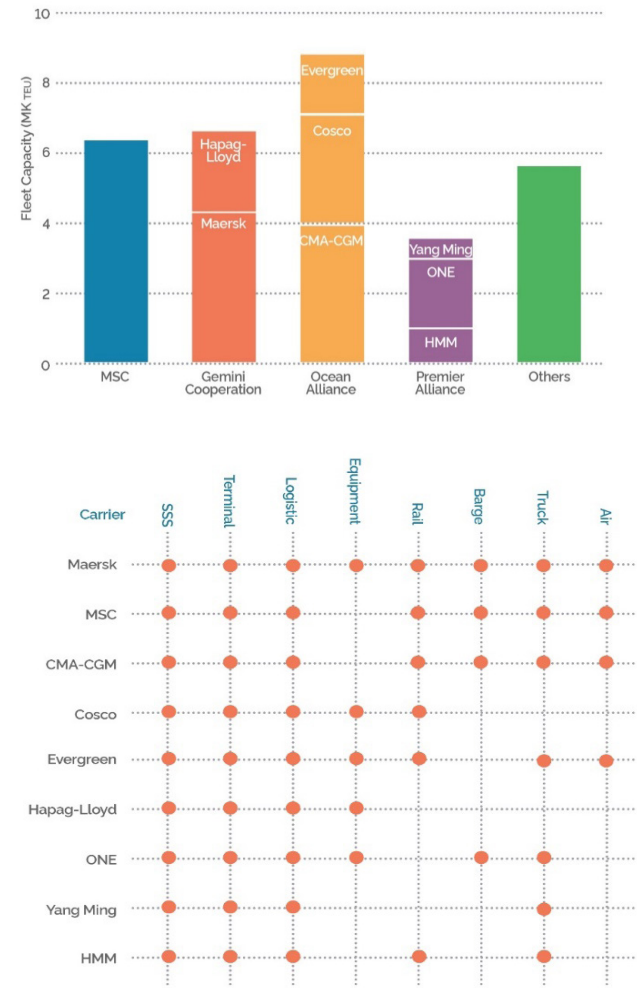
However, it would be a mistake to consider geopolitical events as the sole factors influencing the operations of Mediterranean ports and global shipping routes. Today, additional dynamics are significantly reshaping the structure of maritime transport – particularly container shipping, which acts as a barometer of the health of our manufacturing system.

One of the most significant trends is shipping companies' continued pursuit of ever-larger vessels – a phenomenon known as naval gigantism. Recent orderbook data indicate a substantial increase in maritime capacity, with the introduction of new ships exceeding 15,000 TEUs projected to grow by 14% in 2025, 8% in 2026 and 13% in 2027. This underscores the growing challenge for port infrastructures, both now and in the years ahead. Accommodating these larger vessels requires state-of-the-art equipment and technology for loading and unloading, faster intermodal connections, expanded berths and next-generation cranes. Therefore, major investments will be needed for boosting logistical efficiency – a factor that will play an increasingly decisive role in shaping the future competitiveness of ports.

A second important trend to consider is the growing vertical integration within the logistics supply chain. Major shipping carriers have been increasingly seeking to expand their control beyond maritime transport by acquiring other segments of the logistics process – such as terminals, rail transport, road freight,

and air cargo. This reflects a broader strategy to grow not just within their core industry, but across the entire connected supply chain.

FIG. 6.1 - GLOBAL CARRIER: FLEET CAPACITY (MKTEU) AND VERTICAL INTEGRATION OF LOGISTICS



Source: SRM and transmodal

A third major development in the maritime transport sector is the reshaping of alliances among the world's leading shipping carriers. Since February 2025, the global container shipping landscape has taken on a new structure, with the formation of four major groups: Gemini Cooperation, Ocean Alliance, Premier Alliance and MSC, which will operate independently, forming slot agreements as needed.

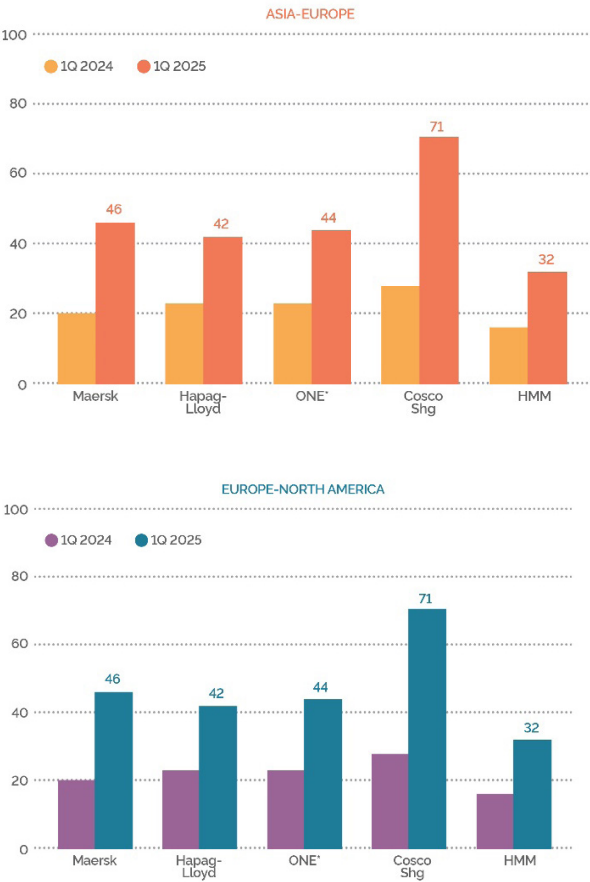
Together, these four players will control around 80-85% of global container shipping capacity, showing a dominant position in the market. They are set to cover all major strategic trade routes, positioning themselves as the key leaders in maritime transport and global freight flows.

Two other developments also deserve attention: the implementation of the Emission Trading System (ETS) and a proposed US tax aimed at discouraging Chinese-built and Chinese-operated vessels from accessing American ports.

The ETS acts as a form of taxation on ships docking at European ports, whereby vessels are required to pay a certain amount for their CO₂ emissions, with varying cost based on the routes they travel. This policy could especially disadvantage European ports in the Mediterranean, as large vessels may reroute towards North African ports where no such docking or unloading fees are currently imposed. This creates a distortion in the system that urgently needs to be addressed.

Recent industry estimates have calculated the surcharges some carriers are applying to cover ETS-related costs. On routes such as Europe-North America and Asia-Europe, additional fees range from €32 to €71 per container. Given the massive volume of containers moving along these corridors, the overall impact on the maritime transport sector is expected to be significant.

FIG. 6.2 – CARRIERS' EMISSIONS SURCHARGES 1Q 2024 VS 1Q 2025 (EUR 7 TEU)



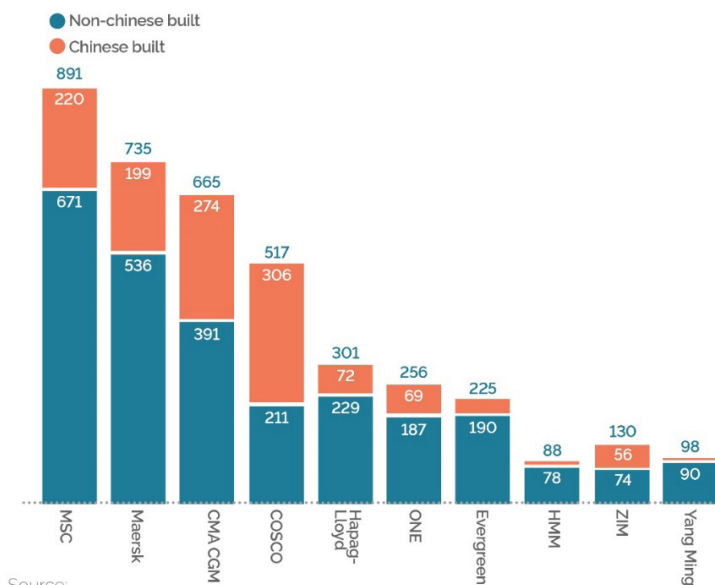
Source: Alphaliner

A different concern arises when we consider the new measures under discussion in the United States aimed at making it more difficult for Chinese ships to dock at American ports. Notably, these restrictions would apply not only to vessels operated by Chinese companies, but also to all ships built in Chinese

shipyards – which currently account for about one-third of the global container ship fleet.

To put this into perspective, 93% of MSC's vessels on order are being built in Chinese yards. For Maersk, that figure is 70%; for CMA CGM, 52%; and for Hapag-Lloyd, 91%. The following chart highlights the existing fleets of these carriers. The impact of this policy could be substantial for all major global shipping lines, which would face significant additional costs when calling at US ports. Current estimates suggest the number of affected ships could reach 37,000 per year.

FIG. 6.3 – TOP 10 OPERATORS' CURRENT FLEET (UNITS)



Source:
Alphaliner

However, these are not the only challenges Mediterranean ports are facing. Beyond regulatory pressures, there is the ongoing issue of port competitiveness. Ports must continuously upgrade their infrastructure to meet the growing demands of efficient logistics. Today, they are expected to adapt to a fundamental

shift in their operating models. Digitalisation and sustainability have become strategic imperatives. To remain competitive, ports must consistently invest in these two key areas.

A new model known as the Green Port, is emerging with a focus on energy efficiency, renewable energy investments, alternative fuels, intermodality and a smarter use of available space. The goal is to minimise the time ships spend at docks, reducing emissions and improving overall environmental performance.

Alternative fuels, in particular, are set to become a decisive factor in how shipping companies choose which ports to work with. Currently, liquefied natural gas (LNG) and methanol are among the most commonly used, but other options – such as hydrogen and ammonia – are being actively explored.

Studies by SRM have shown that over 50% of the ships currently under construction are designed to run on alternative fuels. This means that ports unable to offer bunkering services for these fuels will lose ground in terms of competitiveness. While it is true that there is still uncertainty around which fuel will dominate the future, it is essential to start making investment in the direction signalled by market trends. This is a crucial issue, and Mediterranean ports are already responding by investing significantly in the development of terminals equipped with quays capable of refuelling next-generation vessels.

Another key issue is the electrification of docks, commonly known as cold ironing. This also represents a major challenge, as ships are increasingly being equipped with the technology needed to connect to onshore power while docked. Ports will inevitably need to follow this trend by building infrastructure capable of supplying electricity to vessels, which will require significant investment.

Being a Green Port also means strengthening the port's role as an energy hub – handling ships that transport energy commodities, maintaining efficient connections through pipelines (both gas and oil), and potentially even taking the lead in developing local energy communities.

In this way, the port becomes a powerful driver of development – not only in commerce and logistics, but also in tourism and energy – connecting three of the world’s most strategic sectors: industry, energy and tourism.

As previously mentioned, digitalisation also plays a crucial role in improving the efficiency of port infrastructure. Embracing digital tools means streamlining bureaucratic processes that often hinder investment and complicate cargo handling operations. It involves investing in automation, hardware and software systems, safety and security measures as this is needed to transform a port into a smart, efficient and shipping-friendly hub rather than a bureaucratic bottleneck.

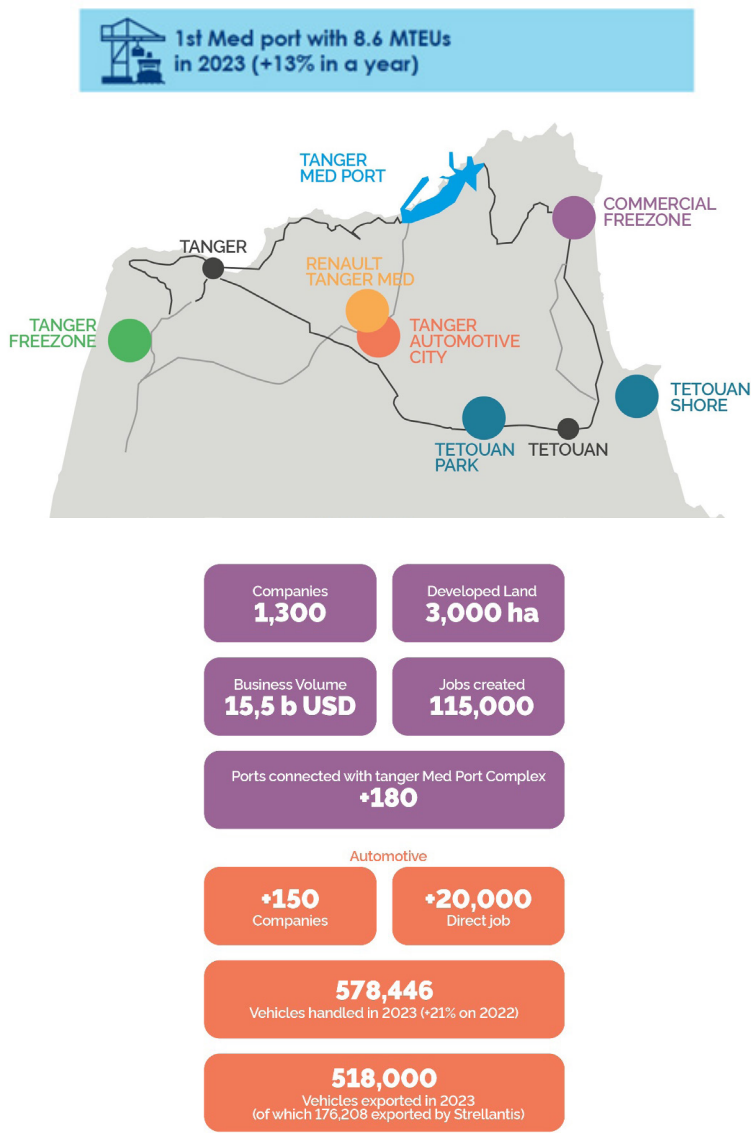
To give a sense of scale, a recent ESPO (European Sea Ports Organisation) study estimated that a panel of European ports will invest around €80 billion over the next 10 years. Of that amount, 35-40% will go towards projects focused on intermodality, sustainability and digitalisation.

Today, the role of the port has fundamentally evolved as this infrastructure is no longer designed to attract cargo traffic but must also act as a driver of national growth. Ports are expected to ensure efficient logistics and energy management, support the international outreach of businesses, and serve as catalysts for both local and foreign industrial investment.

In the Mediterranean, many ports on the African coast are backed by large free zones that attract business investment and enhance port operations. One notable example is the Tanger Med free zone in Morocco. Since its launch around 10 years ago, it has attracted over 1,300 business investments, generated more than \$15 billion in revenue, and helped establish the port as the Mediterranean’s leading hub – with container traffic exceeding 10 million TEUs in 2024 and connections to 180 destinations worldwide.

Obviously, these countries operate within much simpler bureaucratic systems than those in Europe and can make decisions more quickly. While their model may not be easily replicable for European ports, it nonetheless represents a trend worth closely monitoring.

FIG. 6.4 - TANGER MED FREE ZONE – MAIN STATISTICS



Source:
SRM on Tanger Med Port Authority and Tanger Med Freezone

A further important point to consider in this context is the attention that ports have to pay to maritime routes. Indeed, besides the strategic long routes across the Pacific or Atlantic Ocean and the Far East-Mediterranean, there are short routes falling within the so-called Short Sea Shipping type. These account for a significant share of traffic in the Mediterranean, with 600 million tonnes of goods handled in this way, and Italy ranking as the leader thanks to specialised ship-owners and ports in this sector.

Short routes are gaining ground globally as many of the phenomena mentioned above are affecting business decisions to shorten supply chains and bring production closer to end markets. Ultimately, this will result in increasingly shorter sea voyages.

At the same time, it is necessary to focus on strategic routes and look at global trends in the implementation of new trade corridors and routes. This is the case of the Chinese Belt and Road Initiative, whose investments are still ongoing and comprise the acquisition and management of port terminals in the Mediterranean, including Piraeus as well as other investments in Spanish, Turkish, Egyptian and northern European ports.

Another significant initiative is the IMEC (India-Middle East-Europe Economic Corridor) supported by major South-East Asian and Middle-Eastern countries, including India, the UAE and the US, which see this as an opportunity for developing trade with big countries like India as well as for implementing large-scale infrastructure projects. Investigations conducted by SRM indicate that this logistic corridor might accommodate significant potential trade between Europe-India-Asia, with estimates indicating an approximate value of \$170 billion. The ports most closely involved in this would include Trieste and Genoa, which have historically acted as gateways for European Markets.

FIG. 6.5 - CORRIDORS MAP IN THE GLOBAL SCENARIO "CORRIDOR WARS" IN GLOBAL GEOPOLITICS



Source:
SriLanka Guardian on AA.com

It is incredibly complex to fully capture the range of dynamics shaping port competitiveness in the Mediterranean – especially when these are considered within a broader global context. However, what is certain is that ports are now a strategic asset at the heart of global competition.

For this reason, port logistics must be recognised as a national priority. It represents not only a crucial pillar for the development of Italy's economy, but also a powerful lever to strengthen the country's position as a key player in both Europe and the Mediterranean region.

7. ERTMS and TEN-T: Just in Time or Too Late?

Matthias Ruete¹

The vision of an interconnected high speed rail network² is again high on the European agenda, coupled with the pressing need to ensure better military mobility. Equally, an ambitious plan to complete the trans-European transport network (all modes of transport) in stages by 2050 was agreed in 2024. As to rail, the 2024 regulation envisages for the first time a move towards a single, mobile communications based European rail traffic management system replacing the existing national systems in stages and at the latest by 2050.

Both the Letta³ and Draghi⁴ reports call for the rapid advance of a harmonised European rail network and an acceleration of the roll-out of interoperable digital solutions, in particular of the European rail traffic management system (ERTMS)⁵. Indeed, if implemented rapidly and uniformly, we could develop one of the major European industrial projects for smart infrastructure. By end 2024, some 12,000 km were equipped with the European Train Control System (ETCS) and 64,000

¹ The author is currently EU Coordinator for ERTMS. The following represents his personal opinion and does not in any way reflect the opinion of the European Commission.

² Forthcoming, *European commission HSR Action plan 2025*.

³ E. Letta, *Much more than a market*, April 2024.

⁴ M. Draghi, *The future of European Competitiveness*, 2024.

⁵ ERTMS consists of two parts: the European Train Control (ETC) system and the radio communication part, today GSM R, tomorrow the future radio mobile communication system, FRMCS.

km with GSM R; the ambition by 2050 is to have the entire Trans-European Network (TEN-T) (of 120,000 km, some 48000 vehicles equipped, and a modern communications network installed.

Today, most stakeholders agree with the ambition to move to a harmonised single European system. The TEN-T regulation defines deadlines for the phasing out of national systems. However, given that we are not implementing a system in a green field site but organising transition from existing national (brown field) systems, the questions of the **how and when** (rather than the **if**) are still subject to multiple, largely uncoordinated approaches and solutions.

The single European rail area (SERA) relies on joined up, inter-operable railways. However, previous decisions to allow for the coexistence of national and European approaches, long deadlines, multiple exceptions based on national rules, lack of coordinated funding and procurement, missing cross-border synchronization and a weak European governance for implementation are putting into question the overall ambition.

Some of this can be traced back to the timid approach of EU rail transport policy: after initial complete inertia it moved to using the subsidiarity principle to privilege national policies over a joint vision of a harmonized single European rail area. Rail did indeed loose decades in relation to the aviation sector with the overall framework for rail only fully defined in 2016. It is still struggling to accept fully standardisation and harmonization as the principal precept for future rail policy. Admittedly, this is not obvious since at present international, cross-border passenger travel only represents 10% of total rail travel (freight represents 48.5%), however, this share should increase with opening of markets and more high-speed connections.

For multiple reasons, ERTMS deployment was never managed as joint European project in contrast to satellite navigation (GALILEO) or the next generation of air traffic management (SESAR). This also made standardisation and harmonisation more difficult.

In the following, we explore some of the shortcomings and remedies to move to a faster roll-out of a unified European rail traffic management system.

History of European Infrastructure Policy

Before the inception of the 1958 European economic community, important voices (Spaak report⁶) already insisted that infrastructure policy should be included in the EEC treaty. This did not happen and, although feeble attempts were made to develop a European infrastructure policy, it was only with the 1992 Maastricht treaty that trans-European networks became part of a treaty-based European policy. The driver was that especially cross-border links in the European infrastructure network were missing and bottlenecks needed to be removed. This was seen as a much-needed complement to the rules based internal market which was to be achieved by the end of 1992.

Already then, it was clear that infrastructure policy had to have a smart, digital (or, at that time “ICT”) component. In parallel, major European railway companies, and subsequently the European Commission, were already pushing the idea of a harmonised European high speed rail network, building on the first HSR lines developed nationally especially in Italy and France. The Maastricht treaty (and subsequent Treaties such as the TFEU) contained provisions for transport, energy and telecommunications networks and gave the legal basis for more detailed provisions on the substance and funding of the trans-European networks.

The TEN-T was first “detailed” on the infrastructure side in Community guidelines with Decision of 23 July 1996. The

⁶ On the history of TEN T see M. Ruete, “60 ans de politique européenne de transport, revue du droit de l’Union européenne 4/2018”, *Revue du droit de l’Union européenne*, no. 3, 2018, p. 35-56 and Maxim Rusche/Kotthaus/Kullak/Ruete, Art. 90, gemeinsame Verkehrspolitik, January 2022, in Grabitz/Hilf/Nettesheim, *Das Recht der EU*, Kommentar.

decision posited 14 priority projects and a rather eclectic overall vision of the future transport network. Subsequent revisions (2004, 2013 and 2024), especially driven by the 2004-07 enlargement, led to a more coherent structure differentiating between a core network and a comprehensive network and identifying nine European transport corridors, with many qualitative, transport-based standards.

Rail Traffic Management: Interoperability and Innovation

Europe still has over 20 different national or regional rail signalling systems and has been trying to find inter-operable solutions since the mid-nineties. In view of the diversity of systems in place (increased also by subsequent enlargements of the EU), the focus was on a concept of inter-operability, based not on replacing national systems but allowing the co-existence of diverse national and a European system. Whereas **interoperability** was and is considered the key solution,⁷ the initial approach to conceive ERTMS as an overlay system, co-existing with national (so-called “class B” legacy) systems created complexities and costs which are still the reason for many problems today.

The initial approach (indeed effectively only superseded by the 2024 guidelines) corresponds very much to the general subsidiarity principle of the EU but creates many problems for all stakeholders. Rail supply industry must cater for many different solutions, depriving it of economies of scale, railway undertakings and other rolling stock owners face larger costs because of the need to equip and upgrade their rolling stock for different networks; similarly, infrastructure companies must deal

⁷ In 1996, ERTMS was meant to ensure inter-operable control-and -command and signalling systems only for high-speed rail. From 2001 onwards, the issue was also regulated for conventional rail and both approaches were consolidated for all rail in 2004, merged in 2008 and extensively revised in 2016.

with diverse solutions and very often discover inter-operability issues when implementing cross-border connections.

At the same time, ERTMS also seeks to integrate **innovation** but is often faced with bespoke network and rail supply industry's solutions with different versions and a multitude of cross border implementation problems. The innovation cycle in rail is often much longer than in other sectors. With the increasing move to digitalisation, the question is how often standards should be modified given the much shorter innovation cycle of the digital world. There is a need to balance the frequency of modifying TEN-T network standards with the stability required for long-term infrastructure and rolling stock planning and investment.

Moving to a single standard, better transition management and early reflection on deployment issues of new technologies are at least part of the answer. Differentiation between hardware changes and software updates is another. It must be possible to protect investments (especially for vehicle owners) and not be faced with too short deadlines to modify or up-grade but at the same time ensure necessary modernisation. The more this can be done by (ideally over the air) software updates, the easier this equation becomes. In view of still necessary hardware replacements, a modular approach would allow to maintain non affected elements of the system rather than a complete replacement of the installed system. Furthermore, an adapted authorisation and certification framework could bring improvements since the current system is optimised for much longer life cycles for rail safety equipment.

Drivers to Implement ERTMS

Whereas some infrastructure managers (and their Member states) enthusiastically took on the challenge to equip their networks with ERTMS (especially Spain with its green field high-speed network, as well as more recently Luxembourg, Belgium and Czechia), others were more reluctant.

This can be explained by the diversity of systems in place and very different technological levels. Some states indeed felt that their own national solutions were at least equivalent to ERTMS and the little use of their networks by railway companies from other Member states did not justify the costs of “going ERTMS”. Others were reluctant to open their network to competition and saw the continuing national system as a way to protect incumbent companies from competition.

Interoperability In cases, where “interoperability” was the only driver for the deployment of ERTMS, infrastructure managers reluctantly accepted the European obligation to install ERTMS as an additional system but, in reality, had no real ownership, preferring to rely on their national systems.⁸

Obsolescence. This changed when first, the technological evolution of ERTMS allowed to move to a system, where track side signalling was no longer necessary and was transferred from the track to the vehicle cabin (cab-based signalling) and secondly the obsolescence of components of the national system (relay based interlockings) meant that a renewal of the national system became necessary and ERTMS, proven also in multiple sites outside Europe, was the best product on the market.

Safety. In other cases, major railway accidents which could have been avoided with ERTMS, revealing short comings of national systems led to political decisions to implement rapidly the system (for example, Belgium, Luxemburg, Czech Republic).

Capacity. In specific cases, the advantage of ERTMS in providing higher capacity on a given network (France:

⁸ One solution identified (but largely abandoned as permanent solution today) was to require the development of a STM, a “Specific Transmission Module”. The STM approach, allows a train equipped with ETCS and a STM to communicate with the national ‘legacy’ system. This obviously requires different STMs depending on the national system, complex installation and authorization procedures, and decisions of the railway undertaking as to where the specific rolling stock will operate. It also provided an excuse not to move to ERTMS equipped infrastructure. In some cases, it still provides a useful approach to manage transition.

Paris-Lyon from 2026) was the essential driver for the decision to install ERTMS.

Efficiency/punctuality. For several states another important driver was that installation of ERTMS allowed to improve the performance of railways, leading to greater punctuality and efficiency of railway operations. Moreover, its installation prepares the way for future automated train operations and the overall digital transition of railways.

Cost- benefit analyses. Increasingly, several cost benefit analyses were conducted on European and national levels which showed that costs of infrastructure maintenance over the life cycle could be radically reduced with the overall costs of trackside deployment (CAPEX and OPEX) being sizeably reduced in comparison to the older legacy systems (Commission, Italy, Germany). Precondition for this is nevertheless a parallel installation both trackside and onboard of ERTMS and a rapid phasing out of the national legacy system. Moreover, recent price hikes, especially for on board equipment are increasingly leading to an uneasy cost- benefit equation.

Cyber security. In view of the importance also of military mobility; the resilience (and redundancy) of rail traffic management have also become important. Moves to 5G communications, the use of multiple mobile network operators and the prospect of using satellite communications can make ERTMS more robust in view of various threats through cyber warfare.

Focus on Trackside Infrastructure

The initial focus of the EU level was very much on the network, ie the trackside deployment of ERTMS, leaving the on-board deployment very much to the individual Member states. The different versions of TEN-T guidelines specified obligations related to a deployment of ERTMS on the infrastructure and the more detailed European Deployment Plan of 2017 essentially determined deadlines for the deployment of ERTMS on specified lines of the network with an intermediate deadline for 2023.

Move from Track to Cab-Based Approaches

However, it became clear that trackside installation without parallel, synchronous on-board deployment made little sense since it perpetuated the need to maintain two systems with vehicle owners having little incentive to install ERTMS. Indeed, the overall cost benefit analysis showed that benefits essentially accrued to the infrastructure managers and that vehicle owners had little to gain from installing ERTMS. Whereas there was a general legal obligation to equip locomotives and other traction vehicles operating on the core network with ERTMS since 2012, widespread use was made of exceptions in the rules in order not to install ERTMS. Between 2015 and 2019 some 54% of new vehicles did not have ETCS equipment. In order to remedy the situation, Member states set up schemes to at least partially finance the equipment with ETCS, state aid regimes got the green light from EU Competition Authority and the disbursement of EU funds such as Connecting Europe Facility was increasingly oriented to retrofitting or upgrading rolling stock with ETCS. Moreover, the 2024 TEN-T regulation now requires attention to the synchronous deployment of vehicles and trackside, with an obligation to phase out national systems in stages between 2040 and 2050. The 2023 CCS (Command and Control Systems) TSI (Technical Specifications for Interoperability) has considerably reduced the scope for exceptions from the obligatory equipment of vehicles with ETCS, leading to a nearly universal obligation to install ERTMS.⁹

⁹ The exceptions refer only to on-track machines, very old shunting locomotives to be used outside of networks planned to be equipped with ETCS and vehicles running only on infrastructure not subject to the interoperability directive.

State of Play of ERTMS Harmonisation and Implementation

Here is not the place for a thorough evaluation of what has been achieved. As to track side implementation some 12,000 km have been equipped with ETCS by 2024 and 64,000 km with GSM R; considerable number of lines are under construction or planned. 7000 km will be ETCS only by the end of the year. As to vehicles, of a total of some 48,000 vehicles, over 9000 are equipped and some 15,000 are contracted or planned. Almost all Member states have delivered their ERTMS national implementation plans (NIP) and have detailed considerably their national strategies. Technical harmonisation is progressing and successive rules¹⁰ have tightened the exceptions to a joint approach. The major missing element now is the full standard for the future mobile communications system. ERA has been able to reduce national rules considerably from over 14,000 rules to under 1000. What is still missing is a better harmonisation of engineering and operational rules. Whereas the authorisation processes now follow a central one stop shop (OSS) approach, the possibility for reducing administrative burdens such as national ETCS system compatibility (ESC) checks are still being explored.

In short, progress has been remarkable but, if one considers the timeline, too slow and too expensive. Serious questions remain as to the capacity to deliver a rollout at reasonable costs within the legal deadlines.

¹⁰ Technical Specifications for Interoperability (TSI) are the major legal instrument to achieve standardisation and harmonisation. The latest TS for Command and Control Systems was adopted in 2023.

Conclusions: A Streamlined, Stronger European Governance

This is why, with the acceleration of deployment efforts in a number of Member states (but also in Switzerland, Norway and the UK) stakeholders are calling for better European coordination. Increasingly, the problems and accrued costs of a decentralised deployment are becoming visible. Given the multiple different places where coordination takes place on the European level,¹¹ the case for a **stronger, streamlined** governance is becoming more obvious.

The following steps could be considered.

1. Multiple efforts to achieve better coordination for the harmonisation of ERTMS standards and its deployment are being made. Each coordination forum and structure serve different purposes; however, all elements are not always seen together and efforts risk going in different directions. It would be advisable to create a strong focal point (such as a digital rail policy board or task force) to bring together and orient all these different efforts, to strengthen and streamline coordination and to ensure the buy-in of all relevant actors.
2. Such a task force would identify early difficulties and defuse problems. Particular focus should be put on following the cross-border implementation of ERTMS in the nine European transport corridors, the update of the stakeholders memorandum to cooperate, the follow up of the national implementation plans, the development of the next ERTMS deployment plan and, in future, the framework of the high-speed action plan.
3. Attention needs to be given to the implementation of the future radio communication system (FRMCS) in order not to create a situation where investments are blocked because of uncertainty as to the exact

¹¹ See Annex/ Box.

specifications. Moreover, investment of vehicle owners and operators in rolling stock need to be protected for a reasonable time-period.

4. Strong European coordination relies on the appropriate legal and financial framework. In particular, the future EU budget should foresee both sufficient funds and centralised management of this budget. Joint procurement should become possible, combining EU and national funds. This may be particularly appropriate for retrofitting or upgrading vehicles.
5. The creation of an EU level deployment manager should be explored. In particular digital transport projects present significant challenges despite their potential to improve efficiency, safety, and sustainability. Some rail infrastructure managers are still at the beginning of their transformation into digital companies and such entities would receive appropriate support from such an EU deployment manager.
6. What is required now is a strengthening of the European governance for ERTMS. As described, the legal framework is essentially in place. The technical framework has favourably evolved. Individual Member states are accelerating deployment. What is needed is a strengthening of the organisational framework and a reinforcement of the budget on the European level. We now need the political will to work together on overcoming bureaucratic, national and market hurdles for this European industrial project to succeed.

Current Approaches to ERTMS Coordination on EU Level

- The European Commission¹² has the overall responsibility, overseeing the implementation and adaptation of legislation for the rollout of ERTMS, The Commission also coordinates with the Member states in various committees,
- The role of an ERTMS coordinator was created 2004-05, under the TEN T regulation. The initial focus of the coordinator was on making the case for aß Europewide use of ERTMS and on stabilising technical specifications, facilitating cross border agreements and advocating trackside deployment. Rapidly the coordinator also looked at the overall strategies for an accelerated deployment, including finance (track side and on board) and the appropriate governance. This role was considerably strengthened with the 2024 regulation, creating also a forum of national representatives responsible for the national ERTMS deployment.
- The 2016 technical pillar of the fourth railway package gave a central role to the EU Agency for Railways (ERA) as systems authority, with European procedures for the authorisation of vehicles (also checking the appropriate ERTMS equipment) and a procedure to ascertain conformity of national procurement of track side equipment with the specifications on ERTMS in the technical specifications for interoperability for control and command systems (TSI CCS).
- The 2021 regulation on the European research joint undertaking (JU), that established Europe's Rail, created a systems pillar in which that undertaking

¹² Most of these activities are assisted by a deployment management team (DMT) under contract with the Commission.

now coordinates national approaches for the further development of control and command systems, facilitating further development of TSIs in cooperation with the Rail Agency. Equally, the JU has set up a deployment group focussing on specific aspects of ERTMS deployment.

- Some of the nine European Transport Corridor fora also have dedicated ERTMS working groups which serve to coordinate cross border issues and are useful to identify general interoperability issues early.
- The overall development of standards and specifications has been accompanied by the ERTMS users' group (EUG) from the very early stages of ERTMS development, with the EUG being an association of certain infrastructure managers (from 10 Member states and CH, NW and the UK).
- Stakeholders from the different branches of the rail industry (supply, undertakings, owners and infrastructure), the Commission and ERA have also set up and recently revived a ERTMS Stakeholder Platform and plan to adopt a newer version of their 2016 memorandum on commitments for an accelerated roll out.
- The Climate, Infrastructure and Energy Agency (CINEA) manages the funds allocated under the Connecting Europe Facility, with other funds being provided by regional and cohesion funds, the Recovery and Resilience Facility and the EIB.

8. Military Mobility and High-Speed Rail in Europe: Enhancing Strategic Readiness and Shortening European Distances

Alberto Mazzola¹

Military mobility is a crucial aspect of European defence strategy, enabling the rapid deployment of forces and equipment across the continent in response to security threats. Enhancing the EU's preparedness to deter and address such threats has become a top priority on the EU's political agenda. The Niinistö report,² the political guidelines³ of the European Commission President and consequently the mission letters to the relevant Commissioners⁴ provide important information and guidance for the way ahead, emphasising the necessary coordination with NATO. Railways are a robust and reliable instrument for providing mobility services to the EU's citizens and industry. They are particularly well-suited for use in EU defence industry logistics, including material provision and new military asset placement, as well as for the movement of existing military assets and convoys, particularly in a time of crisis.

¹ The views and opinions expressed here are solely of the author.

² European Union, [Safer Together Strengthening Europe's Civilian and Military Preparedness and Readiness](#), 26 November 2024.

³ U. Von Der Leyen, [Europe's choice. Political guidelines for the next European Commission 2024-2029](#), Strasbourg, 18 July 2024.

⁴ [Mission Letters of the Commissioners Designate \(2024/2029\)](#).

Rail is the best prepared land-based system to deal with the specific characteristics of military assets, which are heavy, oversized and dangerous in nature.

High-speed rail is a modern, fast, attractive, comfortable and successful way of travelling over long and medium distances. Where implemented (Paris Lyon, Milan Rome, Madrid Barcelona, Berlin Munich, Paris London Brussels Cologne, Japan and China) it has become the preferred way of travelling.

The Letta⁵ and Draghi report,⁶ the political guidelines⁷ of the European Commission President and consequently the mission letters to the relevant Commissioners⁸ provide important information and guidance for the way ahead. The Letta and Draghi reports both highlighted that high-speed rail strengthens the EU Single Market by making transport more efficient, sustainable, and integrated, creating more opportunities for businesses, workers, and consumers across Europe.

How and if the two initiatives could be merged together providing dual-use benefits should be assessed as most of the HSR network remains to be built. The substantial financial resources required by both demand a thorough assessment.

Legislative Framework of the Trans-European Transport Network (TEN-T)

In June 2024, the European Union approved the new Regulation⁹ concerning the trans-European transport network defining the list of roads, railways, airports and water infrastructures that

⁵ European Commission, E. Letta, *Much More Than a Market*, April 2024.

⁶ European Commission, [The Draghi report on EU competitiveness](#), 2024.

⁷ Von Der Leyen (2024).

⁸ Mission Letters of the Commissioners Designate..., cit.

⁹ European Union, [Document 32024R1679](#), Regulation (EU) 2024/1679 of the European Parliament and of the Council of 13 June 2024 on Union guidelines for the development of the trans-European transport network, amending Regulations (EU) 2021/1153 and (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013 (Text with EEA relevance).

would form part of such a network. The Regulation pursues many positive targets such as digitalisation, intermodality and EU corridors, but two important aspects are missing: a high-speed rail network and a solid military mobility network.

The revised Regulation set as an ambitious target for European transport infrastructure that by 2040, passenger railway lines on the TEN-T core and extended core network should support trains travelling at speeds of 160 km/h or faster. The Community of European Railway and Infrastructure Companies (CER), while supporting the targets of the TEN-T, always called for a high-speed network connecting all EU capitals and major cities as a contribution to the EU Single Market and a positive step towards reducing transport emissions and energy consumption.

When the revised Regulation was proposed, the war in Ukraine had not yet started. The proposal was partially adapted only during the latest discussions when the war was already raging. Notably it included part of the Ukrainian network and upgraded standards to the level required to transport military equipment. The new “Trump” scenario requires a further drive to reinforce military mobility with better defined corridors and stronger integration in ports and airports between rail, air and maritime transport.

High Speed

High-speed rail (HSR) plays a crucial role in strengthening the EU Single Market by improving connectivity, reducing trade barriers, and enhancing economic integration. Here's how:

1. Faster and more efficient transportation

- improved trade and logistics: HSR enables quicker and more reliable transport of goods and people, reducing travel time between major economic hubs.
- better business connectivity: companies can expand their operations across multiple EU countries with reduced costs and delays.

2. Boost to cross-border mobility

- easier labour movement: HSR allows workers to commute longer distances in shorter times, increasing productivity, job opportunities and labour market flexibility.
- tourism growth: faster travel between EU destinations encourages tourism, benefiting local economies.

3. Strengthening economic cohesion

- regional development: peripheral and less-developed regions benefit from better links to economic centres, reducing disparities within the Single Market.
- urban and rural Integration: HSR fosters balanced economic growth by connecting major cities with smaller towns.

4. Sustainable and competitive transport

- reduced dependence on air travel: high-speed rail offers an eco-friendly alternative to short-haul flights, supporting the EU's Green Deal objectives.
- increased market competition: by providing a viable alternative to airlines and road transport, HSR promotes a more competitive transport sector within the EU.

5. Strengthening EU integration

- cross-border cooperation: joint projects like the Trans-European Transport Network (TEN-T) improve infrastructure alignment, fostering deeper EU collaboration.
- standardisation and harmonisation: unified railway standards across Member states enhance interoperability and reduce regulatory fragmentation.

6. Reducing oil consumption

- less oil import: rail transport consumes almost 10 times less fossil fuels than aviation and road transport. Any passenger moving to rail substantially reduces the EU import of oil. A fully fledged EU high-speed network might reduce import to the tune of one oil tanker every two days.

The Challenges

Services that are economically viable

A robust HSR¹⁰ network should be designed to link all major cities in the European Union alongside national capitals. Population centres with at least 250,000 inhabitants and important tourist destinations should be served by the HSR. This ensures that a broad geographical area benefits from high-speed connectivity, fostering economic integration, regional development, and sustainable mobility solutions. With a potential 54% rail modal share by 2070, HSR must be the fastest and most cost-effective option for distances between 350 km and 1,000 km to compete with air and road travel. Tourists and businesspeople travelling on conventional lines connected to HSR could increase rail's potential market share by a further 18%. Completing the TEN-T network, ensuring commercial viability, and improving cross-border interoperability are key to success.

Ensuring long-term funding solutions for Europe's HSR vision

Construction costs for the HSR masterplan covering 49,400 km requires €546 billion with an average construction cost of €16.5 million per kilometre.¹¹ Such a budget for HSR investments is financially possible but requires additional funding compared to the current situation. In the last years, on average, about €40 billion have been invested in rail infrastructure and €10 billion

¹⁰ For High-Speed Rail we use the definition of Directive 2016/797 on the interoperability of the rail system within the European Union of what constitutes high-speed rail. Therefore, it is defined as rail lines specifically equipped for speeds equal to or greater than 250 km/h and upgraded lines equipped for speeds in the order of 200 (200-250 km/h).

¹¹ Smart and affordable rail services in the EU: a socio-economic and environmental study for High-Speed in 2030 and 2050. Published on 23 January 2023.

in new infrastructure. Investments in new infrastructure should be doubled. Financing for HSR infrastructure investments comes from either public funds (subsidies) or market (track access charges). Given the substantial upfront capital costs, governments can provide initial funding through public investments, grants, and low-interest loans. Financing models such as public-private partnerships (PPPs) should also be considered to fill the funding gap. Classical PPPs or Regulatory Asset Base (RAB) models facilitate partnership between governments and private entities, attracting private capital while maintaining public oversight. Additionally, innovative financial instruments like green bonds and infrastructure funds can be leveraged to attract long-term investors committed to sustainable transport solutions. A well-structured funding model is essential to balance affordability, financial returns, and public benefits, ensuring the successful delivery and maintenance of HSR networks.

A sustainable financial framework must account for the cost of capital and seek the right balance for track access charges, which play a crucial role in ensuring fair competition among operators while generating revenue for infrastructure maintenance and upgrades. Stable long-term funding sources, regulatory frameworks that encourage private investment, and policies to complement public funding to deliver the EU HSR masterplan are essential to achieve a sustainable and competitive high-speed rail network.

Ensure simple cross-border operations

One of the biggest challenges for international high-speed rail services is the lack of compatibility across borders, requiring adaptations for different track gauges, signalling systems, power supplies, and safety regulations. To address this, the European High-Speed Master Plan's key measures must ensure interoperability between the new lines and include accelerating certification processes through the European Union Agency for Railways (ERA), harmonising train path allocations to reduce

bureaucracy, and ensuring fully interoperable high-speed rolling stock, particularly through standardised European Rail Traffic Management System (ERTMS) deployment.

Make ticketing seamless

For high-speed rail to compete effectively with short-haul and long-distance flights on key European corridors, a seamless and customer-friendly ticketing experience is essential. While national rail journeys are easily booked, international high-speed rail tickets remain difficult to secure, creating barriers for both business and leisure travellers. To address this, CER members committed to the CER Ticketing Roadmap in 2021, outlining steps for a more integrated and accessible system. Key priorities include enabling 12-month advance booking across all operators, harmonising ticketing conditions, recognising the International Rail Transport Committee (CIT) Agreement on Journey Continuation (AJC) to protect passengers from missed connections, and integrating the Open Sales and Distribution Model (OSDM) into EU interoperability standards. A standardised ticketing system will enhance accessibility, reduce costs, and make rail a more attractive alternative to air travel.

Competing on the same level with other modes

Rail transport currently faces an unfair disadvantage compared to less climate-friendly modes due to imbalanced intermodal framework conditions. Overcoming this requires political action to ensure railway undertakings can expand services in an economically viable way. One major issue is infrastructure costs – while rail passengers contribute to funding tracks through ticket prices, road transport often remains free despite its higher environmental impact. Competitive track access charges (TACs) and increased public investment in rail infrastructure are essential to make high-speed rail more affordable and attractive. Additionally, energy taxation policies put rail at a further disadvantage as rail operators must pay energy taxes while aviation fuel remains untaxed across the EU. Given that

railways rely primarily on green energy, reducing energy taxes would create a fairer competitive environment, allowing rail to better compete with cars and air travel while supporting Europe's climate objectives.

Military mobility

Preparedness now demands an enhanced response from the European transport system, which will need to extend its services beyond the ones it already offers for civilian purposes. These include enabling the swift movement of military convoys for exercises during peace or crisis response, as well as advancing the EU's defence capabilities and industry to bolster its autonomy in this area.

Military mobility via rail can significantly enhance Europe's defence and security by improving the rapid movement of troops, equipment, and supplies across the continent. Here's how:

1. Faster deployment of forces

- rail transport allows for quick deployment of military personnel and heavy equipment, such as tanks and armoured vehicles, across Europe's extensive railway network,
- this is crucial for responding to security threats, natural disasters, or NATO operations.

2. Strategic readiness and deterrence

- improved rail mobility strengthens deterrence by enabling a swift and coordinated response to potential threats, particularly in Eastern Europe where tensions with Russia remain high,
- quick reinforcements can reassure allies and discourage aggression.

3. Cost-effective and sustainable transport

- rail is more fuel-efficient than road or air transport, making it a cost-effective way to move military assets,
- it reduces reliance on fossil fuels and aligns with Europe's environmental goals.

4. Support for NATO and EU defence initiatives

- military mobility is a key aspect of NATO's strategy and the EU's Permanent Structured Cooperation (PESCO) programme,
- investments in dual-use infrastructure (civilian and military) improve overall transport capacity for both defence and commercial purposes.

5. Cross-border coordination and infrastructure upgrades

- many European rail networks have different track gauges, signalling systems, and regulations,
- standardising infrastructure and improving interoperability between countries enhances efficiency in crisis situations.

6. Reducing dependence on roads and airlift

- rail transport helps reduce congestion on roads, which can be critical during emergencies,
- it provides a reliable alternative to airlift, which can be limited by weather or logistical constraints.

Challenges and Solutions

The railway system must be resilient enough to continue providing the essential services that underpin the EU's economy while also enhancing its competitiveness and meeting the increased demands of the military forces. This includes withstanding potential attacks such as hybrid and cyber threats. Therefore, protecting this critical infrastructure should be a priority, as well as strengthening the interconnections and interoperability of each transport network, creating redundancies as well as improving resilience within organisations.

The Challenges

Improving civilian and enhanced military transport services requires a systemic approach to the railway system

Irrespective of whether a crisis scenario is present or not, a systemic approach to the entire railway system is essential to provide the services desired for civilian and military purposes without creating significant disruptions.

There is an estimated 94% overlap between civilian and military networks, which reflects the dual use of the network. Therefore, enhancing military transport capabilities within the network requires urgent implementation of already identified measures to significantly improve network performance. Any other approach will compromise the level of services provided.

The EU and its Member states need to enhance coordination and strive to remove bottlenecks, vulnerabilities, missing links and isolated network portions while increasing transport capacity, in particular by pursuing the objectives and targets of the TEN-T Regulation, as well as effectively implementing the Single European Railway Area. Special attention is needed for priority corridors designated for military movements and regions exposed to higher risk or lacking the necessary interconnections and interoperability with the EU network. This is particularly true of the Baltic states, which face additional investment and operational challenges due to the difference in railway gauge.

Therefore, the EU and its Member states need to coordinate and pursue efforts in order to:

1. Increase capacity in the network by:
 - Constructing new railway lines and closing infrastructural gaps, especially across borders, as required in the TEN-T Regulation, investing *in new railway lines that are fit for purpose* (ensuring the circulation of 740 m long trains, a P400 profile at least 22.5 tonne/axle load and, when feasible,

the recommended 25ton/axle, notably in identified priority corridors) and *new terminals* particularly to complete or create connections to the *EU's ports* and other *multimodal and intermodal terminals*, providing adequate loading and unloading capabilities as well as establishing *connections to and between existing lines* to increase flexibility by offering different alternative routes. Taking into account the Union Action Plans on Military Mobility of March 2018 and November 2022,¹² an assessment is needed to adapt the TEN-T network to accommodate military use of the infrastructure. Based on the gap analysis, the inclusion of *additional railways should be considered in the TEN-T* network to enhance synergies between civilian and military transport rail services.

- Renovating and where possible upgrading the existing network in line with the requirements of the TEN-T Regulation, ensuring that the *existing railway infrastructure* enables the operation of 740 m long trains and that bridges and tunnels on relevant corridors are able to carry the loads and dimensions of military assets as appropriate, adapting them to dual-use rail infrastructure specifications. Investments should include the *modernisation of interlocking and signalling systems* in network sections lacking interoperability with the EU network. These investments should also target *existing terminals* (notably those serving the *EU's maritime and inland ports*) to enable the loading and unloading of military assets, develop a capable and modernised *network of sidings, secondary lines* which connect the rail network to military industrial sites and *military facilities, supply warehouses and fuelling points*.

¹² Military Mobility Action Plan 2.0.

- Improving capacity management in the EU network to facilitate the operation of trains in *swift cross-border movements*, streamlining and simplifying EU and National procedures as far as possible, including by establishing flexible border section agreements until the Single European Railway Area is fully implemented. *Implementing the rail infrastructure capacity management Regulation* can provide capacity gains through improved planning and coordination of capacity within the EU (particularly in cross-border movements also needed for military convoys) resulting in a 4% increase in the existing European railway network.
 - Improving the interoperability of the railway system as a whole, an agenda the railways system has long sought and has the instruments to deal with, as identified in CER's Manifesto "On track for Europe 2024-2029".¹³ This includes further deployment of the *European Railway Traffic Management System* (on-board and trackside units) and across-the-board implementation of the *Technical Specifications for Interoperability* (TSI) as fundamental measures, alongside *train driver training* and development of robust computerised communication tools, improving cross-border operation of trains while ensuring that overall safety requirements are upheld. Pursuing the implementation of digital enablers such as *Digital Automatic Couplers* (DAC) will allow increased loads and longer trains.
2. Replenish the *rolling stock* adapted to the transport of military assets needed to serve the EU's defence industry and for the military movement of convoys, including *special purpose vehicles*, such as those capable of operating in different operational environments or

¹³ CER Manifesto, "On Track for Europe 2024-2029".

adapted to specific needs including for the transport of specialised military personnel and medical support. *Traction* solutions will be needed to operate cross-border in alternative scenarios i.e. locomotives equipped with internal combustion engines in the case of large-scale power cuts. Sufficient and appropriate *wagons* are also needed for the transport of military assets with EU certification duly *specified in the TSIs*, as well as a network of maintenance, parking and fuelling facilities that is fit for purpose.

3. Enhance resilience of the railway infrastructure and management systems, by developing and implementing a strategy *that protects critical railway infrastructure and its support systems* against direct actions (hybrid attacks including cyber-attacks) that could damage or impede operations and enhance the *cybersecurity* of the railway system. There is also a need to ensure the *continuity of critical operations* through system redundancy as well as rapid restoration of critical infrastructure in the event of a crisis.

Increasing Financing, Mainstreaming Railways into Defence Programmes and Adopting Efficient Procurement Will Be Key

There is a need to raise decision makers' awareness of the value of railway services, particularly for defence purposes, where road infrastructure is not a suitable alternative. This has to be *taken into consideration for strategic investments* in the transport infrastructure, for the purpose of achieving an *enhanced security level* but *also for pursuing long-term EU objectives* in essential policies such as, energy efficiency, decarbonisation of the economy as well as the EU's technological and energy autonomy.

In light of the current security risks, the EU and its Member states are called upon to strengthen and mobilise financing through EU and particularly national budgets when this agrees

with their specific constitutional arrangements or international treaties. Military Mobility as well as related strategic projects, *will require further support under the current Multiannual Financial Framework (MFF)*. Upscaling the role of rail transport will need to be increasingly *mainstreamed into 2028/2034 MFF objectives and measures*, taking into account the several traffic flows and services provided, particularly in the priority corridors defined for military purposes.

Dual-use projects in the context of the EU's MFF have proven to be a relevant instrument, which should be substantially strengthened in the next EU budget, allocating more resources and a possibly a higher co-funding rate from the EU. As this chapter demonstrates, *the concept of dual use goes beyond investments in adapting infrastructure for 740 m trains, or bridges and tunnels*. Therefore, *clarification of the dual-use requirements* set out in the specific Regulation¹⁴ is urgently needed as it sets out the basis for determining whether measures are eligible for EU funding. Investments are essential to enable the provision of the railway services. Projects *fitting into any of the three categories mentioned above should be eligible* for financing. Specifically, ERTMS should be part of the Regulation Annex, which defines criteria for dual-use eligibility. Additionally, support for installing onboard units is crucial to ensure full operationalisation of the system.

Mainstreaming defence needs into relevant transport policies, programmes and funding instruments within the EU, will enhance efforts to strengthen the EU's security objectives. Given the overlap between civilian and military services that railways can provide, as well as their contributions and co-benefits to other EU policies (namely energy efficiency and decarbonisation), these synergies should be recognised and rewarded accordingly. This should be reflected in the successors to the appropriate budget lines, including the Connecting

¹⁴ Commission Implementing Regulation (EU) 2021/1328 of 10 August 2021 specifying the infrastructure requirements applicable to certain categories of dual-use infrastructure actions.

Europe Facility, Regional and Cohesion funds, leveraging the mobilisation of resources and other funding sources by the Member states.

An EU strategy to support and accelerate replenishment of the inadequate rolling stock fleet (including special purpose vehicles) will be crucial. This could be achieved through centralised group procurement frameworks, which could provide certainty to the industry, spur competition and reduce costs through economy of scale. Procurement requirements should recognise the specificities of railway assets that serve military purposes and should be streamlined and simplified as much as possible. The EU and its Member states should mobilise adequate funding and establish the appropriate requirements for procurement processes adapted to the acquisition and operational maintenance of rolling stock. This involves defining provisions regarding property, conditions of use, storage and maintenance over time, including for special purpose vehicles as well as any vehicles that may be used for civilian purposes, in full compliance with anti-trust requirements. The EU should strive to adopt or update the adequate technical specification and ensure quick certification processes are set in place, promoting a harmonised approach by all Member states.

Ensuring the readiness of railway infrastructure assets, rolling stock and the necessary personnel as well as making provisions for contingency maintenance, requires adequate framework contracts with infrastructure managers and railway undertakings. This will guarantee the swift mobilisation of resources needed for transport operations, where one valid solution could be to establish stand-by contracts.

Enhanced Cooperation for Better Understanding of Needs and Efficient Planning of Military Logistics and Activities

Improved understanding and cooperation at all levels, will help facilitate operation planning and execution. The EU and its Members states should strive *to streamline administrative*

procedures in order to accelerate the regulatory clearances required to enable the swift, large-scale, cross-border movements of military assets and convoys, as reiterated in the EU's Military Mobility Action plans. In this context it may be necessary to consider procedures for exceptional shipments, establishing priorities for military convoys as appropriate.

Therefore, there is a need to create a functional governance system (at EU and Member state level, as well as with relevant institutions such as NATO) to *enable military and civilian regular coordination* and cooperation, involving railway system representatives as well as other critical modes (port infrastructures and sidings). A steering structure could prove to be essential for coordinating actions particularly during a crisis.

Regular coordination between military and civilian stakeholders will have beneficial effects on *planning and implementing investments and performing railway operations*. Providing selected actors with appropriate access to regularly updated information on the railway's assets and operational conditions can contribute decisively to slashing the timeline for planning and executing military movements.

Conclusion

Enhancing military mobility via rail strengthens Europe's security, supports NATO operations, and improves overall logistics efficiency. Investment in railway infrastructure will boost commercial transport and economic growth while benefiting defence.

Building a HSR connecting all capitals and major cities will strengthen European cohesion and will attract 70% of tourists and businesspeople travelling long distances in the EU to the trains, 54% to HSRs. Rail capacity, which is currently very limited, will substantially increase.

While primarily designed for civilian use, HSR might have significant potential for military applications, provided some

technical specifications are respected such as the axle loading gauge. In peacetime, HSR would only be used for passenger transport, but in the most extreme situations it would be a valuable asset for military purposes.

9. Resilient, Connected, and Inclusive Infrastructure: The Role of Public-Private Collaboration to Lead the Transition

Elisabetta De Bernardi

Infrastructure and the transport sector play a critical role in all aspects of the modern economy, ensuring the movement of people, services, and goods – thus enabling economic and cultural growth. In the current geopolitical climate, characterized by uncertainty and volatility, their role becomes even more fundamental. As pointed out by many prominent figures, including Mario Draghi and Enrico Letta in their reports about EU competitiveness, transport and its dedicated infrastructure are crucial for boosting economic growth, as it enables prosperity across multiple sectors while also promoting social and territorial cohesion. This comes with the recognition that, as global demand continues to grow, infrastructure must evolve and expand – not only to increase security but also to unlock cleaner and more sustainable growth. This applies to all modes of transport, including motorways, which, like other transport infrastructure, can help shape a prosperous and environmentally conscious future while supporting governments and local communities in building greener, more digital, and better-connected societies.

As a global strategic investment holding in the transport and infrastructure sector managing motorways, airports and digital infrastructure across several countries worldwide, what we have

observed is that our role as private actors working in partnership with governments and institutions is not merely to react to new challenges, but to actively lead the transition. To achieve this, boosting public-private partnerships in high-growth transport projects and fostering capital markets that invest in innovation and sustainable development are essential.

Operating globally across diverse territories, each with different needs and characteristics, we have learned that only by combining the pursuit of general interest objectives led by the public sector with private operators' long-term vision, know-how, and agility we can foster true innovation and create meaningful, inclusive growth. This approach has guided our work on the ground, where innovation is of course related with new technologies but also to the way we manage resources, engage communities, impact environment and respond to evolving mobility habits.

Some examples from different regions around the world help illustrate what we mean when we talk about innovation. While it certainly involves the adoption of new technologies, innovation is also about how we manage resources more efficiently, how we create strategic synergies between projects, and how we embed broader sustainability and connectivity goals into the design and operation of transport infrastructure.

Considering the case of Santiago del Chile, the Amerigo Vesputio Oriente II (AVO II) project offers a compelling example of how infrastructure can deliver sustainability gains through intelligent resource management. During the excavation works for a 5-km underground motorway, large volumes of earth were removed – instead of being considered as a construction waste and being discarded, this material was repurposed for another vital public project: the expansion of airport access roads at Arturo Merino Benítez. This approach not only reduced the environmental impact and logistical costs associated with material transport and disposal, but also established a model of circularity within infrastructure development. It shows how, even within the construction phase, innovation can take

shape through coordination, foresight, and a commitment to minimizing waste.

This same spirit of integration and future-orientation also defines our work in Spain, where a different kind of innovation – driven by digital transformation – is taking place. On the C-32 highway, our subsidiaries Aimsun and Autopistas are working together to embed real-time intelligence into the operational fabric of the road network. The project combines traffic sensors, predictive analytics, and incident forecasting tools to improve road safety, reduce congestion, and optimize maintenance. What's particularly promising is the use of connected vehicle technologies: in collaboration with SEAT S.A., we are testing systems that send safety alerts directly to vehicles, offering a glimpse into the possibilities of a fully connected road environment. Here, infrastructure is not just being maintained – it is being enhanced and digitized to anticipate, respond, and adapt to changing traffic conditions in real time. The result is a safer, more responsive and ultimately more human-centred mobility experience.

Moving from digital integration to intermodality, the evolution of motorway infrastructure continues in France, where Sanef is integrating carpooling areas along its motorway network. As mobility patterns evolve and sustainability expectations rise, the need to offer viable alternatives to individual car use becomes pressing. Through the redesign and expansion of more than 1,500 carpooling areas – many located near public transit links – this project facilitates seamless transitions between private and public transport. The enhancements go beyond physical layout: with the integration of real-time information systems, improved lighting, safer access, nearby bus network, and dedicated drop-off zones, these areas are being reimaged not simply as parking lots, but as intelligent mobility hubs. By offering convenient, accessible, and digitally supported alternatives to solo driving, Sanef is helping to reduce emissions and support more flexible, low-impact commuting solutions. And 1000 more spaces has yet to come by 2026.

Taken together, these experiences – from Sud America to Europe – underscore a broader point: that meaningful innovation in infrastructure does not lie solely in grand, headline-making technologies, but also from the way we design, connect, and manage infrastructure with a long-term vision. Whether through circular construction practices, predictive data systems, or the transformation of parking into mobility nodes, each of these examples speaks to a larger shift underway in how transport infrastructure is conceived and delivered with benefits for the entire ecosystem.

This is the direction in which we believe the sector should move. And to get there, collaboration between public and private actors is essential. Innovation does not happen in a vacuum – it requires coordinated vision, long-term planning, and the courage to experiment with new models. At Mundys, we are committed to being a reliable partner in this process. Through global experience, operational know-how, and a focus on sustainability and innovation, we aim to contribute to the creation of resilient, connected, and inclusive infrastructure systems – fit for the challenges and opportunities of the decades ahead.

10. Beyond the Grid: Power Infrastructure for Competitiveness, Security, Sustainability

Stefano Salomoni

Energy infrastructures represent the strategic backbone of modern economic development and geopolitical stability. Today, more than ever, the reliability and robustness of these systems determine the ability of a polity to thrive economically and secure its sovereignty amid geopolitical tensions and climate-related disruptions. Energy security is no longer simply about guaranteed supply; it is fundamentally interconnected with economic resilience and political autonomy.

In this evolving landscape, electricity stands out clearly as the cornerstone of the new global energy paradigm. Particularly in regions like Europe, traditionally reliant on imported fossil fuels (just to bear some numbers in mind, in 2024 the European Union spent almost €376 billion on importing fossil fuels¹), electrification, powered by renewables and next-generation nuclear technologies, is increasingly essential for ensuring sustainable growth, reducing dependency on volatile foreign supplies, and achieving ambitious decarbonisation targets.

Yet, despite rapid progress in clean generation, outdated electricity grids now risk becoming the critical bottleneck in the energy transition. Upgrading and expanding these infrastructures is thus not merely a technical challenge but a

¹ Eurostat, [Imports of energy products to the EU down in 2024](#), 21 March 2025.

strategic imperative. As global competition intensifies and security threats evolve, investing decisively in electricity grids represents a crucial step to preserve economic competitiveness, accelerate climate action, and reinforce geopolitical stability for the decades ahead.

Electricity at the Core of the New Energy Paradigm

“The Age of Electricity”² has become a defining feature of XXI-century energy systems, steering the global shift toward sustainability and economic transformation. This evolution encompasses a dual transition: first, a rapid expansion of renewable energy sources such as wind and solar, which continue to dominate global investment flows,³ complemented in some regions by renewed interest in advanced nuclear technologies; second, the electrification of sectors traditionally reliant on fossil fuels, including transport, heating, and industry, as well as the explosive growth in digital technologies, particularly data centres and artificial intelligence (AI) applications, which are driving unprecedented increases in electricity demand.

Despite recent debates and narratives suggesting a potential slowdown, this transition is not losing momentum; on the contrary, it is accelerating. According to the International Renewable Energy Agency (IRENA), renewable energy accounted for 92.5% of new global power capacity additions in 2024, reaching 585 GW and achieving a record annual growth rate of more than 15%.⁴ Similarly, electrification continues to advance rapidly across sectors. Recent estimates suggest that AI-related electricity consumption could grow by as much as 50% annually from 2023 to 2030.⁵ While it is true that battery-

² International Energy Agency (IEA), *World Energy Outlook*, 2024.

³ International Energy Agency (IEA), *World Energy Investment*, 2024.

⁴ International Renewable Energy Agency (IRENA), “[Record-Breaking Annual Growth in Renewable Power Capacity](#)”, 26 March 2025.

⁵ World Economic Forum (WEF), “[AI’s energy dilemma](#)”, 21 January 2025.

electric vehicle (BEV) sales in Europe experienced a slight decline of nearly 6% in 2024 compared to the previous year,⁶ the global BEV market grew by almost 10%, reaching around 11 million vehicles sold.⁷ This contrast underscores the ongoing global momentum behind electrification, notwithstanding regional fluctuations.

Yet, while this rapid transformation in electricity generation and sector-wide electrification brings substantial opportunities, it also imposes unprecedented demands on existing electricity infrastructure. Grids designed decades ago for stable and predictable consumption patterns now face significant stress from intermittent renewable generation and widely dispersed, decentralised energy resources. The surge of data-driven services, demanding high reliability and constant power supply, further intensifies these pressures, making smarter, more resilient grids essential. Consequently, traditional grids – primarily unidirectional and centralised – must evolve into sophisticated, digitally enabled networks capable of dynamically managing variable renewable energy flows and integrating millions of distributed assets, ranging from rooftop solar panels to electric vehicle batteries. Additionally, interconnections between regions and countries are vital, enabling effective balancing of supply and demand over broader geographic areas, thus enhancing overall grid stability, optimising resource utilisation, and ensuring secure, efficient energy distribution.

Therefore, placing electricity at the centre of energy strategies requires redefining both production and consumption patterns and undertaking a comprehensive infrastructure overhaul. Addressing these challenges demands strategic investments to modernise electricity grids, ensuring they are sufficiently flexible, digitalised, and robust enough to support a sustainable, secure, and economically vibrant future.

⁶ ACEA, “New car registrations: +0.8% in 2024; battery-electric 13.6% market share”, 21 January 2025.

⁷ T. Wicke, “Electric vehicle sales in 2024: Chinese manufacturers on the rise, stagnation in Europe”, Fraunhofer Institute, 23 January 2025.

From Generation to Grids: The New Bottleneck in Energy Systems

In the early decades of this century, global energy strategies primarily emphasised transforming generation capacity, resulting in unprecedented growth in renewable sources like solar and wind. According to IRENA, worldwide renewable electricity generation more than quadrupled in the first two decades of the XXI century,⁸ driven by ambitious climate policies and rapidly declining technology costs.

However, this generation-focused approach has revealed a new global bottleneck: outdated and insufficient electricity grids. Networks originally designed for centralised and predictable fossil fuel generation now struggle to accommodate vast amounts of intermittent renewable energy. In Europe alone, according to WindEurope, over 500 gigawatts of wind capacity remain stalled in connection queues, unable to deliver clean power effectively due to inadequate grid infrastructure.⁹ Similar challenges exist globally. In 2023 more than 3,000 GW of renewable power projects were reported to be in connection queues.¹⁰

This infrastructure inadequacy poses serious risks, undermining climate goals and limiting economic competitiveness and energy security. Without comprehensive grid modernisation and expansion, substantial investments in renewables risk remaining underutilised. Addressing this urgent infrastructure gap has become a critical global priority, essential for realising the full potential of renewables and achieving sustainable, secure, and economically viable energy systems worldwide.

⁸ International Renewable Energy Agency (IRENA), “Renewable Power Generation Costs in 2020”, June 2021.

⁹ WindEurope, “Immediate actions needed to unblock grid capacity for more wind energy”, Press Releases, 5 July 2024.

¹⁰ International Energy Agency (IEA), *Integrating Solar and Wind, Global experience and emerging challenges*, 2024.

The Great Infrastructure Challenge of Our Time: A Historical Parallel

The scale of investment and ambition needed today to transform global electricity grids mirrors the electrification efforts of the early 20th century when electricity infrastructure dramatically expanded, transforming economies and societies. Massive public and private investments built power plants and extensive transmission networks, underpinning rapid economic growth and industrialisation. Similarly, today, achieving global climate goals and enabling economic sustainability requires unprecedented electricity infrastructure investments. Globally, according to Bloomberg New Energy Finance (BNEF), reaching net-zero targets by 2050 would require over \$21 trillion in grid investments.¹¹ Europe alone must invest over €584 billion by 2030 to modernise grids and integrate renewable sources.¹² This immense financial requirement demands coordinated governance between public authorities and private investors. Effective public-private collaboration will ensure strategic alignment, mobilise capital efficiently, and mitigate risks inherent to large-scale infrastructure projects, replicating the historical success of mass electrification and meeting today's pressing economic and environmental objectives.

However, unlike in the early XX century, today's electricity infrastructure challenge extends beyond mere expansion. Modern grids must simultaneously balance complex and sometimes competing priorities that define contemporary energy systems – sustainability, affordability, and security – collectively known as the “energy trilemma”.

¹¹ “Global Net Zero Will Require \$21 Trillion Investment In Power Grids”, *BloombergNef*, 2 March 2023.

¹² European Union, Eur-Lex, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Grids, [An EU Action Plan for Grids](#), COM/2023/757 final, Document 52023DC0757, 2023.

Electricity Grids and the Energy Trilemma

Modern electricity grids play a pivotal role in solving the energy trilemma – achieving sustainability, affordability, and security – through a coherent set of infrastructure and system innovations. Unlike past electricity systems built around centralised fossil fuel generation, modern electricity networks are expected to enable deep decarbonisation, contain costs for consumers and businesses, and withstand increasingly complex risks and disruptions.

Meeting these simultaneous objectives demands a new generation of electricity infrastructure that is smarter, more flexible, and more interconnected. From enabling the integration of a variety of renewables to managing demand peaks and ensuring resilience during crises, the performance of our grids will determine the success of the energy transition.

To fully understand how electricity infrastructure contributes to navigating this trilemma, it is useful to examine each dimension individually, starting with the central role that grids play in accelerating sustainability and decarbonisation.

Electricity Infrastructure as an Accelerator for Decarbonisation

Advanced electricity infrastructure is a powerful accelerator for decarbonisation, primarily by minimising renewable energy curtailment and maximising the efficient use of generated clean energy. Curtailment – the loss of renewable electricity due to insufficient transmission capacity – is a significant global challenge. In Germany alone, approximately 19 TWh, roughly 4% of the nation's annual electricity generation, was curtailed in 2023.¹³ California experienced a similar issue, curtailing around 5% of its total solar and wind generation in the same year.¹⁴

¹³ “Engpässe im Stromnetz kosteten 2023 knapp 3,1 Milliarden Euro”, *Spiegel Wirtschaft*, 8 April 2024.

¹⁴ California ISO (CAISO), “2023 Annual Report on Market Issues and

Modern, enhanced grids reduce curtailment by efficiently channelling excess renewable energy from regions with abundant wind and solar resources toward high-demand urban and industrial centres. Prominent examples include Europe's North Sea Wind Power Hub and China's extensive transmission initiatives, both linking remote renewable generation sites directly to major consumption hubs. At the same time, smart grids significantly enhance decarbonisation through dynamic and intelligent management of decentralised energy resources (DERs) such as residential solar installations and electric vehicle batteries. These advanced systems allow for precise, real-time adjustments to energy flows, optimising the integration of renewables and drastically reducing reliance on fossil fuels.

Critically, reducing renewable curtailment and improving resource utilisation does not only benefit the environment; it also directly translates into enhanced economic efficiency and competitiveness by ensuring affordable and stable electricity prices.

Economic Competitiveness: The Impact of Electricity Infrastructure on Costs and Inflation

Robust electricity infrastructure underpins economic competitiveness by reducing energy costs for businesses and households. Integrated electricity markets, exemplified by Europe's single-market approach, demonstrate significant cost efficiencies through cross-border trading, effectively lowering wholesale electricity prices and reducing price volatility. According to ACER, market integration across EU Member states already delivers €34 billion per year in consumer benefits¹⁵ by enabling electricity to flow where it is most needed and cheapest. Further integration could raise these annual benefits to €40-43 billion by 2030, according to the European

Performance", 2024.

¹⁵ European Union Agency for the Cooperation of Energy Regulators (ACER), "Final Assessment of the EU Wholesale Electricity Market Design", April 2022.

Commission. Moreover, price spikes above €250/MWh during summer 2023 in South-East Europe were directly linked to insufficient cross-border capacity, highlighting the cost of incomplete integration.¹⁶

This integration considerably reduces operational expenses for energy-intensive sectors, strengthening industrial competitiveness in global markets. Moreover, lower and more predictable electricity costs help contain inflationary pressures, thereby preserving household purchasing power and economic stability. Thus, strategic investments in electricity grids yield substantial economic dividends, reinforcing broader economic resilience and sustainable growth.

However, the economic benefits of integrated electricity systems are contingent upon ensuring continuous operational reliability and resilience. Economic gains could quickly vanish if grids are unable to respond effectively to unforeseen disruptions, underscoring the importance of robust energy security measures.

Energy Security Through Resilient Electricity Grids

Ensuring robust electricity grids is critical not only to sustaining economic competitiveness but also to guaranteeing national energy security through resilience and reliability. As the world's energy systems become increasingly interconnected and electrified, their exposure to potential disruptions – whether due to extreme weather events, technical failures, or cyber-attacks – has intensified significantly.

¹⁶ European Union, EUR-Lex, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, “[Action Plan for Affordable Energy Unlocking the True Value of Our Energy Union to Secure Affordable, Efficient and Clean Energy for All Europeans](#)”, COM/2025/79 final, Document 52025DC0079.

Recent global experiences highlight the vulnerability of insufficiently resilient grids. For instance, in February 2025, Chile suffered a massive blackout due to its fragmented electricity network and limited redundancy, severely impacting industrial output and citizen welfare. Similarly, fragmented grid infrastructures in regions like ASEAN and parts of Latin America regularly struggle to cope effectively with sudden demand fluctuations or generation failures, exposing them to recurrent outages and heightened economic risks. In contrast, grids incorporating advanced digital technologies, robust interconnections, and strategic redundancy mechanisms can swiftly reroute power, mitigate impacts, and maintain essential service continuity even during disruptions.

Thus, strengthening the operational resilience and reliability of electricity grids is fundamental not only for maintaining day-to-day energy supplies but also for securing sustained economic stability, protecting the competitiveness gains achieved through integrated markets, and preserving national autonomy against external and internal vulnerabilities.

Strategic Assets for Comprehensive Security

While the reliability and resilience of electricity grids are vital for national economic stability, the concept of energy security today extends far beyond domestic technical and operational robustness. Modern electricity networks increasingly represent strategic geopolitical instruments, essential for ensuring external security, diplomatic influence, and international cooperation. Recent events in Eastern Europe clearly illustrate this dimension: following Russia's invasion of Ukraine in 2022, Ukraine and Moldova swiftly synchronised their grids with the continental European network, significantly reducing their vulnerability to external disruptions and enhancing their geopolitical autonomy. Similarly, the Baltic states expedited their detachment from Russian networks, fully integrating into Europe's electrical grid in early 2025, reinforcing their sovereignty and energy security through strategic interconnections.

Cross-border electricity infrastructure is thus emerging globally as a powerful geopolitical asset, shaping international relations and regional stability. Strategic interconnections, such as the ELMED link between Tunisia and Italy, the UK-Morocco Xlinks cable project, and the India-Middle East-Europe Economic Corridor (IMEC), exemplify electricity networks' potential to build profound diplomatic and economic relationships that transcend mere physical energy exchanges. Initiatives such as the Australia-Singapore Sun Cable and the Green Grids Initiative further demonstrate how renewable energy interconnections foster diplomatic engagement and stable international partnerships. Unlike traditional fossil-fuel infrastructures, electricity networks establish lasting interdependencies, rooted in shared renewable resources, mutual trust, and harmonised regulatory frameworks, becoming essential tools of sustainable statecraft.

However, this growing reliance on integrated and interconnected grids also brings heightened vulnerabilities, especially concerning cybersecurity and supply chain stability. Global supply chains for critical grid components, particularly large power transformers, face significant pressure, with production lead times reaching over 4 years in 2024.¹⁷ Such bottlenecks can critically delay essential infrastructure projects and compromise grid reliability, undermining economic and strategic interests. At the same time, increasing grid digitalisation introduces severe cybersecurity risks, as interconnected digital control systems represent attractive targets for cyberattacks. The repeated cyber-attacks against Ukrainian electricity infrastructure starkly illustrate these risks, highlighting the urgent need for stringent cybersecurity standards, coordinated international cooperation, and robust digital defences.

Therefore, electricity grids today embody comprehensive security concerns – spanning technical resilience, geopolitical

¹⁷ Wood Mackenzie, “[Supply shortages and an inflexible market give rise to high power transformer lead times](#)”, 2 April 2024.

stability, cyber-security and supply chain infrastructure serviceability – making strategic grid investments indispensable for safeguarding economic prosperity, political autonomy, and global energy stability.

Conclusion: Towards Strategic Electricity Infrastructure

Electricity grids have evolved from purely technical infrastructures into pivotal strategic assets central to economic prosperity, energy security, and geopolitical stability. Investing in robust, interconnected and secure electricity infrastructure today equates directly to investing in tomorrow's economic resilience, energy sovereignty and global stability.

In an increasingly interconnected yet vulnerable world, electricity grids represent not only the backbone of sustainable energy systems but powerful instruments for international cooperation and integration. Strategic focus on grid expansion and modernisation is thus essential to navigate future global energy challenges successfully.

11. The Role of Cross-Border Energy Infrastructure in the EU Energy System

Cristina Lobillo Borrero

The EU is undergoing a transformative shift in its energy system to ensure competitiveness, sustainability, and security of energy supply. As part of this transition, the European Commission underpins policies to boost renewable energy production, expand and modernise the EU's domestic energy infrastructure as well as cross-border interconnections, and support partner countries to fully untap their renewable potential.

Energy infrastructure lies at the heart of the EU's strategy to achieve a secure, integrated, and decarbonised energy system. Recognising the importance of cross-border infrastructure to fully untap the integration of renewables, the EU has established a framework that prioritises the development of cross-border energy infrastructure through Projects of Common Interest (PCIs) and, more recently, Projects of Mutual Interest (PMIs) with neighbouring regions under the framework of the Trans-European Energy Networks (TEN-E) Regulation.

These projects are key to ensure energy security, integrating renewable energy sources, and reducing greenhouse gas emissions in line with the European Green Deal and the 2050 climate neutrality target.

PCIs are selected as essential infrastructure for the completion of the EU's internal energy market. By enhancing cross-border interconnections and ensuring the flow of energy across EU Member states, PCIs address market fragmentation, improve

energy resilience, and reduce dependency on single suppliers.

The European Commission facilitates their implementation through regulatory support, accelerated permitting processes, and financial backing from instruments such as the Connecting Europe Facility (CEF).

Nearly 100 PCIs have been effectively deployed to significantly reduce vulnerabilities to supply disruptions in the wake of the Russian aggression against Ukraine and hence also contributing to the REPowerEU objectives. Over 50 electricity PCI projects and more than 30 gas infrastructure PCI projects have been recently completed.

Building on the successful experience with PCIs, the EU has also introduced Projects of Mutual Interest to extend infrastructure cooperation beyond its borders. Given the strategic importance of energy trading with non-EU partner countries, PMIs aim to support the mutual integration of energy markets and the development of renewable energy corridors. These projects play a crucial role in enabling hydrogen supply chains and future trading of renewable hydrogen, offshore electricity interconnections, and CO₂ transport networks, underpinning both the EU's and partner countries' climate ambitions.

Accelerated and increased cross-border infrastructure investment is key to meet the EU's decarbonisation objectives. By facilitating the deployment of renewable energy across borders, modernising the electricity grid, and advancing low-carbon technologies, PCIs and PMIs contribute directly to ensuring energy resilience and competitiveness and reducing dependency on fossil energy.

The present chapter will explore the role of EU instruments to support cross-border energy infrastructure projects within the EU and with partner countries, bringing concrete examples of the benefits underpinned by the EU policy and financial support toolkit. It will provide insights into the regulatory and policy mechanisms underpinning PCIs and PMIs, as well as their role in fostering a resilient and sustainable European energy system.

Cross-Border Energy Infrastructure in the EU's Competitiveness and Decarbonisation Strategy

Cross-border energy infrastructure underpins the dual objectives of underpinning economic competitiveness and achieving climate neutrality by 2050. The EU's ambitious climate targets warrant accelerated expansion, modernisation, and integration of energy networks, for both economic competitiveness and decarbonisation.

Accordingly, the revised TEN-E Regulation explicitly focuses on electricity grids and hydrogen infrastructure, streamlining permitting processes and enabling the possibility to mobilise financial support via the CEF. This policy prioritisation is meant to simultaneously steer the EU energy system towards increased sustainability and competitiveness, while also reducing excessive dependencies on fossil energy imports and strengthening the EU's energy security.

Complementing TEN-E, the EU Action Plan for Grids, adopted in November 2023, addresses critical infrastructure needs by supporting investments, regulatory improvements, and permitting processes to swiftly deploy advanced, flexible, and interconnected electricity grids. One of the main goals is to significantly increase cross-border transmission capacity within the next decade, which is crucial for integrating substantial offshore wind energy, renewable hydrogen, and securing energy supply for enhancing industrial competitiveness. Improved cross-border energy interconnections are projected to reduce electricity generation costs by €9 billion annually by 2040, against an estimated €6 billion annual investment for new cross-border capacity and storage infrastructure.

The Clean Industrial Deal (CID) recently adopted by the Commission further integrates these objectives by combining climate action and industrial competitiveness into a cohesive growth strategy. It addresses the challenges faced by energy-intensive industries – such as high energy costs and global competition – by supporting accelerated electrification,

integration of clean technology, and reinforced infrastructure networks. The CID directly addresses the challenges faced by energy-intensive industries by implementing specific actions such as accelerating the uptake of Power-Purchase Agreements (PPAs) and Contracts for Difference (CfDs), simplifying State aid rules to expedite renewable energy and decarbonisation investments, and reducing taxation on electricity. On the infrastructure front, the Deal calls for rapid deployment of grid upgrades through streamlined permitting processes and announces a European Grids Package aimed at enhancing internal market interconnections. These actions are designed to lower energy costs, accelerate electrification, and foster innovation, ensuring Europe remains competitive in the global clean technology market

Simultaneously, the Action Plan for Affordable Energy (AEAP) underpins structural reform in energy markets, especially through electricity market design, grid flexibility, and taxation frameworks, as critical for lowering energy prices. Integration of European electricity markets already yields consumer savings of around €34 billion annually, with further integration expected to increase these annual savings to between €40-43 billion by 2030. The AEAP also underpins the need to reduce Europe's dependency on imported fossil fuels, supporting increased domestic renewable energy generation and improved network efficiency.

The EU also actively promotes cross-border infrastructure cooperation beyond its borders through Projects of Mutual Interest (PMIs). These projects enhance energy connectivity with neighbouring countries, developing key corridors for exchange of renewable energy, offshore interconnections, and carbon dioxide transportation networks, aligning external energy partnerships with internal competitiveness and decarbonisation goals.

Projects of Common and Mutual Interest: Strengthening Cross-Border Energy Infrastructure Cooperation

As outlined above, PCIs and PMIs play an instrumental role in the EU's strategy for energy integration, resilience, and decarbonisation. Under the TEN-E framework, these strategic infrastructure projects are selected based on their capacity to significantly enhance cross-border energy flows, improve market integration, integrate renewable energy sources and increase energy security, while supporting the EU's climate goals.

PCIs are primarily focused on strengthening the EU's internal energy market, underpinning tangible economic and sustainability benefits within the EU. The Celtic Interconnector between Ireland and France, a subsea high-voltage direct current (HVDC) connection valued at approximately €1.6 billion, will enable more efficient and price-competitive cross-border electricity exchanges. The interconnector is expected to lower wholesale electricity prices in Ireland by reducing market isolation and enhancing competition, thereby saving Irish consumers an estimated €200 million annually.

Another notable PCI is the Biscay Gulf Interconnector linking Spain and France, with an investment of about €3.1 billion. This project will nearly double cross-border electricity exchange capacity, significantly alleviating congestion costs and fostering greater integration of renewable energy. According to ENTSO-E forecasts, this interconnector could reduce overall electricity generation costs by up to €400 million per year, driven by improved market efficiency and the integration of lower-cost renewable generation.

Germany's SuedLink project, estimated at €10.6 billion, further exemplifies the transformative potential of PCIs. Designed to transmit substantial renewable energy from wind-rich northern Germany to southern industrial regions, SuedLink is projected to substantially decrease Germany's reliance on fossil fuels, lowering national electricity costs by approximately

€500 million annually due to reduced curtailment of renewable energy and decreased dependence on imported energy.

Concerning PMIs with neighbouring countries, the ELMED Interconnector between Italy and Tunisia is expected to be particularly impactful. With a projected investment of €850 million, this subsea HVDC interconnector will enable significant renewable electricity flows between Italy and Tunisia and deliver a reduction of approximately 2 million tonnes of CO₂ emissions per year. It is expected to reduce electricity generation costs across Italy and the broader European market, potentially saving consumers hundreds of millions of euros annually due to increased competition and renewable integration.

Data from projects already implemented confirm the tangible impact of PCI projects. For example, interconnections between the Iberian Peninsula and France, such as the Santa Llogaia-Baixas line, have already improved market liquidity and reduced electricity prices in Spain and Portugal by approximately €50 million annually. Similarly, the LitPol Link connecting Lithuania and Poland significantly reduced electricity prices in the Baltic states, enhancing market integration and energy security. The results already achieved via PCI projects are concrete illustrations of their added value within the European energy architecture in terms of lowering consumer energy prices, integrating renewables, and bolstering energy security across the EU.

Financing and Policy Support for Projects of Common and Mutual Interest

The successful realisation of PCIs and PMIs relies on targeted EU financial support mechanisms and supportive regulatory frameworks. Given the substantial upfront investment necessary and the complexity of cross-border energy infrastructure, EU policy instruments and funding schemes are crucial for bridging financial gaps, mitigating investment risks, and accelerating project timelines.

The Connecting Europe Facility (CEF) is the main EU financial instrument to support energy infrastructure, providing substantial funding to critical projects. Between 2021 and 2027, around €5.84 billion are available under the CEF to support PCIs and PMIs. The Celtic Interconnector, for example, received a CEF grant of €530 million. The substantial EU financial backing for this interconnector, essential for integrating Ireland into the broader European electricity market, is meant to overcome financial barriers upfront, and support the materialisation of the cross-border energy benefits expected from the project.

Besides CEF, the European Investment Bank (EIB) plays a complementary role in supporting PCIs through favourable lending conditions and financial guarantees, significantly enhancing project bankability. EIB financing was instrumental for example in the realisation of the Baltic Synchronisation Project, crucial for integrating Baltic states into the European electricity network, with €300 million in funding. In light of the sizeable infrastructure costs to enable

As exemplified by these PCIs, the availability of EU financial instruments such as CEF and EIB loans is essential to enable critical cross-border infrastructure projects.

Beyond financing, regulatory measures and policy incentives are key elements of the support system developed by the EU. Cross-border Cost Allocation (CBCA) mechanisms under the TEN-E Regulation are designed to fairly distribute cross-border infrastructure investment costs between beneficiary Member states, ensuring projects with wide-reaching benefits are not hindered by national cost concerns. For instance, the CBCA process facilitated equitable cost-sharing for the Lithuania-Poland electricity interconnection (LitPol Link), accelerating project approval and ensuring timely implementation.

The Innovation Fund, part of the EU Emissions Trading System, also contributes significantly by funding innovative low-carbon technologies and infrastructure, including renewable hydrogen projects and associated networks under

the PCI framework. An illustrative example is the “Green Octopus” hydrogen network, which connects industrial clusters across Germany, Netherlands, and Belgium, benefiting from Innovation Fund support to overcome initial technological and financial hurdles.

For PMIs, EU external financial instruments, such as the Neighbourhood Investment Platform (NIP), provide additional funding and facilitate cooperation with partner countries on cross-border energy infrastructure. The ELMED interconnector between Italy and Tunisia exemplifies this crucial role, receiving substantial EU financial support, including a CEF grant of €307.6 million and an additional €27 million from the Neighbourhood Investment Platform. The CEF grant, with the NIP, has significantly reduced financial risks and facilitated loan agreements totalling €125 million from major financial institutions, including the European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD), and the German Development Bank (KfW). This integrated financial approach demonstrates how EU grants can effectively leverage additional financing essential for complex infrastructure projects.

Considering the EU’s sizeable investment needs in energy infrastructure – estimated at €584 billion by 2030 for electricity grids alone – there is a clear imperative to ensure broad-based mobilisation of financial resources. The next Multiannual Financial Framework (MFF) will present an opportunity for the EU to substantially enhance the funding of cross-border energy infrastructure critical for the competitiveness and sustainability of the EU energy system. Increasing EU financial support will be critical not only for securing Europe’s energy resilience and accelerating decarbonisation, but also for enhancing industrial competitiveness in expanding markets for decarbonised products.

Conclusion

As highlighted in this chapter, PCIs and PMIs play a crucial role for achieving the EU's energy competitiveness and decarbonisation goals. These strategic projects, backed by EU financial mechanisms and supportive regulatory frameworks, are critical for facilitating the integration of renewable energy sources, ensuring security of supply, and strengthening the EU's position in the global energy market.

Projects such as the Celtic Interconnector, the Biscay Gulf Interconnector, and Germany's SuedLink significantly enhance the efficiency of energy markets by reducing costs, optimising renewable energy utilisation, and addressing infrastructure bottlenecks. Similarly, the ELMED interconnector exemplifies how PMIs facilitate critical energy cooperation beyond EU borders, fostering regional stability and energy integration while significantly reducing the carbon emissions of the energy system.

EU financial support mobilised via the CEF, EIB loans, and EU external financial instruments such as the Neighbourhood Investment Platform have proven indispensable, enabling complex infrastructure projects to overcome financing hurdles. The strategic use of EU grants to leverage additional private and institutional financing clearly underpins the multiplier effect of EU-backed financial mechanisms.

Projects of Common Interest have proved to be one of the key tools to enhance the EU's overall energy competitiveness. By facilitating better market integration and increased renewable energy penetration, they contribute to lowering consumer and industrial energy prices, thereby strengthening the EU's economic competitiveness. They also significantly enhance energy security and resilience by diversifying energy sources, reducing reliance on fossil fuel imports, and mitigating geopolitical risks related to energy dependencies.

To ensure that the EU effectively tackles its energy competitiveness and sustainability challenges, a strong pipeline

of PCIs and PMIs, coupled with strengthened EU financial support and supportive regulatory frameworks, remains crucial. As the EU transitions towards a decarbonised energy system, sustained investment in key cross-border energy infrastructure projects will not only reduce dependency on fossil energy imports but will also ensure a secure, resilient, and competitively priced energy supply more evenly distributed across the whole EU.

12. Logistics for a Low-Carbon Economy: Hydrogen and Ammonia Distribution. Opportunities and Challenges

Nicola De Blasio

Clean hydrogen is emerging as a key energy carrier in the transition to a low-carbon economy. However, its large-scale distribution presents significant logistical challenges. Multiple transportation methods are available, ranging from pipelines and liquefaction to conversion into carriers such as ammonia, each with distinct advantages and trade-offs. The optimal distribution approach will depend on factors such as distance, existing infrastructure and specific end-use applications. While pipelines offer an efficient solution for regional distribution, liquefied hydrogen enables long-distance transport, but at much higher energy costs. Alternatively, hydrogen can be converted into ammonia, facilitating storage and global shipping due to its higher volumetric energy density and mature global infrastructure. Given the diverse needs of a global hydrogen economy, a hybrid approach that leverages a combination of these methods will likely be necessary to enable cost-effective, scalable and sustainable hydrogen distribution. This chapter outlines the strategic priorities for scaling hydrogen supply chains, emphasising innovation, coordinated investment and effective policy frameworks.

The remainder of this chapter is structured as follows: Section 2 reviews the technology landscape and evolving market dynamics. Section 3 analyses hydrogen logistics options,

focusing on pipelines, liquefied hydrogen and ammonia. Section 4 outlines key strategies related to innovation, policy and market development.

Technology and Market Dynamics

As the world advances toward a cleaner energy future, clean hydrogen is emerging as a promising energy carrier. However, its role in the transition to a low-carbon economy will depend not only on efficient and sustainable production^{1,2} but also on developing and deploying effective logistics for its distribution – often across long distances – from production sites to consumption hubs.³

A rainbow of colours⁴ dominates almost every conversation on the transition to a low-carbon economy: green, grey, blue, turquoise, pink, yellow, orange – an ever-increasing palette to describe the same colourless, odourless and highly combustible molecule, hydrogen. The only difference is the chemical process used to produce it.

Hydrogen is the most abundant element in the solar system, but it naturally occurs only in its compound form on Earth. Therefore, it must be produced from molecules that contain it, such as water or hydrocarbons, through specific processes, including thermo-chemical conversion, biochemical conversion or water electrolysis.

¹ F. Pflugmann and N. De Blasio, “The Geopolitics of Renewable Hydrogen in Low-Carbon Energy Markets”, *Geopolitics, History, and International Relations*, vol. 12, no. 1, 2020, pp. 9-44, doi:10.22381/GHIR12120201.

² N. De Blasio, F. Pflugmann, H. Lee, C. Hua, A. Nuñez-Jimenez, and P. Fallon, “Mission Hydrogen: Accelerating the Transition to a Low Carbon Economy”, Harvard Kennedy School, Belfer Center for Science and International Affairs, 29 October 2021.

³ L. Eicke and N. De Blasio, “[Green Hydrogen Value Chains in the Industrial Sector: Geopolitical and Market Implications](#)”, *Energy Research & Social Science*, vol. 93, no. 102847, 2022, pp. 2214-6269.

⁴ N. De Blasio, “The Colors of Hydrogen”, Harvard Kennedy School, Belfer Center for Science and International Affairs, July 2024.

The colours of hydrogen are crucial for the energy transition because each production pathway generates different amounts of greenhouse gas emissions and results in different production costs. Today, renewable (or green) hydrogen⁵ is two to three times more expensive than hydrogen produced from fossil fuels.

On a mass basis, hydrogen has three times the energy density of gasoline (120 MJ/kg compared to 44 MJ/kg). However, the situation is reversed on a volume basis: liquid hydrogen has an energy density of about 8 MJ/L, while gasoline has a significantly higher density of 32 MJ/L (see Figure 1).^{6,7,8} Thus, larger hydrogen volumes must be transported to achieve energy equivalence, a significant cost barrier to large-scale distribution.^{9,10}

Hydrogen can be compressed to increase energy density, but achieving substantial gains requires high pressures. While liquefaction more than doubles hydrogen's density compared to compression, it needs extremely low temperatures,¹¹ and consumes nearly a third of the total energy content.^{12,13}

⁵ Green or renewable hydrogen is produced from renewable energy sources like wind and solar through a process known as water electrolysis, where an electrolyzer splits water molecules into oxygen and hydrogen. No CO₂ emissions are generated during the production process.

⁶ Based on lower heating values.

⁷ U.S. Department of Energy (DOE), [Hydrogen Storage](#).

⁸ M. Usman, "Hydrogen storage methods: Review and current status", *Renewable and Sustainable Energy Reviews*, vol. 167, no. 112743, 2022.

⁹ P. Preuster, A. Alexander, and P. Wasserscheid, "Hydrogen storage technologies for future energy systems", *Annu Rev Chem Biomol Eng*, vol. 8, 2017, pp. 445-51.

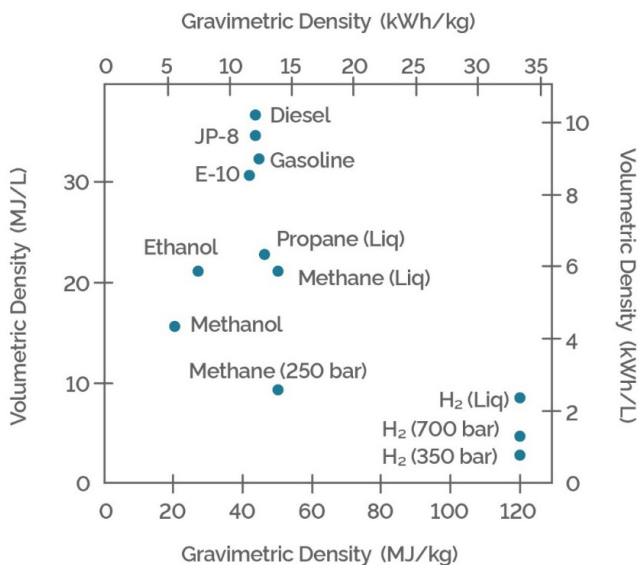
¹⁰ D.J. Durbin and C. Malardier-Jugroot, "Review of hydrogen storage techniques for on board vehicle applications", *Int J Hydrogen Energy*, vol. 38, 2013, pp. 14595-97.

¹¹ The critical temperature of hydrogen is -240°C (temperature above which hydrogen cannot be liquefied).

¹² H. Barthelemy, M. Weber, and F. Barbier, "Hydrogen storage: recent improvements and industrial perspectives", *Int J Hydrogen Energy*, vol. 42, 2017, pp. 7254-52.

¹³ International Energy Agency (IEA), "[Hydrogen production and storage: R&D priorities and gaps](#)", Paris, 2006.

FIG. 9.1 - GRAVIMETRIC VS. VOLUMETRIC ENERGY DENSITIES



Source: DOE 2025

Therefore, transporting hydrogen via carriers such as ammonia (NH_3) or methanol (CH_3OH), which contain multiple hydrogen atoms, can enable the distribution of significantly larger volumes relative to the tank size.¹⁴ Unlike pure hydrogen, which requires cryogenic storage at -253°C , ammonia can be stored as a liquid at -33°C or at ambient temperature under moderate pressure, making it easier to distribute.

From a greenhouse gas (GHG) emissions perspective, hydrogen carrier systems entail incremental energy demands at each value chain stage, including carrier synthesis, transportation and reconversion to hydrogen. These processes can generate substantial life-cycle emissions, depending on both the carbon intensity of the energy sources and the design and efficiency of the overall supply chain.

¹⁴ Although both ammonia and methanol are viable hydrogen carriers, this study prioritises ammonia due to its carbon-free nature.

For instance, hydrogen liquefaction requires approximately 6 kWh per kilogram of hydrogen (primarily for compression), which translates into 0.6 kg CO₂-equivalent per kilogram of hydrogen for every 100 g CO₂/kWh increase in the carbon intensity of the electricity grid. While renewable electricity could significantly reduce these emissions, liquefaction facilities necessitate a continuous power supply, and stable operation under intermittent renewable inputs has yet to be demonstrated. Similarly, in the case of liquid organic hydrogen carriers (LOHCs), emissions on the importing side – arising from dehydrogenation and compression – are estimated at 0.2 kg CO₂-equivalent per kilogram of hydrogen per 100 g CO₂/kWh increase in grid carbon intensity.¹⁵

These values underscore the critical importance of electricity sourcing: the lower the carbon intensity of the grid, the lower the indirect emissions associated with hydrogen transport and storage. Ultimately, the environmental impact of each hydrogen carrier – be it ammonia, methanol, LOHCs or liquefied hydrogen – is influenced not only by energy consumption but also by factors such as infrastructure compatibility, safety considerations, storage conditions and overall lifecycle efficiency. Therefore, selecting the most appropriate carrier involves a nuanced trade-off between environmental, technical and economic priorities.

From a market perspective, global hydrogen demand reached 97 million metric tons (Mt) in 2023, a 2.5% increase from 2022. However, this growth was driven mainly by broader economic trends rather than the impact of targeted policy measures. Hydrogen consumption remains concentrated in refining and industrial applications, where it has been a staple for decades. Its adoption in emerging key sectors of the energy transition, such as energy storage, heavy industry and long-distance transport, remains limited, accounting for less than

¹⁵ International Energy Agency (IEA), [Global Hydrogen Review 2024](#), Paris, IEA, 2024.

1% of global demand, despite a 40% increase compared to 2022.¹⁶

Ammonia, by contrast, is already a strategically important carbon-free global commodity. In addition to its role in sectors such as chemicals, refrigeration, mining and pharmaceuticals, its primary application in fertiliser production makes it critical to global food security.

Ammonia accounts for approximately 30% of hydrogen demand. In 2023, global production reached 152 Mt,¹⁷ with approximately 10% traded internationally.¹⁸ This established global trade network provides a strong foundation for ammonia's emerging role as a hydrogen carrier, leveraging well-established transport infrastructure such as ports, vessels and storage facilities.

While hydrogen and ammonia have been used safely in various industrial applications for decades, their deployment in new energy systems requires thorough safety evaluations. Both compounds pose specific risks that must be carefully managed. Hydrogen, for instance, is highly flammable due to its low flashpoint. However, it requires a higher concentration in air to ignite – 4% compared to 1.6% for gasoline.^{19,20} At the same time, its low density and high diffusivity help reduce some of the risk, as hydrogen tends to disperse quickly in open environments. As a result, effective ventilation and leak detection systems are critical components in the safe design of hydrogen infrastructure.

Ammonia, by contrast, is toxic and corrosive, requiring strict handling and storage procedures to prevent leaks and

¹⁶ Ibid.

¹⁷ “Production of ammonia worldwide from 2010 to 2024”, *Statista*, 2025.

¹⁸ J. Egerer, V. Grimm, K. Niazmand, and P. Runge, “The economics of global green ammonia trade – Shipping Australian wind and sunshine to Germany”, *Applied Energy*, vol. 334, no. 120662, 15 March 2023.

¹⁹ The Royal Society, “[Ammonia: zero-carbon fertiliser, fuel and energy store](#)”, 2020.

²⁰ The Royal Society, “[The role of hydrogen and ammonia in meeting the net zero challenge](#)”, 2021.

environmental damage. Fortunately, its pungent odour allows for early detection at concentrations well below those that pose lasting health risks. These considerations underscore the critical need for real-time monitoring systems and regularly updated safety protocols in all future applications. Equally important is the promotion of public awareness campaigns to build trust, address safety concerns and secure long-term political and societal support.

In summary, multiple transportation methods are available for hydrogen, including pipelines, liquefaction and conversion into carriers such as ammonia, each offering unique advantages and trade-offs associated with energy density, cost, infrastructure maturity and safety (see Table 9.2). Given the diverse demands of a global hydrogen economy, a hybrid approach that combines these methods will likely be essential to achieve cost-effective, scalable and sustainable hydrogen distribution.

Hydrogen Transportation

Pipelines

Hydrogen can be distributed as a gas through dedicated pipelines or blended with natural gas in existing infrastructure. While hydrogen pipelines operate similarly to natural gas pipelines, they require specialised materials and designs due to hydrogen's unique properties.

In the early stages, hydrogen can be blended with natural gas in existing networks at low concentrations, often without significant upgrades. However, blending faces regional limitations: while some networks and end-use applications can tolerate higher hydrogen levels, others are limited to only small percentages due to concerns such as hydrogen embrittlement.²¹

²¹ Hydrogen embrittlement is a degradation process where metals, especially high-strength steels, become brittle and prone to cracking due to the absorption of hydrogen atoms, leading to a loss of strength.

Furthermore, differing national blending limits present a significant barrier to cross-border hydrogen trade. This underscores the need for internationally harmonised standards, certification schemes and tracking frameworks, all of which are essential but complex steps toward developing integrated and efficient hydrogen markets.

In later stages, transitioning to new infrastructure or converting existing gas networks to pure hydrogen will be necessary. However, the ultimate challenge lies in managing the final step of this transition. A critical yet often overlooked issue is that converting a distribution zone to pure hydrogen requires all end consumers, including residential users, to switch simultaneously – a complex logistical hurdle. Strong policy guidance and public-private coordination will be crucial to managing this transition from planning and financing to deployment.²²

Pipelines are well-suited for short- to medium-distance transport, particularly within industrial clusters. However, large-scale deployment requires substantial capital investment and long-term infrastructure commitments, underscoring the need for strategic planning. Furthermore, their fixed routes make them inflexible, limiting adaptability to shifting supply and demand. Unlike shipping or trucking, which offer dynamic routing, pipelines require extensive planning and investment, making them less viable for regions with evolving supply chains. This rigidity also complicates scaling, as rerouting or expanding networks incur high costs and regulatory challenges.

Planned Hydrogen Projects - Notable examples

A growing number of international projects underscore the global momentum behind hydrogen. Countries are collaborating across borders to scale up production, establish trade routes and develop integrated value chains.²³

²² N. De Blasio, F. Pflugmann, and H. Lee, “Hydrogen Deployment at Scale: The Infrastructure Challenge”, Harvard University, August 2021.

²³ N. De Blasio and D. Zheng, “The Future of Energy Value Chains in the

- European Hydrogen Backbone (EHB)^{24,25}. A consortium of European gas network operators is developing a dedicated hydrogen pipeline infrastructure by repurposing existing natural gas pipelines and constructing new dedicated ones as needed. The initiative, including the SouthH2 Corridor project²⁶, aims to connect hydrogen production hubs in Spain, North Africa and the North Sea with industrial consumers in Germany, France and the Netherlands.
- Hydrogen Pipeline Network (US). Several initiatives are under way to expand pipeline infrastructure, including clean hydrogen hubs in Texas, the Midwest²⁷ and California,²⁸ however, these face uncertainty due to proposed policy changes by the Trump administration.
- China's Hydrogen Infrastructure Expansion. China is building one of the world's largest hydrogen pipeline networks, backed by both state and private sector investments. This includes the world's longest hydrogen pipeline,²⁹ aimed at enhancing hydrogen production, distribution and industrial integration.

Transition to a Low-Carbon Economy", Harvard Kennedy School's Belfer Center for Science and International Relations, August 2023.

²⁴ European Hydrogen Backbone, *European Hydrogen Backbone: A European Hydrogen Infrastructure Vision Covering 28 Countries*, April 2022.

²⁵ Hydrogen Europe, *Hydrogen Infrastructure Report*, 2024.

²⁶ *The South H2 Corridor*.

²⁷ T. Gardner, "US awards up to \$2.2 billion to speed clean-hydrogen development", Reuters, 20 November 2024.

²⁸ Office of Clean Energy Demonstrations, "California Hydrogen Hub", 2024.

²⁹ R. Parkes, "World's longest hydrogen pipeline, covering 700km, set for construction work this year at a cost of \$845m", *Hydrogeninsight*, 29 February 2024.

Liquefied Hydrogen

Shipping hydrogen as liquefied hydrogen (LH₂) presents a promising pathway for international trade, thanks to its higher volumetric energy density compared to compressed hydrogen, which enables more efficient long-distance distribution and supports market expansion.

However, several challenges must be overcome for widespread adoption to occur. As discussed, LH₂ requires cryogenic temperatures (around -253°C), resulting in high energy consumption during liquefaction. Boil-off losses³⁰ during storage and transport further reduce overall efficiency.^{31,32} Moreover, the supporting infrastructure – such as specialised tankers, terminals and cryogenic handling systems – is still in its early stages of deployment and requires significant investment to become commercially viable.

Safety is another critical consideration. Hydrogen's flammability and the complexity of ultra-cold handling require robust safety protocols and clear regulatory frameworks. In parallel, LH₂ faces growing competition from alternative hydrogen carriers, such as ammonia and liquid organic hydrogen carriers, which may offer more scalable or cost-effective options depending on the specific use case.³³

Addressing these technical, economic, and logistical challenges is essential for LH₂ to become a mainstream hydrogen transport solution. Nonetheless, ongoing advancements in cryogenic technology are steadily improving storage and

³⁰ Boil-off refers to the unavoidable evaporation of cryogenic liquids during storage and transportation. Despite advanced insulation, a portion of the liquid gradually warms up and transitions into a gaseous state, leading to energy losses and requiring venting or recapture.

³¹ U.S. Department of Energy (DOE), [Hydrogen Delivery](#), 2025.

³² T. Zhang et al., "Hydrogen liquefaction and storage: recent progress and perspectives", *Renewable and Sustainable Energy Reviews*, vol. 176, no. 113204, 2023.

³³ M. Bhuiyan and Z. Siddique, "Hydrogen as an Alternative Fuel: A Comprehensive Review", *International Journal of Hydrogen Energy*, vol. 102, 2024, pp. 1026-44.

transportation efficiency, thus reinforcing LH₂'s long-term value chain potential.³⁴

Planned Liquefied Hydrogen Projects - Notable examples

- Hydrogen Energy Supply Chain (HESC)^{35,36}. Japan and Australia are partnering to produce hydrogen from coal in Australia and transport it to Japan using specialised LH₂ carriers. The pilot phase has successfully demonstrated the feasibility of liquefaction and transport, with full-scale commercialisation planned for the 2030s.
- European NAVHYS Project³⁷. Co-funded by the European Union, Ariane Group is leveraging its expertise from space rockets to lead a project advancing LH₂ as a viable maritime energy carrier. By integrating know-how from shipbuilding, space technology, energy and safety, the initiative aims to accelerate maritime decarbonisation. Furthermore, it will address critical challenges, including adapting ship design, port infrastructure and operational frameworks for seamless LH₂ integration.

Ammonia

Thanks to its higher volumetric energy density compared to liquefied hydrogen (see Table 9.1), ammonia is emerging as a strategic, carbon-free hydrogen carrier, particularly for

³⁴ A. Osman et al., "Advances in hydrogen storage materials: harnessing innovative technology, from machine learning to computational chemistry, for energy storage solutions", *International Journal of Hydrogen energy*, vol. 67, 2024, pp. 1270-94.

³⁵ HESC, "[About the Pilot](#)", 2025.

³⁶ Kawasaki Heavy Industries, "[Hydrogen Energy Supply Chain \(HESC\) Project Overview](#)", 2022.

³⁷ Ariane Group, "[NAVHYS project: liquid hydrogen for maritime transport](#)", 2025.

long-distance and international transportation. Synthesised from hydrogen and nitrogen (N_2) via the established Haber-Bosch process,^{38,39} ammonia benefits from existing global infrastructure, providing a practical pathway for scaling hydrogen adoption. Unlike LH_2 , which suffers from boil-off losses, ammonia can be stored with minimal energy loss.

Its dual functionality – as a direct fuel and carrier that can be converted back to hydrogen at the point of use – enhances its market appeal and versatility across sectors. As our research shows,^{40,41} these advantages position ammonia as a key enabler in the development of a global hydrogen economy, prompting a strategic shift in production toward locations near hydrogen generation hubs.

However, its deployment faces critical challenges. The conversion processes to and from ammonia are energy-intensive, affecting overall efficiency. Additionally, reconversion technologies – like catalytic cracking – require further advancement to become commercially viable.⁴²

Countries such as Japan and Australia are already investing in ammonia-based supply chains to facilitate the transport and trade of hydrogen. As of February 2025, the Ammonia Energy Association (AEA) had listed 485 projects worldwide, with a combined annual capacity exceeding 451 million tons.⁴³

³⁸ Nature Synthesis, “Green Ammonia Synthesis”, Editorial, 2, July 2023, pp. 581-82.

³⁹ Green ammonia is produced using hydrogen made from the electrolysis of water using renewable energy sources.

⁴⁰ A. Nuñez-Jimenez and N. De Blasio, “Competitive and Secure renewable Hydrogen Markets: Three Strategic Scenarios for the European Union”, *International Journal of Hydrogen Energy*, 2022.

⁴¹ A. Nuñez-Jimenez and N. De Blasio, “MIGHTY: Model of International Green Hydrogen Trade”, Belfer Center for Science and International Affairs, Harvard Kennedy School, August 2022.

⁴² K. Trangwachirachi et al., “Recent progress on ammonia cracking technologies for scalable hydrogen production”, *Current Opinion in Green and Sustainable Chemistry*, vol. 49, no. 100945, 2024.

⁴³ Ammonia Energy Association, “[LEAD: Low-Emission Ammonia Plants](#)”,

Planned Ammonia Projects – Notable examples

- NEOM Green Hydrogen Project (Saudi Arabia).^{44,45} The NEOM Green Hydrogen Project, one of the world's most prominent initiatives of its kind, aims to produce green hydrogen-derived ammonia for export to global markets. Developed in partnership with ACWA Power and Air Products, the project aims to achieve an annual output of up to 1.2 million tons of green ammonia by 2026.
- Baytown Project (Texas, US).^{46,47} Mitsubishi and commodity trader Trammo signed agreements to off-take up to 1 million tons of low-carbon ammonia annually from ExxonMobil's hydrogen facility, which is expected to begin operations in 2029.
- Yara International's Green Ammonia Initiatives (Norway).⁴⁸ Yara International opened Europe's largest green hydrogen and ammonia plant in Norway in 2024. It also partnered with PepsiCo to supply European farmers with decarbonised fertiliser and signed purchase agreements with renewable fertiliser producers in India, Egypt and Oman.
- Japanese Consortium's Investment in Indian Green Ammonia Project.⁴⁹ A consortium of six Japanese companies, including IHI Corporation and MOL, is

February 2025.

⁴⁴ Air Products, "NEOM Green Hydrogen Complex", 2023.

⁴⁵ NEOM, "NEOM Green Hydrogen Company completes financial close at a total investment value of USD 8.4 billion in the world's largest carbon-free green hydrogen plant", News and Media, 22 May 2023.

⁴⁶ "Japan's Mitsubishi to buy stake, offtake ammonia from ExxonMobil in Texas", *Reuters*, 13 September 2024.

⁴⁷ L. Collins, "Commodities trader in talks to buy up to 500,000 tonnes of blue hydrogen-based ammonia", *Hydrogeninsight*, 27 January 2025.

⁴⁸ "Europe must push for low CO₂ bread, says fertiliser group chief", *Financial Times*, 8 September 2024.

⁴⁹ A. Habibic, "Japanese consortium considering investment in green ammonia project in India", *Offshore Energy*, 25 March 2025.

exploring investment opportunities in a green ammonia production facility in India. The plant aims to produce approximately 400,000 tons of green ammonia annually by 2030, to export it to Japan.

Conclusions and Recommendations

The choice between hydrogen pipelines, liquefied hydrogen and ammonia depends on factors such as distance, cost, safety and existing infrastructure. Our research shows how pipelines are best suited for regional, continuous supply along fixed routes, while ammonia and liquefied hydrogen facilitate long-distance and international trade.

Among these, ammonia currently holds a strategic advantage due to its higher energy density, well-established global infrastructure and lower energy-intensive handling requirements compared to liquefied hydrogen. Therefore, ammonia presents a compelling option for establishing an international, carbon-free hydrogen supply chain, facilitating efficient and flexible connections between production hubs and demand centres.

Looking ahead, hydrogen logistics are likely to follow a hybrid model – leveraging pipelines in regions with mature infrastructure and liquefied hydrogen and ammonia for cross-border and intercontinental transport. Innovation in storage technologies, ammonia cracking and the optimisation of liquefied hydrogen transport will be critical in determining the most cost-effective and scalable solutions.

Unlocking hydrogen's full potential will require coordinated action from industry leaders, policymakers and researchers. A supportive policy and regulatory environment, driven by government incentives and international cooperation, will be key to deploying hydrogen distribution networks at scale. Nations and companies investing early in enabling infrastructure will gain a competitive edge in the energy transition.

From this perspective, we would recommend an approach that includes the following elements:

- **Infrastructure Investment & Integration.** Prioritise coordinated public and private investment in hydrogen pipelines, ammonia shipping and terminal infrastructure, ensuring integration with renewable energy sources to support carbon-neutral and efficient hydrogen value chains. Synchronise demand growth, production scale-up and infrastructure deployment to enable balanced and resilient logistics.
- **Technology Innovation & Cost Reductions.** Support innovation and industrial-scale deployment to reduce costs across the value chain. Focus on key technologies such as ammonia-to-hydrogen conversion, liquefaction efficiency and advanced pipeline materials to mitigate hydrogen embrittlement.
- **Regulatory Frameworks & Safety Standards.** Develop harmonised, transparent regulations and streamlined permitting processes. Define ownership and sharing of enabling infrastructure. Implement real-time monitoring and continuously updated safety protocols.
- **International Collaboration & Market Development.** Coordinate with global partners on standardisation, certification and tracking frameworks. Ensure uninterrupted energy supply to end-users by facilitating cross-border trade and reducing market friction through multilateral agreements.
- **Public Engagement.** Promote awareness campaigns to foster public trust and secure long-term political and societal support.

Hydrogen logistics will be a cornerstone of the clean energy transition. Coordinated action across infrastructure development, regulatory alignment, technological innovation and international cooperation will be essential to realising its full potential.

Early investment in infrastructure, cost-reduction strategies and integration with renewable energy systems will position

hydrogen as a globally viable and sustainable energy carrier, driving decarbonisation and enhancing energy security in the decades ahead.

TAB. 9.1 - SUMMARY OF MAIN VARIABLES

Parameter	Hydrogen Pipelines	Liquefied Hydrogen	Ammonia	Methanol	Liquid Organic Carriers
Temperature [°C]	Gas @ Ambient	Liquid @ -253	Liquid @ -33 Gas @ Ambient	Liquid @ Ambient	Liquid @ Ambient
Energy Density [Kg/L]	0.040 @ 700 bar	0.071	0.12	0.05-0.15	0.047-0.056
Boil-Off Losses	None	High	Minimal	Minimal	None
Infrastructure	Established in key areas	Limited	Established	Established	Established
Conversion to Hydrogen	N/A	Regassification High energy intensity	Cracking	Steam reforming Yields CO2	Dehydrogenation High energy intensity
Safety Concerns	Hydrogen embrittlement risks	Cryogenic conditions and flammability	Toxicity and corrosivity	Toxicity and flammability	Flammability

Source: Author's elaboration^{50 51}

⁵⁰ E. Spatolisano et al. “Liquefied hydrogen, ammonia and liquid organic carriers for harbour-to-harbour hydrogen transport: A sensitivity study”, *International Journal of Hydrogen Energy*, vol. 80, 2024, pp. 1424-31.

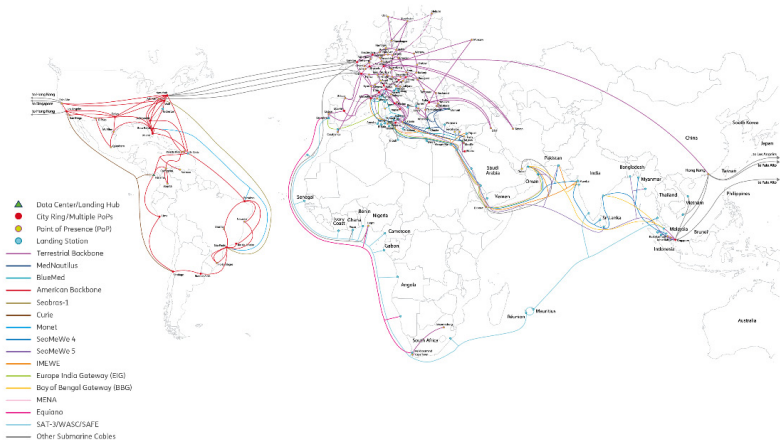
⁵¹ Ambient or Standard conditions: 25 °C and 1 atm.

13. Empowering Global Connectivity: Sparkle's Undersea Strategy

Gabriella Improta, Fabio Panunzi Capuano

Submarine digital cables are critical components of today's global connectivity, shaping the world's communication landscape by enabling the daily exchange of financial, commercial, security, and personal data. Among communication technologies, submarine cable systems stand out for their reliability, resilience, and capacity to meet the ever-growing demands of global communication. Given their role in supporting economic growth and digital transformation, especially considering increasing reliance on secure and high-capacity networks, these infrastructures have become fundamental.

SPARKLE GLOBAL BACKBONE



Today, over 95% of global communications are transmitted via submarine cable systems, underlining their essential function in the modern digital ecosystem.

Sparkle: A Key Player in the Undersea Cable Industry

The implementation of infrastructure projects related to these fundamental communication networks may encounter difficulties of both regulatory and mainly geopolitical nature, which can be addressed and solved with diplomatic tools and the fundamental support of dialogue between institutions of the countries involved.

Sparkle, which brings the heritage of Italcable – the company that already in 1925 laid the first submarine cable between Anzio and Buenos Aires – has in global telecommunications through undersea cables its core business and its company vocation. A major player in the industry, with a history of experience and know-how in a multitude of markets, Sparkle owns and manages a global and technologically advanced proprietary network of more than 600,000 km of fibre with proprietary terrestrial and subsea backbones in Europe, the Mediterranean Basin and the Americas and ownership in submarine cables connecting Europe with South-East Asia.

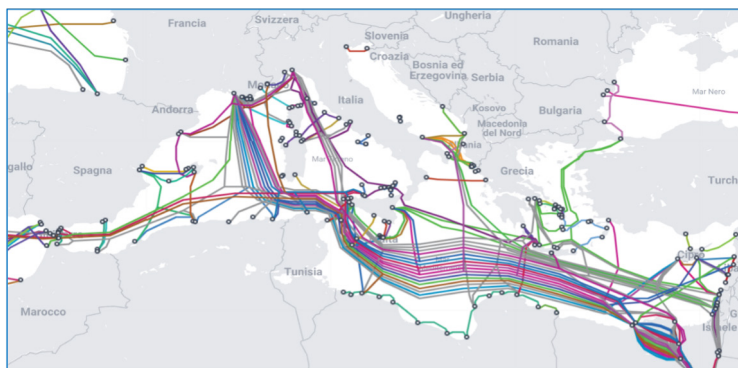
The fibre optic infrastructure enhances customer networks footprint, providing high level of resilience. A fundamental element for the reliability of a network system is redundancy and diversification, that consists in providing multiple paths for traffic and the duplication of critical components to ensure continuous operation and service quality of data flows in the event of failure or cable cut.

Sparkle's Innovative Approach

Sparkle is a global player in communication solutions, offering an ever-evolving platform that serves as a dynamic infrastructure enabling interaction among internal and external developers, as well as both local and international partners

The strategic relevance of submarine infrastructures – particularly in telecommunications – is increasingly recognized, making their protection more urgent and essential than ever. Sparkle has long been committed to safeguarding its assets through continuous monitoring and the adoption of cutting-edge physical and digital security systems.

Beyond enhancing network resilience through infrastructure diversification, Sparkle is pioneering an innovative, multi-layered approach to network security that addresses both immediate and emerging threats. The first layer encompasses robust cybersecurity protocols designed to defend the network perimeter and services against threats such as DDoS attacks. The second, more advanced front focuses on quantum security: in 2024, Sparkle introduced a NaaS (Network-as-a-Service) solution that ensures communication protection from the potential risks posed by quantum computing. The final element is physical security. This angle enables the monitoring and protection of cables across the network in collaboration with Marina Militare through the development of a specific partnership for the monitoring and protection of critical infrastructure. The Italian Navy also provides cartographic support for the seabed of interest as well as assistance in emergency operational situations.



To further strengthen its commitment to submarine cable safety, Sparkle has signed an agreement with Fincantieri, one of the world's leading shipbuilding groups, for the development of innovative technological solutions for the surveillance and protection of submarine telecommunications cables. Efforts of the company are also to develop future solutions for enhanced features of submarine infrastructures, as envisaged within the collaboration with Polo Nazionale della Dimensione Subaquea lead by Marina Militare.

The average life of a submarine telecommunications cable is approximately around 25 years, and there is a need to replace obsolete cables and dispose of those that have reached the end of their life. To help reduce environmental impact, Sparkle collaborates with Oceanic Environmental Cables (OEC) for the recovery and recycling of multiple unused subsea telecommunications. OEC will acquire from Sparkle over 22,000 km of telegraph, coaxial and fibre optic subsea cables laid in the Mediterranean, generating an estimated saving of more than 35,000 tons of CO₂ through secondary material manufacturing reuse cables. With a sustainable, circular economy-based solution, will be recovered and recycled over 9,000 km of disused submarine cables, generating a saving in excess of 35,000 tons of CO₂. Sparkle's Out-of-Service submarine cables will be taken from the seabed and transported

to the facilities of OEC and its partners, which will dismantle, separate, clean, and analyse the various components (optical fibre, copper, steel, aluminum, HDPE, and LDPE) until they are processed into high-quality regranulates. OEC will then return the materials with renewed value to industrial use as secondary raw materials.

Exploring Diverse Applications of Sparkle's Connectivity Initiatives

But submarine cables are not only for communication business. A project is underway to make available transmission technologies via submarine cables for the detection of seismic phenomena on the seabed with a timely advance that allows early detection and, as a final objective, the possibility of activating an early warning.

With this aim, Sparkle started a cooperation with the National Institute of Geophysics and Volcanology (INGV) and joined the European research project ECSTATIC, a consortium of academic and industrial partners, to transform Submarine Fiber-Optic Cables into Global Sensing Systems. Using fibre sensing techniques it is possible to detect the mechanical vibrations induced on the optical fibres of submarine cables by earthquakes, volcanic eruptions, anomalous waves and tsunami detection in real time and in a difficult-to-access environment such as the seabed.



Research activities are employing the Tyrrhenian segment of Sparkle's BlueMed submarine cable system, from Genoa to Palermo, to validate the use of these new technologies for seismic early warning, predictive maintenance, and network integrity, while also leveraging Sparkle's Network Operation Center (NOC) in Catania for data storage.

A Global Network: Blue Med, Blue Raman, GreenMed, MANTA

Sparkle's digital global infrastructure network is constantly expanding. Blue Med is Sparkle's new cable submarine connecting Italy with France, Greece and several countries bordering the Mediterranean. It is part of the Blue & Raman Submarine Cable Systems built in partnership with Google and other operators that stretch further in the Middle East up to Mumbai, India.

With 16 fibre pairs and an initial design capacity of more than 18 Terabits per second (Tbps) per pair, Blue Raman creates a digital highway between Europe and the Middle East and Africa and, as a future extension of the Raman Submarine

Cable, South Asia, bringing unprecedented data transmission capability up to 400Tbps throughout the region. The cable system introduces diversification in many crucial aspects: for the first time, an international system passes in the Tyrrhenian Sea, through the Strait of Messina rather than through the Sicilian Channel. Moreover, the cable arrives in Genoa – and then connects to the Milan digital ecosystem – whereas most cables from Asia end up in Marseille. The final aspect of diversification is the corridor through Israel, which establishes a new route between the Red and Mediterranean Seas. As a confirmation to its strategic role the Med segment of the system, Blue Med has also received financial support within the Connecting Europe Facility (CEF) scheme. The Blue Raman Cable has been considered already as part of the India Middle East Economic Corridor (IMEC).



A new diversified digital corridor will be deployed in the Eastern Mediterranean area. The GreenMed, the first submarine cable system that will cross the Adriatic Sea, creates an innovative fiber optic infrastructure to connect, through a diversified and low-latency route, Central Europe, the Balkans, and the Central-Eastern Mediterranean countries. From Italy's Adriatic coast, the system will connect by land to the rich digital hub of

Milan and, from there, to the other major European internet and cloud nodes. With the GreenMed system Sparkle will connect also the island of Crete in Greece, which in recent years has become a significant digital gateway for the region and the landing point for Sparkle's BlueMed cable. The project also aims to support the strong development of the Balkan digital market – with a growth forecast of 25% (CAGR 22-29) – by offering a secure and diversified route in addition to the already existing terrestrial backbones.

To extend its American Backbone, Sparkle takes part in the implementation of “MANTA”, the first international submarine cable in the Gulf of Mexico, connecting Mexico and the USA with Central and Latin America. With new landing access points in Veracruz, Mexico, and Apalachee, Florida, the “MANTA” system aims to improve traffic flow in the region by providing new low latency routes to interconnect major data hubs in Mexico City, Queretaro, Bogotá, and Panama City with the US.

14. The Latest Frontier in Global Power Dynamics: The Complex Network of Undersea Cables

Katja Bego

Long a largely forgotten infrastructure, undersea cables – the thin garden hoses on the seabed which together facilitate almost 99% of international internet traffic – have recently moved to the forefront of political and security debates. This sudden surge in attention has in particular been sparked by a series of high-profile incidents in the Baltic Sea¹ and off the coast of Taiwan,² in which undersea cables were damaged under suspicious circumstances. In response, we are witnessing a flurry of new initiatives – on an EU-level,³ within NATO⁴ and elsewhere – which seek to better protect cable networks against sabotage and interference. A parallel dynamic which has received far less attention, but is no less important, is the growing geopolitical and geoeconomic competition over the laying and controlling of submarine cables. This rivalry over the seabed, primarily driven

¹ “‘Incredibly difficult to prove’ Two Baltic Sea Internet cables were damaged within 24 hours. Was it Russian ‘hybrid warfare’ or just a coincidence?”, *Meduza*, 25 November 2024.

² “‘Taiwan charges Chinese captain with damaging undersea cables’”, *The Guardian*, 11 April 2025.

³ European Commission, *Joint Communication to strengthen the security and resilience of submarine cables | Shaping Europe’s digital future*.

⁴ E.M. McNamara, “Reinforcing resilience: NATO’s role in enhanced security for critical undersea infrastructure”, *NATO Review*, 28 August 2024.

by the United States, China and to a lesser extent Europe, may be a less headline-grabbing topic, it is one which in its own way threatens the resilience of this vital global infrastructure. In this new scenario, the main players are also different in nature from the past, primarily divided into two distinct types: on one side are major US-based tech companies; on the other, Chinese firms that are predominantly state-run.

Geopolitical competition over the contours of the cable network, which both focuses on where new cables can be laid, and on who gets to own and operate them, has intensified in recent years, with national security concerns increasingly driving decisions about cable routes and suppliers. This securitisation of the cable domain has now started to rewire the global network itself, as countries seek to insulate their vital communication links from being weaponised, while simultaneously increasing their influence over others'. Over time, such developments risk fragmenting not just the global cable network, but could contribute to splintering the global, open internet itself into separate, bifurcated spheres.

This chapter explores the increasing entanglement between the geoeconomic, geopolitical and security-led forces driving the global undersea cable network's development and outlines how Europe – now frequently a bystander in battles over global connectivity – can set out its own, third way in the cable domain.

A Market Transformed

The global undersea cable network had since the end of the Cold War been governed by a relatively small, close-knit community of specialised cable-laying and telecommunications companies, which together coordinated the financing, laying, maintaining and operating of cables. The entrance of two new actors into the cable sphere would upend this old order, and would over time begin to pull a previously technocratic and insular industry into the broader geostrategic competition between China and the United States.

One set of new actors were the hyperscalers, the largely American cloud giants, such as Google, Amazon and Meta, which from 2010 onwards increasingly began to fund and own their own submarine cables,⁵ and have become an increasingly dominant force in the market.

The second set of new actors were Chinese-state linked cable companies such as Huawei Marine Networks (later HMN Tech),⁶ which around the same time began to grow their own footprint in the global cable industry, relying heavily on Chinese state subsidies and foreign policy vehicles such as the Belt and Road initiative (BRI) to extend China's global reach.⁷

The growing involvement of these two new players not only upended the economics and business models of the existing cable industry, they would also increasingly come to serve as exponents of their respective governments' wider geopolitical ambitions.

China's Rise as a Cable Player

China has emerged as an important player in the global subsea cable landscape, leveraging its growing innovation ecosystem and manufacturing base to build a largely indigenous cable supply chain that serves both its economic and geopolitical goals. Beijing initially focused on expanding its own direct network and links, through laying terrestrial links to the countries directly on its borders, and increasingly also the laying of submarine cables in its wider neighbourhood. China's cable expansion has increasingly moved further afield. Central to this effort is the strategic use of its state-backed firms, which have played a leading role in constructing China's domestic cable

⁵ W. Patalon III, "Google Joins Consortium Planning High-Speed Undersea Cable to Asia", *Money Morning*, 27 February 2008.

⁶ New Build

⁷ S. Rahman, "The cable ties to China's Digital Silk Road", *Lowi Institute, theinterpreter*, 29 April 2024.

system and extending frequently highly-subsidised connectivity throughout the Global South. Many of these projects have been advanced under the umbrella of the Digital Silk Road,⁸ the digital arm of the BRI, which has served as a vehicle for growing China's global market reach as well as soft power.

One of the “crown jewels” in China's expanding cable network is the PEACE (Pakistan and East Africa Connecting Europe) cable,⁹ China's biggest cable system yet, which links the country to Africa and Europe via the Red Sea. Though nominally a commercial project, the PEACE cable is widely considered to be an instrument for China's geopolitical ambitions, showcasing its prowess as a serious player in the cable realm and enabling it to control data flows to the countries in which the cable lands, including in Europe. There are also suggestions that the PEACE Cable serves a more directly dual-use purpose – connecting as it does to Djibouti, the site of China's first overseas military base.¹⁰ Through the Digital Silk Road and other investments, China's national cable champion HMN Tech was able to secure a growing share of the global cable market, and would begin to challenge the traditional “Big Three” cable-laying companies: France's ASN, Japan's NEC and the US's SubCom. By 2019, the company would account for around 18% of the market,¹¹ a remarkably rapid growth.

Soon, this rapid rise would begin to invite scrutiny however, particularly from the United States. Washington has raised repeated concerns that Beijing's cable activities serve a “dual-use” purpose, and are intended to strengthen the People's Liberation Army (PLA)'s global reach. The US has also warned that the traffic moving through Chinese cables can be interfered

⁸ S. Patil and P. Gupta, “The Digital Silk Road in the Indo-Pacific: Mapping China's Vision for Global Tech Expansion”, Observer Research Foundation (ORF), 3 January 2024

⁹ <https://www.submarinenetworks.com/en/systems/asia-europe-africa/peace>

¹⁰ “Djibouti hosts first Chinese overseas military base”, *Africanews*, 13 August 2024.

¹¹ J. Brock, “U.S. and China wage war beneath the waves - over internet cables”, *Reuters*, 24 March 2023.

with – in situ, or at landing stations –,¹² and may be susceptible to backdoors being built into the hardware. This influence can also be more insidious, with suggestions that subsidised digital infrastructures, such as submarine cables, serve as a “Trojan horse” of sorts, through which China can export its wider techno-surveillance model for the global internet,¹³ ranging from the adoption of technological norms and standards to the export of surveillance technologies to Belt and Road recipient countries. As a result, Chinese subsea cable drive is increasingly viewed not only through the lens of economic competition, but as part of a broader contest over “digital hegemony” in an increasingly contested global order.

Moreover, Chinese researchers unveiled a “first-of-its-kind” compact,¹⁴ deep-sea cable-cutting device capable of disrupting critical undersea networks, in February 2025. This tool, which can sever cables at depths of up to 4,000 metres, has been developed by the China Ship Scientific Research Centre (CSSRC) to operate with China’s advanced submersibles. Although it was presented as a machine for civilian salvage operations and seabed mining, its potential dual-use application has raised concerns about the risk of using it to sever cables near critical chokepoints, thus effectively threatening the stability of global communications.

The United States and the Hyperscalers

From semiconductor export controls to restrictions on Huawei 5G infrastructure: the growing geopolitical rivalry between the United States and China is increasingly being mediated through the highly-strategic technology and digital infrastructure realm.

¹² [Undersea Telecommunication Cables: Technology Overview and Issues for Congress](#), Congress.gov | Library of Congress, 13 September 2022.

¹³ T.S. Eder, “Networking the “Belt and Road” - The future is digital”, *Merics*, 28 August 2029.

¹⁴ S. Chen, “China unveils a powerful deep-sea cable cutter that could reset the world order”, *South China Morning Post*, 22 March 2025.

Undersea cables are increasingly at the forefront of this contest. Starting with the first Trump presidency,¹⁵ successive US administrations have taken steps, as part of a broader strategic de-risking and de-coupling, to limit China's expanding role in global connectivity networks. These efforts are in part driven by national security concerns, but commercial interests and geopolitical leveraging also play no small part in this strategy. Washington's emerging approach to curtailing the global reach of Chinese cable suppliers appears to follow a three-pronged approach.

First, there are direct interventions to block cable projects involving US entities which either involve Chinese ownership or cable-laying, or land in China's direct sphere of influence. The most famous example of Washington flexing its regulatory muscles in this way was the Pacific Light Cable Network (PLCN), a transpacific system, which would connect the US to South-East Asia. The PLCN, which relied on significant backing from both Meta and Google, was originally intended to include a landing station in Hong Kong – this became highly controversial, however, in the wake of the city state's passing of its contentious National Security Law. The project was put to a halt after a US security review by Team Telecom raised concerns about the risk of data travelling through the cable being intercepted by Chinese authorities.¹⁶ This incident set a precedent for the US to oppose cable systems deemed susceptible to Chinese state influence, and has effectively made it impossible for US companies to invest in cables involving Chinese manufacturers or landing stations.

A second, more proactive strand, involves the US not just blocking new cables in China's influence sphere, but also countering Chinese cable projects by offering its own, subsidised, alternatives. These attempts at cable diplomacy

¹⁵ United States Department of State, [The Clean Network](#).

¹⁶ United States Department of Justice, Office of Public Affairs, [Team Telecom Recommends that the FCC Deny Pacific Light Cable Network System's Hong Kong Undersea Cable Connection to the United States](#), 17 June 2020.

frequently rely on close cooperation with allies like Australia and Japan, which offer up their own co-financing to counter Belt and Road projects, especially in geographies where China seeks to grow its military and economic influence, such as in the Pacific Islands.¹⁷

A third pillar focuses on laying new cables that seek to avoid major chokepoints and areas of vulnerability altogether. A key enabler of this strategy is the dominance of the US-based hyperscalers – such as Google, Amazon, and Microsoft – which now account for an estimated 71% of global subsea cable capacity and are involved in 60% of new cable investments.¹⁸ These firms have evolved from being primarily key buyers of connectivity to highly-strategic and increasingly geopolitically-driven cable owners, which allow them to play an increasingly central role in shaping the contours of the global network. Their growing influence over global digital infrastructure by extension allows the US government to grow its own hold over global data flows and provides Washington with a powerful tool to constrain China's room to manoeuvre. The recently announced Waterworth cable,¹⁹ a fully Meta-owned and funded cable project, which at 50,000 kilometers will be the world's longest, will touch on five continents – connecting Australia, via India, South-Africa and Brazil, to both the US west and east coasts – entirely bypassing the traditional routes through the Red Sea, Europe, and the South-China Sea.

Washington's multipronged strategy to limit China's reach in the undersea cable domain has so far proven quite effective. By leveraging both the US own role and control over vital global infrastructures, as well as the growing indispensability of its hyperscalers in global cable supply chains, it has been able

¹⁷ C. Packham “[Australia to use aid funds to build internet connections for two Pacific nations](#)”, *Renters*, 8 May 2028.

¹⁸ L. Dobberstein, “[Hyperscalers tying up the world in submarine cables](#)”, *The Register*, 25 September 2024.

¹⁹ S. Moss, “[Project Waterworth: Meta announces world's longest subsea cable project spanning five continents](#)”, *DCD*, 14 February 2025.

to get other countries across the world to follow its example. HMN Tech's star is now indeed waning – with its market share in future projects down to 4%.²⁰

Europe Caught in the Middle

Unlike in many other layers of the technology stack, Europe continues to play a significant leadership role in the global undersea cable domain. Alcatel Submarine Networks (ASN), which is now majority-owned by the French government, is still the largest cable company.²¹ Europe also has its own domestic champions across other key areas of the cable supply chain, from its own fibre optic cable manufacturers, to repair ship capacity, to a large – arguably too fragmented²² – web of telecommunications companies.

The European Union has turned this prowess in the cable industry into a strategic tool for furthering Europe's global influence. The Global Gateway Initiative,²³ launched in 2021 as Europe's answer to the Belt and Road initiative, seeks to mobilise upwards to €300 billion in investments in global infrastructure projects by 2027. The roll-out of submarine cables play an important role in this strategy. So far, the EU has committed almost 1 billion worth of investment in new cable projects, with projects ranging from cables connecting through the Black Sea to the Mediterranean and the Caribbean. While Global Gateway has quietly emerged as a significant force in the funding of undersea cables in the development sphere, the initiative currently still lacks the name-recognition and strategic focus that made the BRI so effective.

²⁰ [Subscribe to the Financial Times](#)

²¹ S. Besch and E. Brown “Securing Europe's Subsea Data Cables”, Carnegie Endowment for International Peace, 16 December 2024.

²² [The Draghi report on EU competitiveness](#)

²³ [Global Gateway - European Commission](#)

A second challenge for Europe faces in the undersea cable sphere is its lack of hyperscalers or other major players which can match the investment levels provided by the American giants. Submarine cables are highly-strategic infrastructures and key enablers of the digital economy, but owning and running them is not an especially profitable business in its own right – meaning traditional funders of new cables, such as large telecommunications companies, find it increasingly difficult to compete in the market. Hyperscalers, instead, make most of their profits higher up in the technology stack, notably in the cloud sphere, which enables them to make the kind of multi-billion investments required to make a project like Waterworth happen. While the hyperscalers' footprint in especially the most ambitious, geopolitically-significant project grows, Europe's is instead at risk of waning – leaving the continent very beholden to American cable investments and by extension geostrategic calculus in route planning and data management.

As the transatlantic relationship continues to fray, Europe's dependence on hyperscaler-owned cables becomes a potential leverage point that could be used against it – mirroring similar concerns about Europe's digital sovereignty in other layers of the technology stack.

Recommendations

The European Commission is increasingly cognisant of this risk, and has taken important steps towards strengthening Europe's heft and strategic autonomy in the undersea cable space, with the EU's Action Plan²⁴ a particularly key document giving substance to the EU's strategy in this domain. Other upcoming policy communications, such as the EU's forthcoming External Tech Strategy,²⁵ offer an opportunity to translate the

²⁴ European Commission, [Joint Communication to strengthen the security and resilience of submarine cables, Shaping Europe's digital future](#).

²⁵ European Commission, [EU seeks input on its future external digital policy](#),

recommendations set out in the Action Plan, and fill remaining gaps. In particular, priority should be on:

- **Further strengthening Europe's cable diplomacy toolbox:** the Global Gateway initiative has helped bring cohesion and ambition to the European Union's cable diplomacy efforts, but more can be done to bring geographical focus to these efforts and to use this mechanism as a vehicle for selling a European model for connectivity. Europe has an opportunity to now seize the vacuum left by the U.S. retreat from the global stage, for example its defunding of USAID, and growing concern about the reliability of its systems and articulate a more compelling, outward-facing vision for its own technology.
- **Build resilience through increasing redundancy:** The European Commission should continue to build partnerships and provide funding for cable projects that can help remove weak spots from the cable network, and diversify routes. Redundancy remains the single best remedy for ensuring secure connectivity. Laying additional undersea cables does not only help bring more resilience in the network, but also serve a commercial and geoeconomic purpose – these goals should be seen as operating in tandem.
- **Further embed subsea cables into Europe's digital sovereignty strategy:** To enhance its strategic autonomy in the tech sphere, Europe must not only continue to strengthen its position in cable manufacturing but also develop alternative business models, or potentially cultivate its own sovereign cloud giants, that can help counter the dominance of hyperscaler investment flows into the cable domain.

15. Beyond Subsea Cables: How Satellites Strengthen Global Communication Networks

Clelia Iacomino

The Quiet Revolution Under the Sea: Submarine Cables and the Future of Connectivity

In recent years, the submarine fiber optic cable network has seen rapid expansion, becoming the key infrastructure for global data traffic. These cables, laid on the ocean floor, stretch across thousands of kilometers and enable ultra-fast transmission capabilities, connecting continents and powering essential digital services such as cloud computing, streaming, and international communications.

Since 2020, there has been a significant acceleration in the construction of new infrastructure: over 25% of the cables installed since 2010 were activated between 2020 and 2024. This trend is expected to continue, with at least 68 new cables projected to be installed by 2027. Supporting this growth is the massive surge in data generated and stored globally, estimated at around 337,080 petabytes (PB) per day. Despite the rise of satellite communication, more than 95% of international data traffic still flows through submarine cables.¹

¹ P. Anastasio, “[Minaccia ai cavi sottomarini e nuove tecnologie satellitari](#)”, *Key4Biz*, 6 January 2025.

Major tech companies such as Google, Meta, Amazon, and Microsoft have intensified their investments in this sector, aiming to strengthen connectivity between their global data centers, reduce reliance on third-party operators, and enhance the performance of their digital services. Projects like Grace Hopper, 2Africa, and Marea are just a few examples of the new race toward undersea digital infrastructure.²

Unseen Battlefields: Submarine Cables and the New Geopolitical Front Line

In recent years, submarine cables have emerged not only as vital infrastructure for global connectivity but also as strategic assets vulnerable to both accidental damage and deliberate attacks. As geopolitical tensions rise and digital dependence increases, incidents affecting undersea cables are drawing more attention from governments, security analysts, and telecom operators. In today's highly interconnected world, submarine communication cables have become strategic targets in geopolitical conflicts. Recent events in the Red Sea have underscored just how vulnerable this infrastructure could be. In early 2024, four major undersea cables – AAE-1, EIG, Seacom, and TGN – were reportedly disrupted between Saudi Arabia and Djibouti. Although there has been no official confirmation, it is suspected that fighters from Yemen's Houthi movement were responsible. According to reports, an anchor from a Houthi-sunk vessel may have caused the damage, reinforcing the idea that these cables are no longer seen as passive infrastructure, but rather as critical assets at risk during times of conflict.³

² A. Gili and L. Favarotto, “[Cavi sottomarini: le nuove ‘autostrade’ dei dati](#)”, Commentary, ISPI, 6 December 2025; B. Koley, “[Announcing the Grace Hopper subsea cable, linking the U.S., U.K. and Spain](#)”, BLOG, Google cloud, 28 July 2020.

³ J. Huggins, “[Global communications are under attack - optical satellite networks can bolster them](#)”, *SpaceNews*, 13 March 2024.

This case highlights that the global internet backbone might turn out to be fragile. While intentional sabotage is alarming, even routine disruptions – caused by ship anchors, fishing activities, or natural disasters – can take place. On average, there are nearly 200 cable disruptions per year.⁴The recent Red Sea incident should serve as a wake-up call for both governments and private companies to further protect cables, while considering to invest in alternative or backup connectivity solutions, including satellite-based systems.

Table 15.1 provides a summary of some of the most significant submarine cable disruptions reported over the past decade, highlighting both conflict-related sabotage and accidental damage.

TAB. 15.1 - MAJOR SUBMARINE CABLE DISRUPTIONS – PAST 10 YEARS

Year	Location	Event
2013	Egypt	Attempted cutting of the SEA-ME-WE 4 cable by divers near Alexandria.
2015	Yemen	FALCON cable disrupted during military conflict.
2017	Somalia	EASSy cable damaged, causing nationwide internet outage for weeks.
2022	Faroe Islands & Shetland	Cables damaged under suspicious circumstances – possible sabotage suspected.
2023	Taiwan Strait	Multiple cables damaged, reportedly by Chinese vessels.
2023	Baltic Sea	Cables connecting Finland, Sweden, and Germany damaged; investigations pointed to sabotage.
2024	Red Sea	AAE-1, EIG, Seacom, and TGN-EA cables disrupted – suspected involvement of Houthi movement.

Source: author's elaborations on multiple sources.

⁴ [Submarine cable resilience](#), ITUCouncil, Geneva 2025.

What Are the Alternatives to Mitigate the Risks Associated with Undersea Cabling? Do Satellite Systems Serve as a Replacement or a Complement?

In recent years, systems like Elon Musk's Starlink, which currently provides coverage to over 70 countries – including Ukraine and, reportedly, Russia – have helped popularize the use of satellite-based internet. However, while radio frequency (RF) satellite connectivity such as that offered by Starlink represents a valid alternative for end-user access, it comes with inherent physical limitations. Transmission speeds remain significantly lower than those delivered by submarine fiber-optic cables, which ensure reliable, high-capacity data flows across continents. Moreover, although Starlink reduces dependence on terrestrial infrastructure for local access, it still relies on traditional internet backbone networks to route data between different regions – networks that include the very submarine cables recently cut in the Red Sea.

A more promising alternative is the development of Optical Ground Station (OGS) networks, which utilize laser communication to transmit data between satellites and ground terminals. These systems can achieve transmission speeds of up to 100 gigabits per second, over 1,000 times faster than traditional satellite RF links. Laser technology for satellite-to-satellite and ground-to-space communication is now mature and offers a resilient, high-performance supplement to undersea cables – especially relevant in times of geopolitical instability.⁵

OGS networks also offer significant advantages in terms of geographic flexibility. Unlike cables, which are tied to fixed routes and physical landing points, optical communication networks can leverage satellite mesh architectures deployed in geopolitically stable and accessible areas, close to terrestrial infrastructure. While the absolute latency of fiber-optic cables

⁵ Huggins (2024).

remains lower due to light traveling through glass in a straight path, optical satellite networks can reduce end-to-end latency in specific scenarios – for instance, by shortening the number of terrestrial hops, bypassing congested networks, or directly linking remote regions without intermediate infrastructure.⁶ Moreover, laser beams are highly secure: their narrow focus makes them extremely difficult to intercept – only within approximately 12 meters of the beam – making any attempted intrusion easily detectable and preventable through basic monitoring.

Previously, a major limitation of optical communication was its sensitivity to atmospheric conditions such as turbulence, temperature variations, wind, and humidity, which could degrade the signal. However, recent technological advancements have effectively addressed these issues, enabling stable laser communication even in variable environmental contexts.

In this context, private companies have played a key role in accelerating the development of OGS networks. Among the most active players is Mynaric, a German company leading the production of laser terminals for both commercial and defense applications. Another German firm, Tesat-Spacecom, is a key supplier for the European Space Agency and various low-Earth orbit (LEO) constellations⁷. In the U.S., BridgeComm is building a global network of optical ground stations to enable ultra-fast, secure communications. Meanwhile, SpaceX has begun integrating inter-satellite laser links into its latest generation of Starlink satellites, further reducing reliance on ground infrastructure. In Europe, organizations such as TNO and Airbus are pushing forward advanced optical

⁶ A. Chaudhry and H. Yanikomeroglu, *Optical Wireless Satellite Networks versus Optical Fiber Terrestrial Networks: The Latency Perspective - Invited Paper*, June 2021

⁷ “Mynaric selected by Raytheon Technologies to supply optical communications terminals for SDA Tranche 1 Tracking Layer program”, *SpaceNews*, 22 June 2023; *Optical Ground Stations for PIXL-1, TESAT*, 3 February 2021; <https://bridgecomminc.com/>.

communication technologies under programs like Scylight, aimed at ensuring ultra-secure, resilient connectivity even in unstable geopolitical environments. This technological momentum signals that optical space communication may become a key pillar of the future global network infrastructure.⁸

TAB. 15.2 - COMPARATIVE OVERVIEW OF LONG-DISTANCE CONNECTIVITY SOLUTIONS

Feature	Submarine Cables	LEO Satellite Internet	Optical Ground Station (OGS)
Data Speed	Very High (Tbps)	Medium (Gbps)	High (up to 100 Gbps)
Latency	Very Low	Medium-High	Low
Coverage	Coastal and urban areas	Global, including remote regions	Selective (based on satellite mesh & ground stations)
Resilience to Attacks	Lower (vulnerable to sabotage & accidents), but redundancies help limit the impact on the service	High (in space, harder to attack)	Very High (difficult to intercept laser links)
Implementation Time	Long (years to deploy)	Fast (months)	Medium (depending on infrastructure)
Cost	High (but efficient over time)	High (deployment & satellite launch)	High initial cost, scalable
Security	Moderate (cables can be tapped)	Moderate	Very High (laser signals hard to intercept)
Geopolitical Vulnerability	High (must pass also through territorial waters)	Medium	Low (flexible satellite deployment)
Stage of Maturity	Fully mature	Commercially mature	Emerging / rapidly maturing

⁸ J. Roulette, “[SpaceX to sell satellite laser links that speed in-space communication to rivals](#)”, *Reuters*, 19 March 2024; “[Airbus and TNO to develop aircraft laser communication terminal](#)”, *Airbus*, 8 April 2021.

Europe at a Crossroads: Can Iris² Compete in the New Space Race?

Satellites are not intended to replace terrestrial infrastructure such as fiber-optic cables or mobile networks. Instead, they serve a complementary role, enhancing global connectivity by adding resilience and extending coverage to remote or underserved areas. Their integration with ground-based systems is crucial, particularly for ensuring connectivity during emergencies when terrestrial infrastructure may be compromised or unavailable.

As Eva Berneke, CEO of Eutelsat, stated, “Convergence with terrestrial networks is absolutely fundamental to the future of the satellite telecommunications industry” (Kratos Defense).⁹ This hybrid approach between satellite and terrestrial networks is not only a technical evolution, but a strategic necessity. The utility of non-terrestrial networks (NTNs) was made especially clear during the war in Ukraine, where satellite systems helped sustain communication despite damaged infrastructure.

In this context, IRIS² (Infrastructure for Resilience, Interconnectivity and Security by Satellite) is the European Union’s strategic response to increasing reliance on non-European space infrastructures for critical communications. The constellation will consist of 292 satellites: 264 in low Earth orbit, 10 in higher altitudes, and the rest in medium orbit. This hybrid and interconnected configuration is designed to provide wide and redundant coverage without requiring the deployment of thousands of LEO satellites, as seen with Starlink. Unlike the U.S. model, IRIS² is not aimed at global commercial service but at ensuring secure, reliable, and resilient communications for governments, agencies, and critical European infrastructure. The total investment for the IRIS² project is estimated at €10.6 billion. Funding is structured through a Public-Private Partnership (PPP), with €6.5 billion sourced from public funds

⁹ “The new age of IoT: 5G terrestrial and satellite networks working together”, *Smart Water Magazine*, 30 September 2024.

– including €550 million from the European Space Agency (ESA) – and over €4 billion contributed by private industry partners.¹⁰

Complementing IRIS², the GOVSATCOM constellation – expected to launch starting in 2026 – will operate in geostationary orbit and serve institutional and defense needs across the EU. It will work alongside national programs such as Italy’s SICRAL. However, the European vision comes with political and operational complexities. Currently, only 25% of IRIS²’s capacity is earmarked for governmental use, with the remaining 75% to be commercialized – potentially even to the same public institutions that the system is meant to serve. This raises valid concerns about the infrastructure’s real strategic autonomy.

The SpaceRise consortium, which leads the IRIS² initiative, includes SES, Eutelsat, and Hispasat. Notably, Airbus and Thales Alenia Space, two major European aerospace players, are only listed as subcontractors. This reflects ongoing industrial tensions within the European space ecosystem and a broader lack of unified strategic direction on the global stage.

Meanwhile, across the Atlantic, US dominance in satellite technology continues to strengthen. SpaceX has already deployed inter-satellite laser links in its Starlink constellation, enabling a low-latency, autonomous network increasingly relevant for defense and commercial sectors. Simultaneously, China is rapidly scaling up: backed by the government, SpaceSail aims to launch 648 LEO satellites in 2025 and up to 15,000 by 2030. In 2024 alone, China launched a record 263 LEO satellites and is investing heavily in multi-satellite launch systems and constellation-tracking technologies, including those with military applications (Reuters).¹¹

¹⁰ European Commission, [EU space policy - space-based secure connectivity initiative](#).

¹¹ J. Sensi, “[Starlink competition intensifies as China and Amazon invest in space](#)”, *Capacity media*, 24 February 2025.

Amid this intensifying technological and geopolitical competition, Europe stands at a crossroads. With IRIS² not expected to become operational until 2030, questions are emerging about whether the continent can afford to wait. Some member states are already exploring bilateral pathways to accelerate access to critical capabilities. Italy, for instance, has shown increasing interest in closer ties with the US in the space sector. A notable example is Prime Minister Giorgia Meloni's recent interactions with Elon Musk, including official meetings focused on innovation and security. This dialogue could open the door to a bilateral technological partnership between Rome and Washington, potentially granting Italy faster access to cutting-edge capabilities. Yet such a move could also challenge the idea of European sovereignty in space and highlight the fragility of a cohesive EU approach. However, tensions between Musk and President Trump escalated sharply in early June 2025, following Musk's public criticism of Trump's legislative agenda and subsequent personal accusations. This fallout has contributed to uncertainty about Italy's potential technological partnerships.

The question now is: can Europe afford to wait? The global competition is intensifying – actors around the world are rapidly populating low Earth orbit, and telecommunications systems are becoming increasingly strategic, not only for economic development but also for military and security purposes.

If IRIS² aims to compete on a global scale, the lack of strong European-level integration risks making it uncompetitive. Outdated technologies, fragmented governance, and operational delays could discourage private investment and hinder scalability. To mitigate these risks and attract capital, IRIS² should explore the use of hybrid financial instruments – such as convertible bonds or preferred equity – as a way to balance risk and optimize the capital structure. Combining the stability of debt with the flexibility and innovation incentives of equity would strengthen the project's financial foundation.

Moreover, transitioning gradually from a fully concession-based model to one that allows for greater private sector participation would reduce dependence on public funding. This evolution would encourage private stakeholders to take a more active role in IRIS²'s development and operations, ultimately fostering a more dynamic, innovation-driven ecosystem.

By building a balanced financial framework and promoting collaboration across public and private sectors, IRIS² can emerge as a flagship European project – driving growth, resilience, and technological sovereignty in the space domain.

In the XXI century, a secure and autonomous communications network is as strategically vital as energy supply. And today, more than ever, time has become a geopolitical variable that Europe can no longer afford to overlook.

16. Cables, Pipelines, and Power: International Laws Governing Critical Marine Infrastructure

Roxana Vatanparast

In November 2024, two cables in the Baltic Sea linking Finland and Germany were damaged within 24 hours. Sweden, Germany, and Lithuania launched criminal investigations as a result, seeking information from the Chinese bulk cargo carrier Yi Peng 3, a ship with coordinates that matched the location of the cables at the time of the breaches.¹ While US Naval Intelligence thought the cuts were accidental, German Defence Minister Boris Pistorius claimed they were sabotage.² The ship had landed in Russia before entering the Baltic Sea and the captain was Russian, sparking concerns that the cable breakages were a form of Russian “hybrid warfare”. The Chinese flagged Yi Peng 3 remained anchored off the coast of Denmark for several weeks after the cable damage, pending investigation.³ The cable breakages raised concerns about sabotage, since the 2022 explosions of the Nord Stream gas pipelines in the Baltic Sea running from Russia to Germany, though still officially unsolved, have likewise been attributed by some to Russian actions.⁴ These

¹ “Sweden Urges Chinese Ship to Return for Undersea Cable Investigation”, *Reuters*, 27 November 2024.

² *Ibid.*

³ M. Schwirtz and H. Pryser Libell, “Chinese-Flagged Ship Suspected of Cutting Cables Remains Halted Weeks Later”, *The New York Times*, 12 December 2024.

⁴ R. Milne, “Germany and Finland ‘Deeply Concerned’ about Severed Undersea

incidents reveal the vulnerabilities of critical infrastructure to intentional damage, and show how concerns around undersea critical infrastructure reflect geopolitical tensions.

99% of global capital, communications, and data are transmitted via undersea telecommunication cables,⁵ and an estimated \$10 trillion in daily financial transfers are dependent on them, making them critical for the global economy and communications.⁶ The Internet and the global digital economy cannot function without them. Cables are also critical from a security perspective, due to the sensitivity of communications that can be intercepted through them, and the reliance of governments on them for communications, including diplomatic cables and military orders.⁷ Undersea pipelines transport crude oil and natural gas extracted from the ocean floor for large-scale energy production. Submarine power cables are an increasingly important component of the global power grid due to increased demands for clean electricity. In recent years, there has been significant investment in the construction and growth of undersea infrastructure networks. This is due to increased demands for data by hyperscalers such as Amazon, Meta, and Google, growth in global Internet usage and data-intensive artificial intelligence models, the transmission of power over longer distances from offshore renewable energy sources, and increased extraction of oil and gas from the ocean floor.

Due to their significance, undersea gas pipelines, power cables, and telecommunication cables (collectively, Critical Marine Infrastructure or CMI) are critical and vulnerable infrastructure that impact global security, economic activity,

Cable”, *Financial Times*, 18 November 2024.

⁵ D. Main, “Undersea Cables Transport 99 Percent of International Data”, *Newsweek*, 2 April 2015)

⁶ R. Vatanparast, “The Infrastructures of the Global Data Economy: Undersea Cables and International Law”, *Harvard International Law Journal Frontiers* vol. 61, 2020.

⁷ C. Wall and P. Morcos, “Invisible and Vital: Undersea Cables and Transatlantic Security”, Center for Strategic and International Studies (CSIS), 11 June 2021.

and international law. Their location under the sea renders them subject to international legal regimes, such as the Law of the Sea, as well as coastal state regulations. They are vulnerable to intentional and unintentional damage as critical chokepoints of global energy and communications; they present unique security risks and are subjected to geopolitical contestation as critical infrastructure. Yet international legal regimes concerning Critical Marine Infrastructure face limitations due to their complex ownership structures, the role of non-state actors, difficulties with state attribution, and the lack of express prohibition of intentional damage to CMI.

This contribution will outline some of the international legal principles applicable to CMI generally, focusing on the Law of the Sea as reflected in the 1982 United Nations Convention on the Law of the Sea (UNCLOS). It will also discuss laws applicable to the damage of CMI, as well as their limitations. In light of these limitations, the contribution will also discuss alternative governance structures and institutions that play an important role in the distribution of rights and duties in this domain, including international and regional voluntary cooperation arrangements, private law regimes, and increased securitisation, surveillance and militarisation of the seas, with NATO taking on a prominent role in areas of geopolitical tension, such as the Baltic Sea.

International Law on Critical Marine Infrastructure

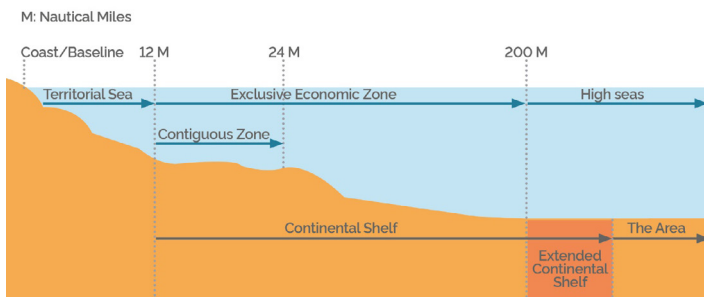
The Law of the Sea

UNCLOS was adopted in 1982,⁸ building on the foundation of prior international conventions, such as the 1884 Cable Convention, and the 1958 Geneva Convention on the High

⁸ UN Convention on the Law of the Sea, opened for signature 10 December 1982, 1833 U.N.T.S. 397 (entered into force Nov. 16, 1994) [hereinafter UNCLOS].

Seas and Continental Shelf (High Seas Convention). The international legal frameworks governing Critical Marine Infrastructure under UNCLOS differ based on their location within the distinct maritime zones identified in it. The first distinction for determining applicable legal regimes is between areas within national jurisdiction and areas beyond national jurisdiction (ABNJ). The territorial sea, contiguous zone, exclusive economic zone, and continental shelf are areas within national jurisdiction, while anything beyond 200 nautical miles is ABNJ and therefore considered as high seas. As will be discussed next, each of these maritime zones has a distinctive legal regime under UNCLOS, with different rights, duties, and limits to coastal state sovereignty and jurisdiction.

FIG. 16.1 - MARITIME ZONES UNDER THE INTERNATIONAL LAW OF THE SEA⁹



Source:
Adapted from Danish Energy Agency (2021) and Collins and Schomäcker (2022)

⁹ Image source: “[About ECS](#)” (United States Department of State, no date).

The Territorial Sea and the Contiguous Zone

UNCLOS provides that the sovereignty of states extends into territorial waters, defined as up to 12 nautical miles from the baseline.¹⁰ Coastal state jurisdiction extends to the contiguous zone, up to 24 nautical miles from the baseline.¹¹ Coastal states enjoy full state sovereignty over the territorial sea, meaning that coastal state regulations are applicable within these areas and the laying of CMI will require permissions from the coastal state, most often in the form of landing licenses. In areas within the territorial sea of a state, the coastal state must consent to the laying of cables and pipelines, and may restrict those actions according to its domestic regulations.

Landing licenses are one way in which governments regulate undersea cables that land on their territories. In the United States, for example, cable operators seeking to land a cable must first obtain a landing license from the Federal Communications Commission (FCC).¹² Cable operators must disclose foreign ownership interests if foreign ownership exceeds 10% under the Communications Act of 1934.¹³ In instances where foreign ownership exceeds 10%, the FCC refers the applicant to national security agencies, informally called Team Telecom, which then make recommendations to the FCC.¹⁴

Due to the political and security concerns around telecom infrastructure developed by Chinese companies that are state-owned, cable projects by Chinese companies or touching territories subject to Chinese laws have been blocked by the United States. For example, the US Department of Justice partially blocked a project involving Google and Facebook's subsidiaries, the Pacific Light Cable Network linking the US,

¹⁰ UNCLOS, Artt. 2, 3.

¹¹ UNCLOS, Art. 33.

¹² U.S. Cable Landing Licenses Act (1921); Executive Order No. 10530 (1954).

¹³ U.S. Communications Act §310(b) (1934) (as amended).

¹⁴ J.C. Gallagher, "Undersea Telecommunication Cables: Technology Overview and Issues for Congress", Congressional Research Service, 13 September 2022.

Hong Kong, Taiwan, and the Philippines, due to security concerns of the cable landing in Hong Kong and being within China's reach. The decision was based on a recommendation from Team Telecom.¹⁵ The parties moved forwards by removing the Hong Kong connection.

Exclusive Economic Zone and the Continental Shelf

The exclusive economic zone (EEZ) is the area beyond and adjacent to the territorial sea that extends 200 nautical miles beyond the coastal state's baseline.¹⁶ States have exclusive rights to exploration and extraction of resources within their EEZ.¹⁷ States also have exclusive rights to mineral resources in the continental shelf, which is the seabed and subsoil of areas that are beyond the territorial sea but not beyond 200 nautical miles from the baseline.¹⁸

All states have the freedom to lay submarine cables and pipelines in the EEZ of coastal states, subject to their laws and regulations.¹⁹ UNCLOS also provides that all states are entitled to lay cables and pipelines on the continental shelf, but the delineation of cables is subject to the coastal state's consent.²⁰ Coastal states have the right to establish conditions for cables and pipelines entering their territories or territorial seas.²¹

The EEZ of coastal states can be subject to dispute, especially where the 200 nautical mile boundary line overlaps or intersects with other states' EEZs. This is particularly so in areas of

¹⁵ "Team Telecom Recommends that the FCC Deny Pacific Light Cable Network System's Hong Kong Undersea Cable Connection to the United States", United States Department of Justice, 17 June 2020.

¹⁶ UNCLOS, Artt. 55, 57.

¹⁷ UNCLOS, Artt. 56.

¹⁸ UNCLOS, Artt. 76, 77.

¹⁹ UNCLOS, Art. 58.

²⁰ UNCLOS, Art. 79.

²¹ Ibid.

geopolitical significance, such as the Mediterranean Sea. For example, in 2019, Turkey entered into an accord with Libya to renegotiate maritime boundaries.²² Some commentators claimed this was an attempt by Turkey to obtain a stronghold in the Mediterranean.²³ The accord was challenged by Greece, Cyprus, Egypt, and Israel as a violation of the Law of the Sea, and was later invalidated by a Court of Appeals in Libya. The Turkey-Libya accord prompted Egypt and Greece to enter into a maritime agreement to delimit EEZ boundaries.²⁴ In 2025, Turkey is purportedly attempting to increase its power in the Eastern Mediterranean through a deal with Syria to renegotiate maritime boundaries similar to its prior deal with Libya.²⁵

With the proliferation of gas and oil exploration and extraction from the ocean floor, there may be more disputes and negotiated agreements over EEZs and maritime boundaries between states to determine exclusive extraction rights in those areas.

The High Seas

ABNJ, or the high seas, are areas that are beyond the territorial seas and EEZs, and are not subject to any state's sovereignty.²⁶ The freedom of the high seas enjoyed by all states includes "the freedom to lay submarine cables and pipelines".²⁷ Article 112 of UNCLOS also ensures that all states have rights to lay cables and pipelines on the bed of the high seas beyond the continental

²² Memorandum of Understanding Between the Government of the Republic of Turkey and the Government of National Accord-State of Libya on Delimitation of the Maritime Jurisdiction Areas in the Mediterranean, UN.org, November 2019

²³ E. Badi and A. al-Jabassini, "Turkey's Syria and Libya Strategies Add up to a Mediterranean Power Play", Atlantic Council, 13 January 2025.

²⁴ N. Elhennawy, "Egypt, Greece Sign Maritime Deal to Counter Libya-Turkey One", *AP News*, 6 August 2020.

²⁵ Badi and al-Jabassini (2025).

²⁶ UNCLOS, Artt. 86, 89.

²⁷ UNCLOS, Art. 87(1)(c).

shelf.²⁸ In the high seas, coastal states may not restrict other states or their nationals from laying and maintaining cables.²⁹ As the cables themselves are not registered under any flag,³⁰ they are not subject to any one state's exclusive enforcement jurisdiction when those cables are located in ABNJ.

Under Article 113 of UNCLOS, states are required to adopt laws that make the intentional breaking or injury of a submarine cable or pipeline in the high seas by a person subject to its jurisdiction, including ships flying its flag, a punishable offense.³¹

Moreover, owners of submarine cables and pipelines that cause damage to other cables and pipelines while attempting to lay or repair their own must bear the cost of repairing the other cables and pipelines they damage.³²

Damage to Critical Marine Infrastructure

Undersea cables are vulnerable to breakage, damage, and destruction, for accidental and intentional reasons, as well as manmade and non-manmade causes. Disruptions can be caused by physical and digital vulnerabilities. Disruptions to the operation of a cable can occur as a result of shipping and fishing accidents, vessels dragging anchors, earthquakes, shark bites, and even intentional damage or disruption caused by

²⁸ UNCLOS, Art. 112.

²⁹ D.R. Burnett, "OSPAR and Coastal State Encroachment on High Seas Submarine Cable Freedoms", in K. Markus et al. (eds), *Sustainable Ocean Resource Governance: Deep Sea Mining, Marine Energy and Submarine Cables*, Brill | Nijhoff 2018. Limitations include "taking measures to avoid the possibility or prejudicing cable repair and due regard for other freedoms of the sea and activities conducted in the Area".

³⁰ D.R. Burnett, T.M. Davenport, and R. Beckman., "Introduction: Why Submarine Cables?", in Idem (eds), *Submarine Cables. The Handbook of Law and Policy*, 2014.

³¹ UNCLOS, Art. 113.

³² UNCLOS, Art. 114.

tapping cables, rerouting data, and cyber-attacks on network management systems.³³ In recent years, intentional damage has been a less common cause of cable damage than fishing accidents and geological events.

Existing international legal frameworks do not clearly prohibit intentional CMI damage or outline robust enforcement measures. UNCLOS, for example, does not explicitly prohibit states from intentionally damaging cables and pipelines in the high seas or in the territorial sea.³⁴ Moreover, UNCLOS grants sovereign immunity to warships and government ships operating for non-commercial purposes in the high seas and EEZ.³⁵ The only avenue of recourse for coastal states in the event of cable damage in the territorial sea that violates the coastal state's laws is to "require the warship to leave the territorial sea immediately".³⁶ UNCLOS also limits accountability by granting jurisdiction for the prosecution of intentional cable damage to the flag state, which may not be willing to pursue such claims. This limits recourse for intentional damage to cables.³⁷

While most damage to cables is not intentional or deliberate, the threat of deliberate damage poses significant security and economic risks. Nevertheless, challenges remain for cable damage to give rise to state responsibility, as state responsibility under international law requires that the conduct of a natural person or other intermediary be considered an "act of state".³⁸ The conduct of non-state actors can be attributed to states only

³³ R. Sunak, *Undersea Cables: Indispensable, Insecure*, Policy Exchange, December 2017.

³⁴ T.M. Davenport, "Intentional Damage to Submarine Cable Systems By States", Aegis Series Paper no. 2305, Hoover Working Group on National Security, Technology, and Law, Hoover Institution, 2023.

³⁵ UNCLOS, Art. 95 (applicable to the EEZ pursuant to UNCLOS, Art. 58(2)).

³⁶ UNCLOS, Art. 30.

³⁷ M. Cardillo, "Navigating International Law Safeguards for Submarine Cables: Charting a Course for Effective Protections", *Yale Journal of International Law*, vol. 49, no. 311, 25 September 2023.

³⁸ J. Crawford, *State Responsibility: The General Part*, Cambridge University Press, 2013, p. 113.

in limited circumstances, even if the vessel owners and operators responsible for damage are state-owned corporate entities.³⁹ These actors' conduct can be attributed to states only if the vessel owner or operator has been granted power to exercise "governmental authority" on behalf of the state, if the owner or operator is acting under the "instructions of, or under the direction or control" of the state, or if the state acknowledges the conduct as its own.⁴⁰

CMI ownership further complicates the issue of applying international law in this context. Telecommunication cables are usually owned by consortia of telecommunication companies that may include tech giants like Google or Microsoft, as well as state or state-owned entities, incorporated in different jurisdictions, or may have single entity ownership, such as Meta's recently announced Waterworth Project.⁴¹ Natural gas pipelines and power cables share similar ownership structures, with either consortium ownership models between gas or energy companies, telecommunication companies, and other investors, or single ownership models. In such cases, it is unclear which, if any, government would be considered the "injured party"⁴² if a cable or pipeline is cut, or how compensation could be pursued.

Moreover, extant international legal frameworks do not address attacks on cables by terrorists and pirates. UNCLOS Article 101(a)(ii) applies to piracy with regard to cables and pipelines, but no international legal instruments apply to hostile actions outside of territorial seas, which scholars have identified as one of the vulnerabilities in the current international governance of submarine cables.⁴³

³⁹ Davenport (2023), p. 7.

⁴⁰ International Law Commission, Report on the Work of Its Sixty-Fourth Session, UN Doc. A/56/10, at 26, 2001.

⁴¹ G. Nagarajan and A.-H. Aimé, "Unlocking Global AI Potential with Next-Generation Subsea Infrastructure", *Engineering at Meta*, 14 February 2025.

⁴² Davenport (2023).

⁴³ D.R. Burnett, *The 1884 International Convention for Protection of Submarine Cables*

Damage to three major undersea cables linking Europe and Asia in the Red Sea underlined the risks of conflicts in the Middle East and the role of non-state actors in impacting critical information infrastructure.⁴⁴ While concerns were centred around Houthi rebels potentially damaging the cables, the actual cause of damage was not clearly understood and the rebels denied all responsibility.⁴⁵ Still others claimed that the cable damage was due to the Houthi rebels attacking a vessel that sank.⁴⁶ The incident raised concerns regarding the potential impacts of regional conflicts on global communications.⁴⁷

The risks of cable damage have disproportionate impacts on emerging and developing economies in the Global South that may only have a single undersea cable providing digital connectivity. Tonga's only fibre optic cable connection was damaged by a volcanic eruption in 2022 and took five weeks to repair.⁴⁸ In 2017, Somalia lost connectivity for over three weeks due to a ship severing an undersea cable connecting the country, resulting in an estimated economic loss of \$10 million a day.⁴⁹ Moreover, if a country only has one cable landing station, then a breakage in the linked cable can affect its internet access, as well as internet access of other countries that link to that landing station. For example, in 2012, a ship anchor broke a cable linked to a landing station in Mombasa, Kenya, impacting internet access in six

Provisions Not in UNCLOS Deserve Attention Now, Squire Sanders - Legal Counsel Worldwide, 2011, p. 11.

⁴⁴ S. Reed, "[Damage to Cables Under Red Sea Highlights Mideast Conflict's Broader Threat](#)", *The New York Times*, 5 March 2024.

⁴⁵ Ibid.

⁴⁶ S. Monaghan, M. Darrah, E. Jacobsen, and O. Svendsen, "[Red Sea Cable Damage Reveals Soft Underbelly of Global Economy](#)", Center for Strategic & International Studies (CSIS), 7 March 2024.

⁴⁷ Reed (2024).

⁴⁸ T. Bateman, "[Cut off for 5 Weeks, this is What It Took to Restore Tonga's Internet](#)", *Euronews*, 23 February 2022.

⁴⁹ "[Somalia Joins Global Initiative to Protect Submarine Cables](#)", *Hiraan.com*, 1 December 2024.

countries in East Africa that were all linked to that cable and landing station.⁵⁰

These risks and limitations have led to calls for developing updated and comprehensive international legal frameworks to better protect CMI.

Alternative Governance Structures

While there have been many calls to update UNCLOS and related principles that apply to CMI to meet today's needs, there is no indication that they can overcome issues with attribution and the role of non-state actors in this domain. There are still other alternative governance structures that play an important role, whether changes to UNCLOS will be adopted or not. These include cable protection zones and regional cooperation, public and private international cooperation, private law regimes, and militarisation and securitisation involving the North Atlantic Treaty Organisation (NATO).

Some states, such as Australia, New Zealand, Colombia, Uruguay, and Denmark, have started taking innovative measures to protect cables that land in their territories by creating cable protection zones, or key areas where fishing, anchoring, and dredging are prohibited due to the risks those activities pose to undersea cables.⁵¹

Private, industry-led organisations also play an essential role in CMI governance, as illustrated by the International Cable Protection Committee (ICPC), which plays a central role in the governance and protection of undersea cables. The ICPC also plays a vital role in promoting international cooperation with international organisations.

⁵⁰ D. Thorat, "Colonial Topographies of Internet Infrastructure: The Sedimented and Linked Networks of the Telegraph and Submarine Fiber Optic Internet", *South Asian Review*, vol. 40, no. 3, 2019, pp. 252, 259.

⁵¹ D.R. Burnett et al. (eds), "Protecting Submarine Cables from Competing Uses", in *Submarine Cables: The Handbook of Law and Policy*, Martinus Nijhoff, 2013, pp. 275-76; G. Hinck, "[Evaluating the Russian Threat to Undersea Cables](#)", Lawfare, 2023.

In addition to the ICPC and regional cable protection committees, there are a number of private contractual agreements between companies in the CMI industry for cost sharing of protection and maintenance, such as the Atlantic Cable Maintenance Agreement,⁵² the Mediterranean Cable Maintenance Agreement,⁵³ and the Yokohama Zone.⁵⁴

Finally, the risk of cable damage and deliberate attacks on critical infrastructure is leading to increased securitisation, militarisation, surveillance, and monitoring of the seas. NATO responded to the Baltic Sea incident by intensifying surveillance operations in the Baltic and North Seas.⁵⁵ A recently formed Critical Undersea Infrastructure Protection Cell seeks to coordinate efforts among NATO members, private-sector cable owners, and other stakeholders.⁵⁶ In parallel, European countries are dedicating additional resources to enhance naval capabilities and install sensors on the seabed.⁵⁷ These securitisation measures reflect geopolitical concerns about Russian interference and sabotage of critical infrastructure in the region.

Conclusion

Critical Marine Infrastructure is essential to the global economy, energy transport, and digital connectivity. The vulnerability of Critical Marine Infrastructure to intentional and accidental damage highlights the centrality of this infrastructure to the global economy and security as well as the limitations of existing international legal frameworks in adequately addressing risks. Incidents such as the recent Baltic Sea cable

⁵² [Atlantic Cable Maintenance & Repair Agreement \(ACMA\)](#)

⁵³ [Mediterranean Cable Maintenance Agreement](#)

⁵⁴ [Yokohama Zone](#)

⁵⁵ Milne (2024).

⁵⁶ NATO, “NATO Stands up Undersea Infrastructure Coordination Cell“, no date.

⁵⁷ “Europeans Wade into Fighting Seabed Threats with Drones and Sensors“, *Defense News*, 9 January 2023.

breaches underscore how geopolitical tensions can exacerbate infrastructure vulnerabilities, raising challenges around state attribution, enforcement, and governance. Although UNCLOS provides foundational principles governing the rights and duties of states concerning undersea cables and pipelines, it does not explicitly prohibit intentional damage, and attribution issues arising from the conduct of non-state actors further complicate the application of international legal principles.

States and private actors have increasingly turned toward alternative governance structures, including public and private institutions, regional cooperative frameworks, private law regimes, and enhanced security and militarisation arrangements. While these initiatives may strengthen protective measures, protecting Critical Marine Infrastructure effectively will also require clearer international standards and more robust cooperation, especially given escalating geopolitical tensions and the increasing significance of these infrastructures to global economic and political stability.

REGIONAL CASE STUDIES

17. IMEC As a Modern Connectivity Blueprint. Challenges and Opportunities

Kabir Taneja

India's presidency of the G20 in 2023 was a pivotal moment for New Delhi as it looked to use the opportunity of hosting the leaders of the world's top 20 economic powers and simultaneously re-shaping a fast-evaporating post-World War II global order. India's push for multipolarity comes with an equitable push for economic expansion, integration and growth. These aims are central to both the country's domestic and foreign policy approaches.¹

A symptom of India's push for geoeconomic diversification can be seen in the announcement of the India – Middle East Europe Economic Corridor (or IMEC) announced on the sidelines of the G20 summit. Proposed as a new connectivity project bringing together the Indian sub-continent, Gulf partners in the Middle East and major Economies across the Mediterranean in Europe, the envisioned architecture has caught the imagination of both politics and business alike.

However, it is imperative to remember that connectivity projects, at the end of the day, are anchored in geopolitics. While trade, business and connections drive the economic agendas, promotion of the same are done via political decisions,

¹ J. Panda, "[India in a world of asymmetrical multipolarity](#)", Institute for Security and Development Policy, March 2023.

patronage, and leadership. Without political buy in, trans-continental trade traversing through multiple states and aiming to provide a cohesive and wholesome business environment is next to impossible. This is true for IMEC as well.

In addition to India, the partner states for IMEC, named in the Memorandum of Understanding (MoU) signed in September, include US, Saudi Arabia, the United Arab Emirates (UAE), the European Union, Italy, France and Germany.² The MoU states that the project comprises of two separate corridors: the eastern corridor between India and the Gulf, and the northern corridor connecting the Gulf to Europe. Interestingly, two of the other main partners envisioned for the project, Israel and Jordan, are yet to be inculcated in the MoU list. The marketable value for IMEC, or simply what differentiates it from other similar projects, such as China's Belt and Road Initiative (BRI), is that it aims to go well beyond just infrastructure and prioritises a wide gamut of interests ranging from cyber security to green hydrogen.

Impact of Geopolitics on the Economics of IMEC

Within a month of IMEC's announcement, the project was dealt a significant setback, adversely impacting its implementation well into 2025. The Hamas terror attack against Israel on 7 October 2023 came as a shock across the region. With hundreds killed and dozens taken hostage, many of whom have yet to be released, the geopolitics and psyche of the region was re-shaped within hours. The issue of Palestine, prior to October 2023, was on the backburner of most regional powers. This included Israel and its Arab partners. In September 2020, a group of Arab powers led by the UAE normalised political relations with Israel, marking a major change to how the Middle East has developed and operated over the decades. IMEC is a by-product

² “Memorandum of Understanding on the Principles of an India – Middle East – Europe Economic Corridor”, The White House, 9 September 2023.

of the Accords, the latter being seen by a large section of the international community as a rare opportunity to shift the conflict-ridden discourse that has become synonymous with the region.

India's Prime Minister Narendra Modi has called IMEC a "key catalyst of commerce, connectivity, and growth in the entire region".³ Saudi Arabia's own story of remoulding the Kingdom's trajectory and looking to open it up for foreign investments and industries beyond just oil and gas, the state's hallmark commodity, has piqued commercial interest. More importantly, a buy-in into IMEC by both Saudi Arabia and India in the current era of disruption and discontent could place New Delhi and Riyadh, instead of Washington, Paris or Rome, at the centre of responsibility to push this project from theory into practice.

But the challenges of the ongoing war in Gaza between Israel and Hamas remain pertinent. In January 2023, a consortium of companies led by Adani Ports and Special Economic Zone Limited (APSEZ), along with Israel's Gadot Group, purchased the port of Haifa on Israel's Mediterranean coast with an investment of \$1.2 billion. Haifa is the country's second largest commercial port and a strategic asset for the Israeli economy. This purchase by the Indian Adani Group, led by billionaire Gautam Adani, is seen as a strategic investment from an Indian perspective, along with a commercial one by the Indian corporation.⁴ Haifa is earmarked as a critical port for IMEC as it is expected to play a major role as a conduit between the eastern and northern corridors, and at some level, it was underpinned by the possibility of Saudi – Israel normalisation in the foreseeable future.

³ N. Nugali, "Saudi Arabia 'one of India's most valued partners, a trusted friend and strategic ally,' Indian PM Narendra Modi tells Arab News", *Arab News*, 22 April 2025.

⁴ G. Mohan, "Adani paid entire \$1.2 bn to acquire Haifa port", *Business Today*, 22 February 2023.

Despite the strong economic underpinnings, every connectivity project has strategic and security aims. From an Indian point of view, IMEC is often compared to BRI as an antithesis to Beijing's expansive project, which it has utilised to mobilise influence across the region. While this conceptualisation of IMEC as an alternative to China's outreach may not be shared by all IMEC partners, specifically in the Gulf, it certainly has a level of clarity within New Delhi's thinking. Piyush Goyal, India's Minister of Commerce and Industry, speaking at an event related to IMEC in the Indian capital, said that

Good part of the IMEC is that it respects sovereignty and is not trying to foist one idea on other. It's not trying to create an economic union. It's not trying to dominate any of the region, something which the Belt and Road Initiative is now being recognised as becoming a political tool to try and dominate certain regions and their economic future.⁵

The collaborative nature of IMEC, led by a stakeholders and equity and interest sharing design, is seen as a more conducive long-term agenda. But an overt projection of IMEC verses BRI can also complicate application of the core economic agendas led by transport, energy and digital connectivity. This was previously seen in the digital sphere between the US and UAE, where Abu Dhabi's engagements with Chinese telecommunication giant Huawei created a divergence on security-based concerns between the two partners in relation to integration of defence systems and access of Chinese hardware to security-driven software.⁶

⁵ "China Belt and Road Initiative is a political tool to dominate regions of the world: Piyush Goyal", *Firstpost*, 21 April 2025.

⁶ "UAE tells US it will suspend F-35 talks following Huawei unease", *Nikkei Asia*, 15 December 2021.

Transporting IMEC

International connectivity projects are long-term, slow-moving endeavours. India has had extensive previous experience of working on such projects, led by the International North-South Transport Corridor (INSTC), where the Chabahar Port in Iran and New Delhi's investment into its development is a strategic play to connect Central Asia and Russia with India.⁷ While the nature of IMEC is quite different to that of INSTC, the challenges it presents may not be too dissimilar, specifically in terms of financing, funding and implementation. These projects also tend to have disproportionate timeframes of infrastructure delivery, both physical and in terms of policy, compared to the political bluster and narrative that often encapsulates such multi-national projects.

Movement of commerce, predominantly via sea and land, is the bedrock of any connectivity project and this is no different for IMEC. However, it is important here to remember that exclusive development of infrastructure under IMEC is not the aim of this multi-national endeavour. The intention is to connect pre-existing commercial projects, routes and domestic and regional policies into an all-encompassing framework. The prioritised challenge for IMEC should be regulatory connectivity, and not overt focus on physical infrastructure.

Shipping between India and the UAE is already a thriving sector. Indian ports such as Mumbai, Kandla, Mangalore, Mormugao and Kochi on the country's western coast have been home to trade routes between India and the Gulf for centuries. The India – UAE Comprehensive Economic Partnership Agreement (CEPA) signed in 2022 acts as a catalyst on efficient trade growth between New Delhi and Abu Dhabi. In effect, this node of IMEC is already functional and awaiting further integration into the Middle East's economic blueprints. To

⁷ A. Wani, "The Middle Corridor and opportunities for India", Observer Research Foundation (ORF), 15 January 2024.

further expand economic integration in South Asia as well, the decision by India and the UAE to co-develop an energy hub in Sri Lanka could extend accessibility of the maritime domain, using Colombo as a connection point extending into the country's eastern coast and aligning with ports in Chennai, Vizag and potentially even Kolkata.

The second major connectivity push beyond maritime is railways, specifically within the Gulf region. This relies more on the ambitious rail connectivity projects envisioned within the Gulf Cooperation Council framework to facilitate over-land trade. For the success of IMEC, feasibility and cost will be critical. On a per shipping container basis, minimising offloading and onloading between sea and land transport will be critical. At the end of the day, businesses will need to see the attractiveness of this endeavour compared to other options, including those that have been working for decades, such as the Suez Canal. If global business does not see commercial merit in IMEC, then the project will be in troubled waters from the outset.

Energy Centrality

Energy is central to economic growth. No one knows this more than India, a net importer of oil, whose energy security for decades has been reliant on the production and sale of hydrocarbons by other countries. However, oil and gas remain an inherently politicised and hence bilateral issue. The substitutes for hydrocarbons in the future of connectivity are renewables, and in IMEC's case, green hydrogen.

The future of green hydrogen for the time being aligns very well with the immediate energy security aims of Europe, creating commercial interest ranging from technologies to pipelines between the Gulf and continental Europe. Green hydrogen technologies and utility are still at nascent stages. Many challenges remain in making green hydrogen both viable, transportable and a primary source of energy. Nonetheless, European states have begun preparing for a future contingency

where green hydrogen can play a major role in their energy mix. Germany is expected to use hydrogen to cover 50-70% of its 90-130 TWh demand by 2030. IMEC could become a major source of this requirement.⁸

In 2023, India launched its National Green Hydrogen Mission to feed into its aim of becoming a production, export and utilisation power in this space, ranging from industrial utilisation to mobility. India has previously led the space in using relatively newer forms of energy sources in its aim for more efficient mobility solutions. In April 2001, the Indian capital city-state of Delhi made it mandatory for public transport to be run on Compressed Natural Gas (CNG) in a bid to reduce emissions, with mixed long-term results.⁹ Similar policy decisions around green hydrogen could be expected domestically if its production and execution prove to be efficient and cost-effective. Overall, a long road ahead remains for energy to become a core driver of IMEC trade.

Beyond the above, New Delhi-led energy initiatives such as the International Solar Alliance (ISA) led by its One World, One Sun, One Grid (OWOSOG) ideation and plans for electrical grid interconnection are also pushing for momentum in the energy security space.¹⁰

Connecting Digital First

The digital and technological part of IMEC, ranging from sub-sea cables to data sharing and creating trade information, will be one of its most important but challenging areas of development.

⁸ A. Rizzi, “[The infinite connection: How to make the India – Middle East – Europe economic corridor happen](#)”, European Council on Foreign Relations (ECFR), 23 April 2024.

⁹ A. Mathur, “[25 years of making sure Delhi does not run out of gas](#)”, *The Times Of India*, 23 December 2023.

¹⁰ “[Joint State at the conclusion of the state visit of Prime Minister to the Kingdom of Saudi Arabia](#)”, Ministry of External Affairs Government of India, 22 April 2025.

In its early stages, digital connectivity was linked to payments (where India has excelled with its implementation of the Unified Payments Interface or UPI). This interface, beyond its domestic success in re-shaping how the country uses money, is also being exported for other states to inherit as part of their own financial systems. As of 2024, the UAE in the Gulf started to accept payments from Indian UPI interfaces, such as the PayTM app, at selected venues, bringing cooperation to the next level.¹¹

Beyond payments, India has also mobilised a software system called Maitri, which aims to provide real-time trade data for IMEC countries and serve as the backbone of the perceived virtual trade corridor. This is a critical project to serve as a proof of concept that regulatory and institutional integration for seamless movement of goods is prioritised.¹² The digital framework is already getting a positive response from port companies that intend to connect pre-existing ports, railways and related infrastructure through digital tools designed to eliminate multiple checkpoints.

As well as facilitating the use of technology to connect IMEC together, it will also be necessary to build collective infrastructure in this field. As technology debates leapfrog into AI, semiconductors, quantum, and collaborative research and development programs amongst IMEC members in the field for future technologies to facilitate trade will be an immediate requirement moving forwards.¹³

The future co-development of digital tools could also face some headwinds. India's pitch of IMEC as a better alternative to BRI could cause certain grievances with its Gulf partners who are signatories to the BRI and see it as a crucial part of their own fast-growing bilateral trade with China.

¹¹ "PayTM becomes international UPI app", PayTM, 19 November 2024.

¹² A. Law, "India to launch MAITRI middleware for enhanced trade connectivity in IMEC countries", *The Hindu Businessline*, 20 September 2024.

¹³ G. Afterman, N. Janardhan, M. Baharoon, and M. Mayer, "Connectivity and 'Reglobalisation': India-Middle East-Europe Economic Corridor and its potential digital future", Anwar Gargash Diplomatic Academy, March 2025.

Conclusion

The IMEC corridor aims to cut the time it takes to ship goods between Europe and Asia by 40%, while saving 30% of the costs. Currently, due to geopolitical disruptions in the Red Sea, a significant chunk of global trade is utilising shipping lanes around Africa's Cape of Good Hope, adding significantly to both time and costs. IMEC looks to circumvent these challenges by offering a viable and fast alternative cutting through the Middle East.

For the moment, IMEC's largest challenge remains mobilising itself out of the status-quo due to the Gaza conflict. The first meeting of leaders from the IMEC cohort was supposed to take place in November 2023. In 2025 now, that momentum is still missing due to the ensuing challenges. Finally, IMEC's challenge is not whether it can develop itself as a connectivity force but how the next steps towards implementation can be taken in lieu of the political headwinds. The answer to this ultimately lies within IMEC's Gulf partners, while the others wait patiently for the politics to align with the economics.

18. The Trans-Caspian Middle Corridor: Facilitating Connectivity and Securing Central Asia's Economic Sovereignty

Eric Rudenshiold

Central Asia and the South Caucasus are being rediscovered, making headlines and topping travel lists for global leaders and businesspeople alike. Gas and oil; wind, solar, and hydrogen; uranium and vast reserves of rare earths and strategic minerals are abundant lures for international investment in this once-considered remote region bounded by Russia, China, Afghanistan, and Iran. Driving this renaissance is an emerging transit route that is redefining regional connectivity.

The development of the Middle Corridor, also known as the Trans-Caspian International Transport Route, is a multi-modal network of rail, road and sea lanes, linking China to Europe. Traversing Central Asia and the South Caucasus, the Middle Corridor is both a paradigm shift for Eurasian trade, as well as a crucial step in securing the independence and economic sovereignty of the trans-Caspian region.

The Growing Strategic Importance of the Middle Corridor

In connecting China to Europe, the Middle Corridor is proving shorter and faster (15 days China to Türkiye¹) for moving freight than Russia's rail corridor to the north (30 days from China to Europe²), and significantly faster than routing by sea through the Suez Canal (40-60 days Asia to Europe³). Offering a sanctions-free alternative to Russian transit systems, the Middle corridor represents a counterbalancing alternative that reduces dependence on Moscow and affords Europe a measure of supply chain resilience.

It seems almost too good to be true: a direct route connecting the manufacturing powerhouse of China to the vast consumer markets of Europe, passing through the growing economies of Central Asia and the South Caucasus. Ursula van der Leyen described it during the EU-Central Asia Summit as the “very definition of a global gateway, the beating heart of Eurasia”.⁴ The European Union, the European Bank for Reconstruction and Development, the Asian Development Bank, and numerous European entities are making significant investments and supporting Corridor infrastructure improvements as confirmation of this conclusion.

The route itself consists of a network that spans and connects multiple regions, including China, Central Asia, Azerbaijan, Georgia, potentially soon Armenia, and Türkiye, all culminating in Europe. Each of these countries has seen significant investments to expand and modernize infrastructure, from railways and ports to road networks and digital systems.

¹ V. Serbet, P. Lagov, H. Wei, and M. Kofler, “[Discover the Middle Corridor - Your reliable shortcut between Europe & China](#)”, Hellmann.

² S. Mammadov, “[The Middle Corridor set to halve cargo transit time between Asia and Europe](#)”, *Intellinews*, 1 February 2024.

³ Ibid.

⁴ [Speech by President von der Leyen at the plenary session of the first EU-Central Asia Summit](#), 4 April 2025.

For example, the Baku-Tbilisi-Kars (BTK) Railway is currently the freight mainstay of the Middle Corridor, linking the port of Azerbaijan to Georgia and Turkey and connecting goods then into European networks. Undergoing renovation, BTK expects to increase freight capacity from 6.5 to 17 million tons by 2034,⁵ providing a near tripling of the trans-Caspian transport route's current volume.

There are two other regional opportunities expected to vastly expand the trans-Caspian route's potential, if concluded. Ongoing peace talks between Armenia and Azerbaijan hold the promise of reopening a Soviet-era rail corridor to connect Azerbaijan through Armenia to Türkiye and more than double the Middle Corridor's throughput freight capacity.⁶ The 2025 EU-Central Asia Summit declaration acknowledged the importance of this development to the trade route, making the South Caucasus reconciliation a prerequisite to further Middle Corridor project investments.⁷

As well, China's investments in developing a deep-water port in Anaklia, Georgia, should dramatically increase trans-Caspian freight capacity by 100 million tons upon completion in 2062,⁸ which is in addition to the 40 million tons currently being handled by the country's Batumi, Poti, Supsa, and Kulevi ports.⁹ Both prospects seemed unimaginable only a few years ago, but developmental momentum along the new trade corridor continues to accelerate.

Fueled in large measure by trade sanctions and restrictions on Russia and its Northern Corridor, the trans-Caspian region is taking advantage of the opportunity afforded by international

⁵ L. Parkhomchik, "Recent Developments in the Baku-Tbilisi-Kars Railway Project", Eurasian Research Institute.

⁶ E. Rudenshiold, "Winning the Peace: Armenia and Azerbaijan", Caspian Policy Center, 28 October 2024.

⁷ N. Castillo, "Strengthening Ties: EU-Central Asia Summit Paves the Way for a Robust Strategic Partnership", Caspian Policy Center, 4 April 2025.

⁸ "Anaklia Deep Sea Port", Ship Technology, 7 June 2018.

⁹ "Mamuka Khazaradze: 'Anaklia Becomes a Chinese Port'", *Caucasus Watch*, 5 August 2025.

prohibitions to develop new partners and forge a historic shift in global trade routing and relationships to the West. Thanks to soft and hard infrastructure investments, route expansion, trade and customs agreements, the adoption of digitalisation and modern technology, Central Asia and the South Caucasus are becoming increasingly incentivised to cooperate with each other to enhance the sustainability, attractiveness, and profitability of the Middle Corridor.

These regions were not long ago considered secondary or tertiary transit zones, connected to the world largely through Russia. Comprised of approximately 17 million people in the South Caucasus and 83 million in Central Asia, the trans-Caspian region is a viable consumer market in its own right and commercially attractive to China and the EU. But the region is also home to vast amounts of traditional energy (oil, gas, coal) and next generation energy (strategic minerals, hydrogen, solar, and wind) that can be exported along the new trade route to new markets to the East and West.

Recent Milestones: A Path of Progress

Barely noticeable prior to Russia's invasion of Ukraine, the Middle Corridor and its remarkable growth is no mirage. Cargo volumes along the nascent route in 2021 totaled 586,000 tons,¹⁰ rising to 1.5 million tons in 2022, then 2.8 million tons in 2023, reaching 4.1 million tons in the first 11 months of 2024.¹¹ Bilateral freight transit between Azerbaijan and Kazakhstan has significantly increased year on year, with sea shipping volumes reaching 707,700 tons between January and March 2025.¹² Kazakhstan now handles 90% of overland

¹⁰ S. Paterson, "[The Middle Corridor: Competing for influence in Central Asia](#)", hinrich foundation, 1 October 2024.

¹¹ S. Sakenova, "Cargo Transport via Middle Corridor Surges to 4.1 Million Tons in 11 Months", *The Astana Times*, 18 December 2024.

¹² "[Azerbaijan records notable increase in sea cargo transportation in 1Q2025](#)",

freight from China and Europe, according to President Tokayev.¹³ Astana has pledged to significantly increase cargo shipments to 10 million tons.¹⁴

While expensive, the investments being made in this booming route appear to be paying off. In 2024 alone, cargo through Kazakhstan reached a record 514 billion ton-kilometers, demonstrating the immense potential of the corridor. In the first few months of 2025, the Danish shipping giant Maersk completed its first successful trial shipment from Japan to Europe via the Middle Corridor.¹⁵ Preliminary results from this trans-Caspian shipment indicate a significant reduction in both time and transit costs compared to sea and air routes, reducing Japan to Türkiye transit time from 45-60 days by sea to 15-20 days. This marks an important milestone, not just in logistics, but also in demonstrating the practical viability of the route as an alternative to traditional maritime lanes.

In addition to these infrastructural achievements, geopolitical shifts have further highlighted the importance of the Middle Corridor. Russia's 2022 full-scale invasion of Ukraine underscored Europe's vulnerability to dependance on traditional trade routes through Russia. The multi-modal, trans-Caspian network combines rail, sea, and road transport systems and provides flexibility for markets in Europe to enable cargo to be redirected in response to demand changes, seasonal interruptions, and evolving geopolitical conditions.

The war and subsequent sanctions have shown Europe the urgent need to diversify its supply chains and develop new, reliable routes for goods. The Middle Corridor offers such an alternative – an opportunity to bypass Russian-controlled territories while still maintaining efficient and cost-effective

30 trend, 17 April 2025.

¹³ <https://www.linkedin.com/feed/update/urn:li:activity:7313620885779730433/>

¹⁴ S. Sakenova, "Kazakhstan to Increase Middle Corridor's Capacity to Ten Million Tons Annually", *The Astana Times*, 27 August 2024.

¹⁵ A. Dayar, "22 Days from Japan to Europe: East Asia's Middle Corridor Milestone", Caspian Policy Center, 27 March 2025.

trade between East and West. Investments underway to establish new logistics centres, streamline customs processes, and promote trade initiatives have the potential to further boost efficiency and strengthen the corridor's competitiveness.

Numerous European bilateral commitments are also focusing on the trans-Caspian trade route. Bulgaria, for instance, recently announced a massive \$1.8 billion investment in the Middle Corridor's railway network,¹⁶ connecting BTK to Serbia via Bulgaria through a modern, high-speed rail system that will extend the Middle Corridor into the heart of Europe by connecting to the Trans-European Transport Network (TEN-T). Underscoring the growing commitment from European partners to support this transformative trade route, these investments signal a new era of collaboration, with countries across Europe, Central Asia, and the South Caucasus increasingly working together to ensure the success of this trans-Caspian trade route. Connectivity to Europe's own multimodal transport network has the prospect of sustainably linking Central Asia and the South Caucasus to the transport flows of people and goods across Europe to the reaches of Asia.

Promises and Challenges of the Middle Corridor

Despite the clear potential, the Middle Corridor is not without its challenges. On paper, the route offers significant advantages, but in practice, it remains a complex network of interconnected railways, roads, and seaports. Each of these infrastructure components operates within a different set of political, regulatory, and logistical contexts, creating a series of hurdles that need to be addressed for the corridor to function seamlessly.

One of the primary issues is the infrastructure itself. While the Middle Corridor is making strides, there is still much work to be

¹⁶ A. Alasgarli, "Bulgaria commits to railway investment within Azerbaijan-led Middle Corridor - Rosen Plevneliev (Exclusive interview)", *30 trend*, 13 March 2025.

done. Bottlenecks remain at key points,¹⁷ such as ports and rail yards, while gaps in digital infrastructure complicate customs procedures and trade monitoring. The geographical challenges are no less daunting, with harsh winters and strong winds in the Caspian Sea often delaying ferries, thus affecting transit times.¹⁸ Declining sea levels are forcing port and waterway dredging,¹⁹ at times slowing Caspian transit. Moreover, mismatched railway gauges and misaligned tax systems between European and former-Soviet countries make the process of moving goods along the corridor at times cumbersome.²⁰

However, these challenges are not insurmountable. The development of the Middle Corridor is still in its early stages, and investments are being made in all areas of the network. The European Union, for instance, has pledged nearly €90 million to support infrastructure development along the route,²¹ with a focus on modernising ports such as those in Aktau and Turkmenbashi, and investing in digital solutions to streamline customs and trade procedures. These investments are vital to overcoming the existing barriers and ensuring the future success of the route.

The Economic Sovereignty of Central Asia

As the corridor expands, it is clear that this route offers more than just a new path for trade – it provides a critical avenue for securing the economic sovereignty of Central Asia and the

¹⁷ E. Mami, “[The Middle Corridor: trends and opportunities](#),” ODI Global, 22 January 2024.

¹⁸ E. Rudenshiold, *Nine Hard Truths Along The Caspian Middle Corridor: Critical Factors facing the Caucasus and Central Asia*, Special Report, Caspian Policy Center, June 2024.

¹⁹ J. Taganova, N. Hutson, and R. Mattur, “[Merging the Ecological and Trade Challenges of the Caspian](#)”, Caspian Policy Center, 12 December 2024.

²⁰ *Realising the Potential of the Middle Corridor*, OECD, 2023.

²¹ N. Castillo, “[EU Unveils New Middle Corridor Coordinating Platform](#)”, 9 October 2024.

South Caucasus. For decades, these regions have been viewed through the lens of their geographical location – post-Soviet countries situated at the crossroads of major global powers, often regarded as transit zones subservient to the needs of their large neighbours. However, the Middle Corridor is helping to change that narrative.

By becoming central players in a trade route that connects China to Europe, countries like Kazakhstan, Kyrgyzstan, Azerbaijan, and Georgia are asserting themselves as “Middle Powers” and key economic actors in an evolving global economy.²² This not only enhances their geopolitical standing but also strengthens their economies by increasing trade volumes, attracting investment, and fostering regional cooperation. Not delinking their economies from Russia and China, the trans-Caspian region is seeking greater global engagement and alternatives that expand their economic reach and heighten the value of their own exports.

Uzbekistan has significantly expanded trade along the Middle Corridor through connections with Kazakhstan and Azerbaijan, facilitating smoother logistics and increased cargo flow. By November of 2024, trade turnover between Uzbekistan and Kazakhstan reached approximately \$3.8 billion nearly tripling levels from 2021,²³ while trade with Azerbaijan and Türkiye is projected to double due to the new and increased cooperation mechanisms.²⁴ These advances have strengthened regional trade ties and positioned Uzbekistan as a key player in the corridor’s development, connecting China to the Middle Corridor in the East and potentially Afghanistan and the Global South via a proposed rail enhancements.²⁵ Similarly, Kyrgyzstan’s efforts

²² M. Zhiyenbayev, “Kazakhstan in the Middle: Resilience in the Face of Great Power Rivalry”, RUSI, 31 October 2024.

²³ “Kazakhstan-Uzbekistan trade turnover surpasses \$3.8bn”, *Kazinform International News Agency*, 24 December 2024.

²⁴ “Uzbekistan, Azerbaijan, Türkiye can double mutual trade volume”, *Caliber*, 29 January 2025.

²⁵ “Trans-Afghan railway construction set to begin in 2025”, *Kun.Uz*, 5 February 2025.

to enhance multimodal transport through its Asia-Pacific Multimodal Corridor and China-Kyrgyzstan-Uzbekistan-Afghanistan Corridor are further solidifying its position as a key waypoint in the Middle Corridor network.

These developments are crucial for the economic autonomy of Central Asia, as they reduce reliance on external powers – namely Russia and China – for access to global markets. Rail connectivity through Afghanistan would further enable access to markets in the Global South as well as to international sea lanes. The Middle Corridor offers these countries a chance to diversify their economic partnerships,²⁶ engage with European markets, and create a more balanced economic relationship with their global neighbours. Access to international markets on their own terms,²⁷ not those dictated to by their large neighbours who once controlled trade passageways, is a key element of Central Asian engagement and support for the Middle Corridor.

Geopolitical Implications and Europe's Role

In today's complex geopolitical climate, Europe must approach its engagement with the Middle Corridor strategically. The new route offers a clear opportunity for Europe to diversify its trade routing, reduce dependence on traditional pathways, and mitigate risks related to political instability in certain regions. However, this engagement must go beyond strategic ambition – it requires a nuanced understanding of the practical realities and risks involved.

One of the most pressing concerns for Europe is the possibility of sanctioned goods being diverted through the Middle

²⁶ P. Aguiar, “[The Middle Corridor: A Route Born of the New Eurasian Geopolitics](#)”, *Geopolitical Monitor*, 23 January 2025.

²⁷ M. McGraw Olive, R.E. Hoagland, and E. Rudenshiold, “[Perspectives on CPC's Trans-Caspian Forum Maximizing the Middle Corridor](#)”, Caspian Policy Center, 2024.

Corridor, particularly to Russia. In the wake of sanctions on Russia following its invasion of Ukraine, some goods transit through the Middle Corridor to avoid detection and bypass restrictions.²⁸ This creates a potential vulnerability that could complicate Europe's efforts to maintain robust supply chains and maintain support both for sanctions compliance and Middle Corridor partners.

To mitigate this risk, Europe must invest in and further promote transparency and digital infrastructure, ensuring that customs procedures and trade documentation are automated and digitised. By participating in initiatives like the Digital Trade Corridor,²⁹ Europe can help ensure the visibility of goods moving along the Middle Corridor, reducing the chances of illicit trade and circumvention of sanctions while at the same time increasing transit efficiencies, lowering freight times, and lowering transit costs.

The Path Forward: Balancing European and Local Interests

Europe's role in the Middle Corridor must be one of partnership, not just oversight. As Central Asia and the South Caucasus continue to develop the corridor, European stakeholders must respect the sovereignty and agency of these governments. The successful expansion of the Middle Corridor relies on a delicate balance of investment, cooperation, and shared interests. Clear articulation of expectations is critical to ensure that investments and developments achieve the objectives of both European and regional partners.

While Europe's involvement is crucial, it is equally important to ensure that local stakeholders have buy-in and ownership through a central role in decision-making and implementation.

²⁸ W. Woldemar, "Challenges and opportunities of the Middle Corridor", German Economic Team, Nov/Dec 2022.

²⁹ [Digital Trade Corridor \(DTC\)](#).

The region has already demonstrated a strong commitment to developing the Middle Corridor, with countries investing their own funds to modernize infrastructure and improve connectivity.³⁰ As such, Europe should approach its engagement as a reliable partner – investing not only in physical infrastructure but also in the social and economic foundations necessary to ensure the corridor’s long-term success.

Regional governments have made it clear that they prefer multilateral investments, as opposed to those that are dominated by a single global power. Large neighbours, Russia and China, have a legacy of engaging in zero-sum projects with the region, seeking control of key economic sectors to the long-term detriment of regional development and sovereignty. Europe should heed this message to ensure that the Middle Corridor remains a truly international effort that supports both inter-regional integration and intra-regional autonomy – a shared space for cooperation, growth, and prosperity.

Conclusion: A Strategic Opportunity for Europe

The Middle Corridor offers Europe a unique opportunity to diversify its trade routes, strengthen regional ties, and ensure a more secure and resilient supply chain in the face of shifting geopolitical dynamics. By engaging with Central Asia and the South Caucasus in a meaningful and sustained manner, Europe can not only secure its own economic interests but also support the economic sovereignty of the regions that are driving the Middle Corridor’s growth.

Moving forwards, it is essential for Europe to balance its economic goals with a deep understanding of the local context. Supporting infrastructure development, fostering transparency in trade, and strengthening partnerships with regional players will be key to unlocking the full potential of the Middle Corridor.

³⁰ V. Huseynov, “[Multiple Countries Strive to Enhance Middle Corridor Despite Challenges](#)”, *Eurasia Daily Monitor*, vol. 21, no. 156, 28 October 2024.

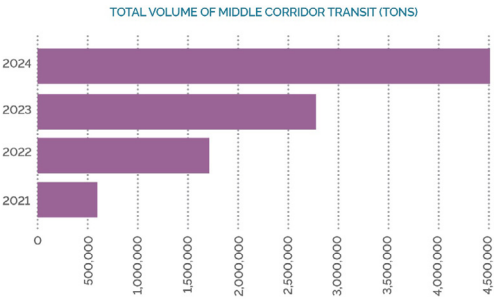
In doing so, Europe will not only create new opportunities for trade and investment but will also contribute to a more stable, prosperous, and interconnected Eurasia.

2024 Transit Statistics

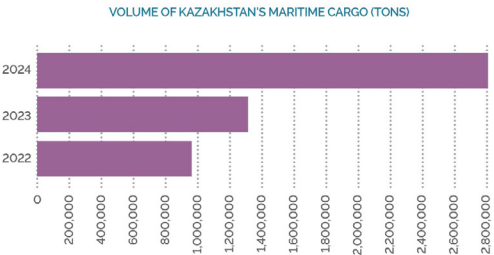
1.5 million tons. The total volume of all Middle Corridor transit as recorded by Kazakh officials in 2024, a growth of 63% from the previous year.

2.8 million tons. The volume of cargo transported via Kazakh ships over the Caspian Sea in 2024.

50,600. The total twenty-foot equivalent units of traffic Kazakhstan reported transiting the Middle Corridor in months of 2024, over **2.7 times** more than the previous year.



Source:
Kazakh Officials as reported in The Astana Times



Source:
Kazakhstan Bureau of National Statistics

19. US Resilient Infrastructure: The Key Tool for Industrial Leadership?

Michael Bennon

The United States is currently undergoing a period of massive change in its economy, which is being spearheaded by three major pieces of federal infrastructure and industrial policy legislation: the Infrastructure Investment and Jobs Act (IIJA), the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act, and the Inflation Reduction Act (IRA). In their totality, these three pieces of legislation will invest trillions of dollars in infrastructure rehabilitation, high-tech manufacturing and supply chain resiliency and the energy transition.

This recent legislation is not simply investing more, however. The legislation also represents significant changes in how the US invests. The CHIPS and IRA mark an American turn towards vertical industrial policy, and directly managed state investment and subsidy programmes, which would have seemed foreign in the United States a decade ago. Similarly, the IIJA includes significant changes to the ways that the federal government invests in infrastructure and the types of projects that it invests in.

In this brief chapter, I review these changes in the “how” of US industrial policy and federal investment, and discuss two of the challenges that the US government faces as it attempts to orchestrate major changes to its economy. The first challenge relates to the infrastructure and other fixed investments in the legislation. While the US has significantly increased investment, it has not changed or otherwise addressed

preexisting environmental and social regulations designed to slow or otherwise constrain growth and dynamism. These regulations are now constraining federal investments in clean energy and resiliency in the same way that they previously constrained investments in other sectors. As a result, “permitting reform” has become a topic of political urgency, but the Biden Administration has yet to make significant changes to speed up investment.

The second set of challenges facing the US transition stem from unique aspects of American governance and the United States’ unique role in the global economy, which differs significantly from many other nations that rely on state-led direct investments and industrial policy for growth. The United States is new to the world of industrial policy, and lacks the clear metrics and controls that other nations have used to prevent goal proliferation or rent seeking, and to adjudicate conflicts between various development goals and interest groups. It is also a divided democracy with checks and balances that tend to pull investment policies in multiple directions. Absent these institutions to direct state-led investments and subsidies, the US risks taking a haphazard approach to delivering its key industrial policy initiatives.

The Legislation

At more than \$2 trillion in direct federal spending, the Biden Administration’s combined industrial policy legislation in the IIJA, IRA and CHIPS Act represent a massive investment programme. More importantly, however, the legislation makes important, potentially precedent-setting changes in how the US government invests, by investing in new sectors, investing through new, more direct channels, and by creating new programmes to supplement private investment.

The IIJA made significant changes to US federal infrastructure spending by adjusting the balance of federal funding between sectors and working more directly with cities and local public

sponsors. The majority of the federal funding in the IIJA remains formula funding programmes through state governments, much of which is allocated towards road infrastructure.¹ However, the legislation also includes unprecedented allocations to transit infrastructure and other sectors, including \$55 billion to water infrastructure, \$65 billion to broadband and digital infrastructure, and \$8 billion to regional rail infrastructure outside of the already massive allocation that the legislation makes to Amtrak.² In the renewable energy and climate mitigation sectors the changes are far more substantial. The IRA alone is estimated to catalyse more than \$1.7 trillion into the climate and renewables industries, and renewable energy is expected to attract 78% more investment per year than it would have otherwise.³

The United States' industrial policy legislation also changed the way that the federal government invests to include more discretionary grant programmes, or programmes that work directly with cities and local public sponsors, rather than allocating capital through the states. For instance, the IIJA and the IRA include 18 new programmes and billions in funding for cities that focus on community design and transportation impacts.⁴ Prior discretionary grant programmes were expanded while other completely new programmes were created, such as the connecting communities programme or the new, \$848 million resilience grant programme to protect transportation infrastructure from the impacts of climate change. While the majority of the transportation and other funding is still being

¹ A. Tomer, K. Caroline, and J.W. Kane, "[The Start of America's Infrastructure Decade: How Macroeconomic Factors May Shape Local Strategies](#)", Brookings Institution, 1 February 2023.

² D. Hampton, "[Amtrak CEO Outlines Plans for Spending \\$66 Billion from Infrastructure Funding](#)," *NBC News*, 8 November 2021.

³ Robinson Meyer, "[A Huge, Uncharted Experiment on the U.S. Economy Is About to Begin](#)", *The New York Times*, 12 February 2023.

⁴ A. Tomer, "[Will the Infrastructure Law and Inflation Reduction Act Transform American Transportation? It's Complicated](#)", Brookings Institution, 1 November 2022.

allocated through state programmes, the direct investment initiative in the IJJA and the IRA mark an important shift towards an investment programme more directly allocated and managed by the federal government.

The IRA and the CHIPS act also expand the number of industrial policy tools that the federal government will use to support select industries, and both pieces of legislation are also focused on relocating or retaining manufacturing jobs and facilities in the United States. This is also a marked shift. For instance, the EV tax credits passed in the IRA are only available for vehicles manufactured domestically. Likewise, the CHIPS Act includes \$60 billion in subsidies across a number of programmes, including tax credits, grants and government loan programmes, but only for domestic manufacturing facilities.⁵ The industrial policy subsidies used are also in some cases more directly linked to policy outcomes, including metrics as specific as a \$3 tax credit per kilogram of green hydrogen.⁶ Between the IJJA, IRA and CHIPS Act, the United States has aggregated an industrial policy programme of direct investments, private sector subsidies and loan programmes that is truly unprecedented in scale or administration.

Conflicting Priorities

As the United States navigates its transition into a more state-led economic development model, it faces challenges in two key areas. The first can be found in the legacy policies and regulations to protect against environmental and social harms by controlling growth. The second is a lack of the institutions that other state-led economies use to direct investment, prioritise among public goods and prevent rent seeking.

⁵ D. Kamin and R. Kysar, “[The Perils of the New Industrial Policy](#)”, *Foreign Affairs*, 18 April 2023.

⁶ “[America’s Government Is Spending Lavishly to Revive Manufacturing](#)”, *The Economist*, 2 February 2023.

To grow or not to grow

Many US environmental regulations were designed during the 1960s and 1970s, in an area of dynamic growth and change, and one with very high levels of capital investment in both public works and the private sector. Significant environmental and social impacts of that growth and development were a key contributor to the creation of those regulations.⁷

The most important of these new regulatory policies was the National Environmental Protection Act of 1970 (NEPA), which would act as a precedent and template for a wide range of similar regulations at the state and regulatory level after it became law.⁸ NEPA has evolved to limit the environmental and social impacts of federal infrastructure investments and other actions in three general ways. First, administratively, it required agencies to complete a detailed environmental study for any action that would have significant environmental impacts prior to undertaking it. Second, it included a democratic process through which agencies were required to present the results of their studies to the public, before accepting and responding to public comments on the proposed project. Finally, it created a judicial private right of action through which citizens or stakeholder groups could challenge an environmental study in court, and potentially block the investment until problems with the environmental study were remedied.

While NEPA application was limited to federal infrastructure projects and the other major actions of federal agencies, NEPA's basic regulatory formula was replicated in many US state environmental laws or even local planning regulations. Other regulations to protect habitat, species or historic buildings were also structured similarly. In the manufacturing sector, the financial liabilities that manufacturers faced from

⁷ D. Bear, "The National Environmental Policy Act: Its Origins and Evolutions", *Natural Resources & Environment*, vol. 10, no. 2, 1995, pp. 69-73.

⁸ D.R. Mandelker, *NEPA Law and Litigation, 2nd Edition*, Clark Boardman Callaghan, 2018.

environmental impacts were also increased through regulations, with enforcement via environmental lawsuits and agency action.⁹

These regulations were broadly successful in improving US environmental outcomes and in many cases reducing the social impacts of large infrastructure or industrial development projects. During the same period, however, the time to develop large federal infrastructure projects in the United States increased significantly, and US manufacturing also declined precipitously as a share of the economy. Today, the median time to complete a federal environmental study for a renewable generation or transmission project is 3.5 years with projects taking 9 years or more in some cases. Other federal permitting actions can take just as long or longer.¹⁰ The longer term decline in US manufacturing employment accelerated after a change in trade policy eliminated the potential for tariff increases in Chinese imports after the turn of the century.¹¹

While this network of policies has been successful at regulating growth and development in the United States, it presents some clear challenges for the new industrial policy development model as well. American development regulations were naturally designed to prioritise local environmental and social impacts, whereas mitigating and adapting to climate change will require significant investments in renewable generation, transmission lines and other infrastructure investments. Reinvesting in high-tech and renewable manufacturing will likewise face the same headwinds today that those industries faced before the federal subsidies in the CHIPS act and the IRA were put in place.

⁹ R. Ryan, "Adequate Agency Action: How Procedural Trends in Environmental Citizen Suit Litigation Prompt a Reconsideration of Deference and Presumptions of Diligence", *Ecology Law Quarterly*, vol. 44, 2017, pp. 445-68.

¹⁰ R. Sud, S. Patnaik, and R. Glicksman, "[How To Reform Federal Permitting To Accelerate Clean Energy Infrastructure](#)", Brookings Institution, nfebruary 2023.

¹¹ J.R. Pierce and P.K. Schott, "The Surprisingly Swift Decline of U.S. Manufacturing Employment", *National Bureau of Economic Research*, NBER Working Paper, no. 18655, December 2012.

In other words, the same constraints on dynamism and change that were designed to prevent their attendant environmental and social impacts are now also constraining the US government's new development agenda of investing in infrastructure, establishing a more resilient manufacturing supply chain and hastening the transition to renewable energy.

Congress and the Biden Administration have struggled to navigate this impasse since passing their landmark legislation. Congress included minor reforms to the permitting process in the One Federal Decision (OFD) policy that was in the IIJA.¹² More recently, the US debt ceiling negotiation produced some minor permitting reforms to NEPA and attempted to set stricter timelines for federal environmental permits.¹³ However, the Biden Administration has also reversed guidance from the prior Trump Administration to clarify the legal requirements of environmental studies under NEPA.¹⁴

The United States is embarking on a reformation of its economy that will require massive capital investments in infrastructure and manufacturing, yet it is not a developing economy that is able to make capital investments quickly. All forms of infrastructure development or industrial investment create environmental or social externalities, to one degree or another. The United States has developed a wide range of laws and policies to mitigate those impacts by constraining development. Those very same policies will also impede the federal government's new development initiatives in infrastructure renewal, the energy transition and resilient manufacturing supply chains.

¹² A. Winkler and O. Minott, "[IIJA Provisions to Accelerate Clean Infrastructure Permitting and Environmental Review](#) | Bipartisan Policy Center", *Bipartisan Policy Center* (blog), n.d.

¹³ M. Catanzaro, "[Permitting Reform in the Debt Ceiling Bill: A First Step, with More to Come](#)", 7 June 2023.

¹⁴ D. Grandoni and A. Phillips, "[Biden Restores Climate Safeguards in Key Environmental Law, Reversing Trump](#)", *Washington Post*, 19 April 2022.

Directing Investment

The second set of challenges that the United States faces in directing its economic transition relates to its governance and unique role in the global economy, which will make industrial policy and direct investment programmes in the United States less resistant to problems common to industrial policy programmes globally – notably goal proliferation and rent seeking. The United States lacks some of the governance mechanisms and performance indicators that other nations with large state-led industrial policy or direct investment programmes take advantage of. It will need to account for these disadvantages as it sets out on implementing its industrial policy programmes in the coming years.

The first problem that the US faces in this regard is a simple matter of governance. The United States does not have an authoritarian or single-party system of governance which can exert significant unilateral control over an investment initiative. It is instead a divided liberal democracy with many checks, balances, interest groups and stakeholders. Major investment programmes run the risk of getting pulled in multiple directions as a result, which can inhibit them from achieving their primary goals. Examples abound already in the major US legislation. In the runup to the IIJA's passing, elected leaders came up with a wide range of justifications for why various sectors and investments counted as "infrastructure".¹⁵ Similarly, after the IIJA became law the Biden Administration issued guidance to states that appeared to direct them to not invest federal funding in projects that would add lane-miles to existing highways. The guidance drew criticism from congressional Republicans before it was eventually withdrawn. The potential for goal proliferation in industrial policy programmes is perhaps even greater. When the US commerce department released its

¹⁵ E. Boehm, "[Everything Is Infrastructure Now](#)", *Reason.Com* (blog), 5 September 2021.

guidance for private companies interested in receiving federal subsidies under the CHIPS Act, the requirements addressed a very wide range of other public policy objectives that had little to do with semiconductor manufacturing, including requirements as wide ranging as providing on-site childcare for any construction workers building the federally supported manufacturing facilities.

The United States is also not a developing economy with an export-led growth model, and this also poses challenges for its industrial policy initiatives in particular. Export promotion is not only an end goal of many industrial policy initiatives, but it also provides a useful metric for programmes to reduce rent seeking and allocate subsidies more efficiently. Many industrial policy initiatives in Asia, for instance, require subsidised manufacturers to successfully increase exports in order to continue receiving or receive higher subsidies.¹⁶ The subsidy programmes put in place in the United States more closely resemble import substitution policies, which have a long history and a nuanced track record.¹⁷

This challenge is largely limited to the execution of the United States' new industrial policy programmes, but in the future the same issue would apply to whether the US creates additional programmes in additional industries. Historically, US interventions more commonly took the form of countervailing duties or tariffs, which were justified based on a subsidy or other trade distortion on the part of a trading partner. If America's new industrial policy programmes are instead justified based on strategic competition, new economic development priorities, or the simple fact that "others are doing it",¹⁸ then there is not a clear

¹⁶ For country level case studies see J. Page and F. Tarp, *The Practice of Industrial Policy: Government-Business Coordination in Africa and East Asia*, Oxford, Oxford University Press, 2017.

¹⁷ For a review of import substitution practices in the global south through the 1980's, see H.J. Bruton, "A Reconsideration of Import Substitution", *Journal of Economic Literature*, vol. 36, no. 2, 1998, pp. 903-36.

¹⁸ J. Harris and J. Sullivan, "[America Needs a New Economic Philosophy](#). Foreign

limit on the potential scope of similar policies going forward. This is likely part of the reason that many allies and trading partners of the United States have expressed significant concerns of their own in response to recent US industrial policy initiatives.¹⁹

Conclusion

America's turn towards industrial policy and state-led direct investment is an effort to further transition its national economy into one that is less carbon-intensive, more resilient with respect to global supply chains and more competitive in high tech and renewable energy manufacturing. It can already boast many achievements. Just one year into the IIJA, billions in federal funding have been deployed for roads, transit, bridge repair, airports and water infrastructure projects.²⁰ Similarly, capital investment in US manufacturing investment is skyrocketing even as production levelled off after a post-pandemic boost.²¹ There are even indications that the industrial policy initiatives in the IRA have succeeded in making renewable energy products manufactured in the United States globally competitive on price.

However, the US faces challenges and inherent conflicts between its new industrial policies and its current regulations and governance. In the end, the United States' new industrial policy initiatives will be judged not by the amount of federal funding they are able to invest, or even on the private capital they are able to catalyse. They will be judged on whether those investments actually achieve their objectives of broad economic growth, supply chains that are more resilient to geopolitical conflict, a more competitive high tech and renewable manufacturing sector and a greener economy.

Policy Experts Can Help", *Foreign Policy*, 7 February 2020.

¹⁹ Kamin and Kysar (2023).

²⁰ Ibid.

²¹ L. DePillis, "After Pandemic Rebound, U.S. Manufacturing Droops", *The New York Times*, 2 May 2023.

20. US vs China: Maritime Challenge Between Great Powers

Gian Enzo Duci

On 26 April 1956, the departure of the ship *Ideal X* from the Port of Newark, bound for Houston, carrying 58 containers, is likely the date that changed the history of logistics – and some say, made the world smaller.¹ An American, Malcolm McLean, on a ship built in the US, flying the same flag, on a US coastal route, had just opened the way for what would become, alongside information technology, the most important economic revolution of the XX century.

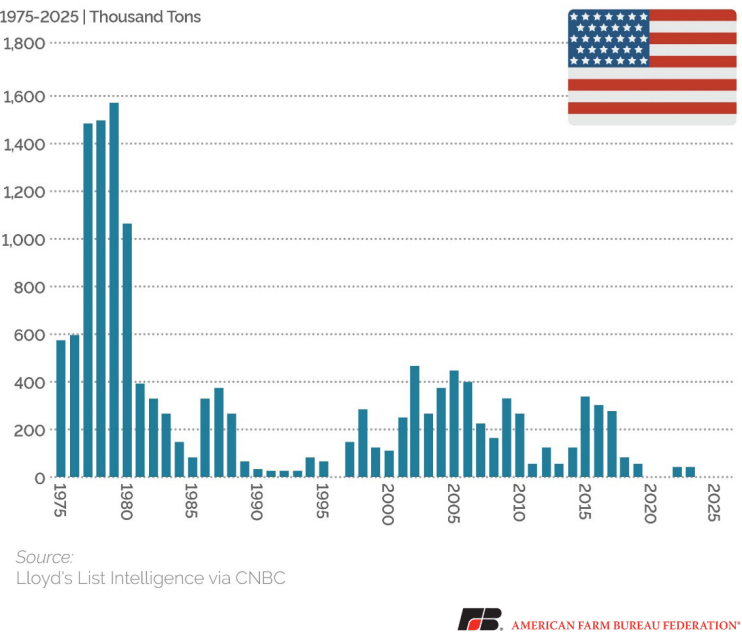
Shortly afterward, in 1958, the California-based Matson Navigation Company awarded a contract to the Pacific Coast Engineering Company (PACECO) to build the first crane specifically designed and engineered to handle a container at the Alameda terminal in the Port of San Francisco. Two similar cranes were later added in Los Angeles and Honolulu in 1960. During the same period, Matson also became the first shipping operator to use a computer to optimize the loading, unloading, and navigation processes of these ships, which had introduced the Fordist method into the general cargo supply chain.

Today, a little over sixty years later, despite being the historical birthplace of the container shipping industry and maintaining its position as the world's leading economic power, the United

¹ *The Economist*, “Why have containers boosted trade so much?”, 21 May 2013. For further details see C. Alemanni, *The Lady of Goods*, LUISS University Press, 2023.

States can boast only two ports among the top thirty globally (Los Angeles/Long Beach in ninth place and New York/New Jersey in twenty-second), compared to China’s eleven.² Among the top thirty container shipping companies, seven are Chinese, while there is only one American company – the previously mentioned Matson – ranked twenty-ninth.³ Shipbuilding, apart from a few protected niches, has essentially disappeared from the North American country.

FIG. 20.1 – DEADWEIGHT TONNAGE CAPACITY OF US-BUILT SHIPS BY YEAR OF CONSTRUCTION



² The ranking is based on the number of containers handled during 2024 (Alphaliner).

³ The ranking is based on the TEU capacity of operated ships combined with that of ships on order (Alphaliner).

The Reasons for the American Decline

The decline of the US maritime-port economy, however, dates back much further. It had already been confirmed at the end of the 1990s, when its two main and iconic shipping companies – American President Line and SeaLand (founded by McLean himself) – were sold to Singapore’s Neptune Orient Line (1997) and Denmark’s Maersk (1999), respectively, amid the “market-driven only” climate of the Clinton presidency (who doesn’t remember the mantra: “It’s the economy, stupid?”).

Similarly, the lack of public investment in port infrastructure, which began to wane progressively starting in the 1980s, left North America lagging behind in terms of capacity and efficiency compared to the other two major regions along the main East/West trade routes (the Far East and Europe).

Although the United States remains the only naval superpower in the military sector, the condition of its merchant maritime industry currently does not make it a maritime nation. This is the argument made by experts like Pablo Rodas-Martini – one of the world’s leading commentators in the field – who has offered a highly detailed (and critical) analysis of the “Report on China’s Targeting of the Maritime, Logistics and Shipbuilding Sector for Dominance”, published by the United States Trade Representative (USTR).⁴ This report became the trigger for the Trump administration to reassert the US role in the sector. His was one of more than 520 comments submitted to the USTR office by associations, companies, and individuals in response to the administration’s call for public input.⁵

Many have pointed out that, over time, it was not so much Chinese competition, but rather the United States’ own protectionist initiatives (starting with the Jones Act of

⁴ United States Trade Representative, [Report on China’s Targeting of the Maritime, Logistics, and Shipbuilding Sectors for Dominance](#), 16 January 2025

⁵ USTR Comments Portal, [Public Docket Request for Comments Concerning Proposed Action Pursuant to the Section 301 Investigation of China’s Targeting of the Maritime, Logistics, and Shipbuilding Sectors for Dominance](#).

1920 and the Merchant Marine Act of 1936, up to the Cargo Preference Act of 1954 and the Maritime Security Act of 1996) that created the conditions for the gradual downsizing of the national maritime cluster – subsidised and protected in a disproportionate way, and consequently confined to the reserve of domestic cabotage traffic. It is worth noting, incidentally, that these laws were not even mentioned in the 170 pages of the Report.

The USTR document concluded that over the past three decades, China has deliberately and knowingly pursued a dominant role in the maritime, logistics, and shipbuilding sectors through a non-market, government-led system, thereby harming U.S. companies, workers, and the broader economy.

The Reaction to Chinese Supremacy

As a result, the USTR's proposal was to impose port taxes on Chinese shipping companies, on ships built in China, and on any operator that has Chinese-built ships in its fleet or on order.

To complement this proposal – and to promote the development of a US-flagged fleet – there was also a suggested plan to gradually mandate the use of vessels flagged or operated by US entities, with the goal of covering 15% of the country's international inbound and outbound trade within seven years. One-third of this share would be required to be carried on ships also built in the United States.

Therefore, neither the issuance of President Trump's April 9 Executive Order, "Restoring America's Maritime Dominance", nor the April 17 release of the USTR's *Final Notice of Action* – which, though moderated compared to the proposals in the Report, still significantly affected Chinese operators, ships, and shipyards, as well as (potentially) shipowners with Chinese-built vessels – should be seen as sudden or unexpected developments.

The Executive Order provides for the creation of a Maritime Action Plan (MAP) aimed at revitalizing various sectors of the United States' blue economy through a range of measures,

including public support for private shipbuilding, the revival of vocational training, the creation of Maritime Prosperity Zones (which suggests a US version of our Special Economic Zones), and the development of a strategy for Arctic routes.

The Order also instructs the USTR to issue recommendations regarding China's anti-competitive practices in the shipbuilding industry, and calls on the Secretary of Homeland Security to enforce the collection of Harbor Maintenance Fees and other charges on foreign cargo entering the United States, preventing their evasion through transshipment via Canada or Mexico.

The USTR's Final Notice of Action, on the other hand, imposed additional port fees on vessels owned or operated by Chinese-affiliated entities. It also applied – albeit at lower rates than originally proposed – to ships built in China even if owned or operated by non-Chinese entities (though these shipowners may be exempt if they invest in vessels to be built in the US).

A special regime was established with a punitive intent for all foreign-built car carriers, and with a favourable (tax-free) treatment for chemical tankers and LNG carriers, though the latter must now meet a quota favouring US-built ships. The additional fees will take effect starting with the first tariffs applied to ships calling at US ports from 14 October 2025, and will progressively increase over the following years, through April 2028.

The USTR has finally proposed imposing additional tariffs on ship-to-shore cranes, containers, chassis, and semi-trailers that are built or assembled in China or contain Chinese components.

Following the issuance of these two government measures, on April 30th a bipartisan initiative in Congress titled the “SHIPS for America Act of 2025” proposed taxpayer support for the creation of a “strategic commercial fleet” of 250 ships to be built and registered in the US over a 10-year period.

Although one could argue that American shipbuilding was already out of the market well before the rise of Chinese shipbuilding, that the additional costs would primarily

burden US consumers and businesses, and that the revival of a shipbuilding industry capable of meeting the timelines and quantities proposed by the USTR Office currently seems unlikely, what clearly emerges is a renewed awareness of the importance of the maritime sector for the country's economic security.

Not by chance, Louis Sola, the new chairman of the Federal Maritime Commission, declared at the March summit of the American Association of Port Authorities (AAPA) that no US President had ever prioritized the maritime sector as Trump did in his early days in office.

On the other hand, in 2022, 78.6% of US international trade by volume (1.6 billion tons), amounting to 44.6% by value (\$2.3 trillion), moved by sea. In the new Trump-era context, where geopolitics takes precedence over the economy, controlling these flows is considered pivotal.

While the National Bureau of Statistics of the People's Republic of China reports that Chinese trade with the US in 2024 was valued at \$688.2 billion – more than the combined trade with the second and third largest partners, South Korea (\$328.1 billion) and Japan (\$308.3 billion) – US Treasury Secretary Scott Bessent points to the “Dirty 15”, the fifteen countries accounting for nearly the entire US trade deficit, which totalled \$1.2 trillion in 2024, with China leading the list at \$263.3 billion.

An Increasingly Heated Comparison-Clash: The Panama Case

The sense of encirclement by the US is growing as China's Belt and Road Initiative – the primary global strategic project opposing the American one – now involves a significant number of Central and South American countries. In line with the fifth President of the United States, James Monroe, and his doctrine, the presence (albeit via videoconference) of Xi Jinping at the inauguration of the port of Chancay in Peru

on 14 November 2024, was deeply stigmatized by what would become, a few months later, the forty-seventh occupant of the White House. A member of his staff, Mauricio Claver-Carone, suggested imposing additional tariffs of 60% on Chinese and South American goods arriving in the US through that port. Built and operated by the Chinese state-owned company Cosco Shipping, located 78 km north of Lima, Chancay has been considered by several analysts as suitable for dual use, potentially able to host a military base.

Based on the same principles, despite the fact that maritime traffic data between the East Coast and the West Coast via Panama represents only 2.5% of total transits, the fear that this strategic point is also under Chinese control – due to the concession of two of the five terminals at the canal's ends to the Hong Kong company Hutchison Ports – has provoked a reaction from the US President. Trump even threatened the use of arms to bring the Canal back under Washington's control. It is unclear if due to these threats, but after losing 25% in stock value in one day, the Hong Kong company announced on March 4 the sale of its port assets to a consortium made up of the US investment firm BlackRock, Global Infrastructure Partners (specializing in infrastructure and controlled by BlackRock), and the terminal operator Terminal Investment (controlled by the Swiss shipping company MSC).

What was hailed as a diplomatic success for President Trump is now being questioned by the Chinese Antitrust Authority. The authority has opened an investigation to determine whether the \$23 billion deal – which includes the transfer of 43 ports worldwide as well as Balboa and Cristobal (which in fact represent only 4% of the entire deal) – violates competition rules and Beijing's interests. This comes after one of the media outlets closest to the Beijing government accused Li Ka Shing, the historic chairman of the CK Hutchison Holding group, of “spineless servility” toward the US.

In an overall scenario where, from diplomacy to the market, certainties are few, maritime operators historically most agile

seem to be seeking to quickly align themselves with White House initiatives. After acquiring Bolloré's logistics sector in Africa – a move welcomed by Washington as a tool to contain Chinese expansion on that continent – MSC, the world leader in the container sector, is once again aligning its economic initiatives in Panama with US geopolitical interests, playing the role of a true white knight for the Trump administration.

The French company CMA CGM, which recently announced surpassing Maersk as the second largest player in the container market thanks to a greater number of ships on order, did not want to be outdone by its Swiss rival, now its main competitor. Two days after press releases concerning the Geneva-USA-Hong Kong axis deal, CMA CGM announced \$20 billion in investments in American shipping. The Marseille-based company plans to add 20 ships to the fleet of American President Line (APL), which it controls, and to develop port infrastructure in key US cities: New York, Los Angeles, Dutch Harbor, Houston, and Miami. The announcement was made directly by President Trump along with CMA CGM CEO Rudolph Saade, standing in the Oval Office.

Overall, doubts about the prospective effectiveness of the measures taken by the Trump administration are mounting even within the United States. Many believe that, aside from the broader tariff battle initiated on 2 April, the actions taken in the maritime and port sector could be self-defeating. The Chamber of Shipping of America (CSA) has hypothesized a concentration of traffic on a few US ports and diversion to Mexican and Canadian ports (even though this is one of the targets of the Executive Order), with a significant impact especially on smaller US ports. Intertanko and the International Chamber of Shipping (ICS) warn of supply chain disruptions and predict that consumers and American businesses will ultimately bear the cost.

Finally, almost like a historical nemesis, is the comment from the China Shipowners' Association: after recalling the principles of free competition underlying maritime trade, the

CSA cautioned against “decisions detrimental to the stability of global trade that are driven by short-term political and economic considerations”, calling for intervention from the World Trade Organization (WTO) and the US-China Maritime Transport Agreement to find constructive solutions to current trade disputes.

21. The State of Connectivity Infrastructure in China and Southeast Asia

Paola Morselli, Ludovica Favarotto, Michele Danesi

As China's international presence continues to grow, its infrastructure initiatives – both domestic and regional, especially in Southeast Asia – have become integral to its strategic objectives. These investments are not solely about constructing physical connections; they represent a concerted effort to reshape regional trade dynamics, secure critical supply chains, and establish technological leadership in an increasingly multipolar world.

The People's Republic of China (PRC)'s push to enhance connectivity begins at home. The rapid expansion of its domestic infrastructure – most notably its high-speed rail network – reflects a strategic effort to integrate and consolidate its vast internal market. These investments aim to strengthen linkages between major economic hubs, boost regional development, and reinforce the country's resilience amid shifting global dynamics. With massive ongoing investment in power grids, railway, ports, and industrial corridors, China is laying the groundwork for long-term economic cohesion and competitiveness.

This internal infrastructure push is mirrored externally through the Belt and Road Initiative (BRI), which has transformed large parts of Central and Southeast Asia into a dense web of railways, highways, ports, and energy networks. These projects are not only designed to facilitate the smooth

movement of goods, but also to consolidate China's economic influence across the region, bypassing traditional geopolitical chokepoints – such as the Strait to Malacca.

Simultaneously, China is positioning itself at the forefront of digital infrastructure development. In an era dominated by artificial intelligence (AI) and cloud computing, control over information flow is as crucial as control over physical trade routes. This has led to significant investments in submarine cables, data centres, and digital trade corridors, forming the backbone of China's digital strategy and extending its reach to Southeast Asia and beyond.

Collectively, these physical and digital investments constitute the pillars of China's approach to embedding itself deeply into the economic fabric of Asia. However, this approach is not without challenges. Despite the substantial investments, there is a notable gap between China's infrastructure pledges and actual implementation in Southeast Asia. Political instability, economic pressures, and strategic rivalries – particularly with the United States – continue to complicate Beijing's ambitions, highlighting the delicate balance between infrastructure as a tool for integration and a potential source of friction in a rapidly evolving global landscape.

Chinese Investment in Domestic and Regional Connectivity Projects

With the BRI in its mind, China is investing heavily in connectivity projects also domestically. Particular attention is being put to implementing new railway lines and strengthening links with ports to increase the efficiency of shipping routes – particularly important in the light of the on-going trade tensions with the United States and the economic uncertainty sparked, not only on China.

At the domestic level, Beijing is putting a lot of effort into fostering its high-speed railway system as well. China Railway, the national company that operates railway transportation

announced it is going to invest \$80.8 billion in infrastructure in 2025 to open 2600 kilometers of new lines, while it recently tested the new bullet train CR450, set to reach the maximum speed of 400 kilometers per hour.¹ Even more notably, the country has pledged to reach 180,000 kilometers of operating lines by 2030, and around 60,000 kilometers will be high-speed of railway, in an effort that is unprecedented on the global stage. In April, the stunning project of building an underwater railway tunnel in the Yangtze River reached its middle point: the line is part of the Shanghai-Nanjing-Hefei high-speed railway, which will run underwater for almost 15 kilometers between the Chongming Island in Shanghai and the city of Taicang and is expected to be operational in 2029.²

At the regional level, China is implementing several developments regarding both land and sea transportation. The project gaining the most relevance in the area is the Trans-Caspian International Transport Route (TITR), also known as the “Middle Corridor”, the network of trade routes that links Europe with Western China through the Black Sea, the Caspian Sea and Kazakhstan, which represents a much shorter and more efficient transport line rather than the Northern Corridor, crossing Russia.³ Between January and November 2024, the Middle Corridor shipped a total volume of 4.1 million tons of cargo, a 63% increase compared to 2023.⁴ However, structural challenges (shortage of vessels or wagons certain areas), geopolitical uncertainties not-yet-harmonized legal constraints (e.g. custom permits) often risk slowing down the shipments or limit the capacity of the Corridor.⁵ On 27

¹ J. Chi, “China to operate 180,000 km of railway lines by 2030, with high-speed railway to hit 60,000 km”, *Global Times*, 2 January 2025.

² W. Zhou, “Underwater Yangtze River railway tunnel construction reaches milestone”, *China Daily*, 16 April 2025.

³ H. Stoll, “The Middle Corridor: A Renaissance in Global Commerce”, *Commentary*, RAND, 12 March 2024.

⁴ S. Sakenova, “Cargo Transport via Middle Corridor Surges to 4.1 Million Tons in 11 Months”, *The Astana Times*, 18 December 2024.

⁵ P. Aguiar, “The Middle Corridor: A Route Born Of The New Eurasian

December 2024, a ceremony for the incoming construction of the China-Kyrgyzstan-Uzbekistan railway was held in the Kyrgyz city of Jalal-abad. After being delayed since the 1990s, mainly due to political instability in the region, constructions of 523 km route from Kashgar⁶ (in Xinjiang Autonomous Region, China) initiated this year and is supposed to begin commercial shipments in 2030, for a total cost of around \$8 billion. The main reason for its construction⁷ lies in two logistic difficulties Beijing is currently facing: connectivity in the area heavily relies on outdated Soviet-time;⁸ and the full-scale invasion of Ukraine made it necessary to find a shipping route that could link China to Europe avoiding traditional passages through Russia or Kazakhstan. This is the reason why the Kremlin has long opposed the project, despite China affirms the construction's only aim is that of enhancing the agenda of the BRI with a new key component of its many investments.

As far as maritime connections are concerned, the PRC is behaving the same way, trying alternative routes to reduce both shipping time and uncertainty given by increased political and economic tensions worldwide. Xinhua News reported the recent opening, in April 2025, of a new land-sea corridor for export to the United Arab Emirates that can aim to substitute the traditional western route, shortening it by 4 to 10 days.⁹ On 7 April, the “Changfa Long” ship by Chang’an Automobile left off from the Qinzhou Port in Guangxi province and arrived in Dubai, marking the inauguration of the “Beibu Gulf-Jebel

Geopolitics”, *Geopolitical Monitor*, 27 January 2025.

⁶ “China – Kyrgyzstan – Uzbekistan railway construction officially launched”, *Railway Gazette International*, 7 January 2025.

⁷ “To secure exports to Europe, China reconfigures its rail links”, *The Economist*, 6 April 2025; Syed Fazl-e-Haider, “The China-Kyrgyzstan-Uzbekistan Railway: China’s Strategic Expansion in Russia’s Backyard” (via Substack), Central Asia-Caucasus Institute, 27 January 2025.

⁸ M. Ozat, “A Possible End to China-Kyrgyzstan-Uzbekistan Railway Line?”, Caspian Policy center, 10 Jun 2023.

⁹ “1st ro-ro shipping route to UAE launched at Beibu Gulf Port”, News, *China Guangxi*, 9 April 2025.

Ali Port” ship route: 4700 nautical miles and 18 days of sailing time, transportation is about 10-15% faster and 8% cheaper. The combination of railway and roll on-roll off ship can improve the connection line starting from Chongqing, that is a major hub in Southern China and going to the Middle East.¹⁰ Such endeavor demonstrates China’s growing emphasis on multimodal trade routes that bypass traditional chokepoints and improve supply chain efficiency between China and the Middle East.

Beyond its borders, China is actively pursuing new port deals and infrastructure projects to diversify and better control its trade corridors. A key driver of this push is the vulnerability of the Strait of Malacca, one of the world’s most critical maritime chokepoints through which over 60% of China’s oil imports pass. The strait, however, is heavily trafficked and under indirect influence from regional competitors, as well as U.S. naval presence thanks to Washington’s agreements with Singapore and other regional partners. To reduce this dependence, Beijing has invested in developing alternative overland and maritime corridors throughout Southeast Asia, which functions not only as a vital transit zone for goods and energy, but also as a testing ground for Beijing’s ability to shape infrastructure and trade governance at the international level.

The PRC involvement in the realm of infrastructure is not always as welcomed as it has been in Southeast Asia. Indeed, in the southern part of the region, the Chinese presence is generating some tensions with the other power in the region, namely Modi’s India. In fact, Xi Jinping has recently closed an agreement with the government of Bangladesh to participate in the construction of the Mongla port and a Chinese Industrial Economic Zone in the country, soon after the completion of the projects of the Padma Bridge and the Karnaphuli Tunnel.¹¹

¹⁰ L. Zhu and F. Zheng, “中国西部地区汽车整车出口有了新路径” (There is a New Route for Car Export in Western China), *Xinhua News*, 9 April 2025.

¹¹ S. Rizve, “Bangladesh Tilts Toward China as Its Lead Economic Partner”, *The Diplomat*, 31 March 2025; K. U. Mahmud, “Bangladesh-China Bilateral

Furthermore, Xi obtained to participate in the management and restoration project of the Teesta river in the North-West of the country, an initiative long courted by New Delhi during the previous administration of Dakha. This event shows how India might lose some grasp in regional economic cooperation in the near future, in favour of Beijing's continued interest for improving connectivity in the subcontinent.¹²

Chinese Investment in Energy Infrastructure

Other than connectivity projects, in the last decades Beijing has focused largely on energy generation plans, both within its national border as well as in foreign countries. Indeed, the PRC is globally the largest investor in electricity grid, hitting \$166 billion in 2022, more than all other countries combined; this massive investment is part of a strategy to diversify from fossil fuels – though in slow decline, as coal still accounts for over 53% of China's energy consumption – that has caused the country's energy investment structure to change significantly since 2019, increasing the generation of energy from renewables by almost 70%.¹³

However, the share of investment dedicated to electricity grids is still moderate (around 10% of total energy investment), with analysts warning that “failing to align grid investment with the rapid growth of renewable energy could undermine the broader energy transition”.¹⁴ For this reason, China is preparing for unprecedented investment in this sector: more

Cooperation: Recent Trends and Future”, CBGA Briefs, The KRF Center for Bangladesh and Global Affairs, 15 February 2025.

¹² M. Danesi, “Un nuovo inizio per le relazioni Cina-Bangladesh”, Commentary, ISPI, 2 April 2025.

¹³ N. Ferris, “Weekly data: grid investment in China more than every other country combined”, *Power Technology*, 15 March 2024; “Statistical Review of World Energy”, Energy Institute, 2024.

¹⁴ X. Zheng, “Green energy spending to top \$1 trillion by 2030”, *China Daily*, 25 December 2024.

than \$800 billion within 2030 to accelerate green transition and improve the efficiency of a system that currently shows several “creaks”.¹⁵ The Chinese strategy encompasses the idea of a “supergrid”, a structure capable of transmitting power obtained through renewable sources to densely populated areas through a net of ultra high-voltage power lines operating at 1.1 million volts:¹⁶ in 2024, China’s largest grid developer, the State Grid Corporation of China (SGCC), opened a 1,000 kV double-circuit project between Wuhan and Nanchang, a good start towards the creation of a new infrastructure of this kind connecting central China.¹⁷

At the same time, China is carrying projects related to energy infrastructure in Central Asia: where it is building new pipelines to integrate some BRI flagship projects. A project to increase the capacity of the China-Kazakhstan Oil Pipeline is expected to go on until 2029, including the construction of an additional pipeline, for a total of \$485 million.¹⁸ Moreover, the China-Central Asia Gas Pipeline has seen in 2024 the final signature to initiate construction of a Line D of the project, to connect Xinjiang with Turkmenistan.¹⁹

¹⁵ E. White and W. Ding (2024), “Gridlock in China: high spending on Network in Shift to Green Energy”, *Financial Times*, 9 July 2024.

¹⁶ E. Bou, “China Is Building A Supergrid - And So Should We”, *Forbes*, 21 January 2025.

¹⁷ “China’s SGCC operationalises 1,000 kV Wuhan–Nanchang UHVAC project”, *Asia-Pacific News*, Global Transmission report, 1 November 2024.

¹⁸ “Kazakhstan-Kazmunaygas-Pipeline-Cost”, *Italian Trade Energy Newsroom*, 27 November 2024; “KazMunayGas, CNPC discuss expansion of Kenkiyak-Atyrau, Kenkiyak-Kumkol oil pipelines”, *Interfax*, 29 May 2023.

¹⁹ C. Liang, “PetroChina looking to resume Central Asia Gas Pipeline Line D construction in 2024”, *S&P Global*, 21 December 2023; “Statement for Media”, Ministry of Foreign Affairs of Turkmenistan, 12 August 2023.

China's Role in Southeast Asia's Infrastructure Development

China's infrastructural expansion in Southeast Asia reflects a complex geopolitical and economic strategy characterized by direct investments, ambitious projects, and the challenges posed by regional instability. Over the past decade, these investments have fluctuated significantly, declining from their peak during the 2010-2020 period but remaining crucial for regional development.

China's investments in Southeast Asia remain concentrated in several key sectors. The region has become a global manufacturing hub due to substantial Chinese investments, particularly in electronics and automotive sectors. Countries like Vietnam, Malaysia, and Thailand host numerous Chinese firms producing electronic components and vehicles. Beijing also heavily invests in the extraction of critical minerals present in Southeast Asia essential for technological supply chains and the global energy transition. Indonesia, with its vast nickel reserves, is a primary beneficiary, while Vietnam and Myanmar are critical sources of rare earth elements.

Of particular importance is Chinese financing of extensive infrastructure projects, including high-speed rail networks, ports and power plants, aimed at strengthening regional connectivity and supporting industrial growth. These projects facilitate trade and integrate supply chains among regional actors, also working to consolidate China's presence and economic influence in Southeast Asia. In this regard, according to data from the Chinese Ministry of Commerce, between January and November 2024, non-financial direct investments from Chinese entities in BRI countries reached \$29.5 billion, accompanied by \$113 billion in new contracts.²⁰ However, this represents a notable reduction compared to the previous decade,

²⁰ "MOFCOM Regular Press Conference", Ministry of Commerce of China, 21 November 2024; C.N. Wang, "China Belt and Road Initiative (BRI) Investment Report 2024", Green Finance and Development Centre, 27 February 2024.

with the number of new agreements falling by 40% between 2020 and 2024. The average number of new projects signed annually has decreased from 120 to roughly 70, reflecting a broader strategic shift both within China – as it focuses more on smaller scale, targeted projects – as well as within receiving states – that have started to be more wary of over reliance on China and fear over indebtedness. Despite this decline, the energy and transportation sectors remain dominant, with the PRC financing nearly 70% of the region's megaprojects, largely concentrated in fossil fuels and critical infrastructure.

Central to this infrastructural push are major corridors aimed at enhancing connectivity between China and Southeast Asia. These include the China-Myanmar Economic Corridor (CMEC) under the BRI and other emerging projects under the Global Connectivity Initiative (GCI), which aim to solidify Beijing's influence across the region.

Among the most significant projects under the BRI framework is the Kunming-Singapore High-Speed Railway, a colossal 5,000 km rail network designed to link Beijing directly with Singapore.²¹ This extensive system passes through Vientiane in Laos, Bangkok in Thailand, and Kuala Lumpur in Malaysia, forming a corridor that integrates some of the region's most dynamic economies, thus creating a seamless link from China to the heart of ASEAN. The first segment, a 1,000 km rail line worth over \$6 billions linking Laos' capital Vientiane to China's Kunming became operational in 2021, with China owning 70%, significantly reducing travel time and enhancing trade flows between the two countries.²² Meanwhile, the second phase in Thailand is currently under construction: Bangkok

²¹ J. Clark, "Myths and realities of the Singapore-Kunming Rail Link", *Future Southeast Asia*, 24 September 2024; H. Chen, "China is trying to connect Southeast Asia by high-speed rail. Here's how that's going", *CNN*, 26 March 2024.

²² A.F. Medina, "The Completed China-Laos Railway: Bringing Opportunities for ASEAN and the Asia Pacific", *ASEAN Briefing*, 21 December 2021; J. McDonald, S. McNeil e E. Kurtenbach, "Laos-China railway to launch as debt to Beijing mounts", *Reuters*, 2 December 2021.

plans to begin operations of this high-speed rail by 2030, almost a decade later than initially planned.²³

In Myanmar, the Kyaukphyu Deep-Sea Port and the China-Myanmar Economic Corridor (CMEC) represent another critical segment of China's strategic infrastructure network. The deep-sea port in Kyaukphyu, partly completed despite political instability in Myanmar, will provide China with direct access to the Indian Ocean, significantly reducing its reliance on the Malacca Strait for energy and trade. This project, which links China's Yunnan province to the ocean, forms a critical part of Beijing's broader strategy to diversify its trade routes and secure vital energy supplies. Discussions began in 2010 on the \$1.3 billion special economic zone adjacent to the \$7.3 billion port project.²⁴ However, China's Belt and Road Initiative projects in Myanmar, focused on hydropower, connectivity, and industrial zones, have faced delays due to debt concerns, COVID-19, and political instability, especially after the 2021 coup, which disrupted projects, made the junta lose control over vast swaths of the country and fueled fears over China's influence.²⁵

Meanwhile, in Cambodia, the Funan Techo Canal is set to become a vital artery for regional trade. The project was first announced in 2021 and officially broke ground on August 5, 2024, will be built by Chinese state-owned construction company, China Road and Bridge Corporation (CRBC). It was initially expected to cost \$1.7 billion, but the budget was later reduced to little more than one billion, with China covering 49% of the cost. The Canal aims to connect the Mekong River with the Gulf of Thailand, enhancing Cambodia's internal connectivity while reducing its dependence on Vietnamese

²³ "Thailand expects high-speed rail link to China to be ready in 2030", *Reuters*, 29 January 2025.

²⁴ Nyein Chan Aye, "Myanmar OKs Resumption of Construction at Beijing-Backed Indian Ocean Port", *Voice of America*, 29 January 2024.

²⁵ M. Kavi, "China's CITIC and Myanmar Junta Discuss Progress on Rakhine Deep-Sea Port", *The Irrawaddy*, 4 March 2025.

ports.²⁶ This channel will facilitate the movement of goods between the region's agricultural heartland and global markets, reinforcing the economic integration of the Mekong subregion.

A project that could become a central component of China's infrastructure push is the Thai Land Bridge, designed to connect the Andaman Sea with the Gulf of Thailand. This ambitious plan, currently still in the advanced planning stages – with the Bangkok government actively courting Chinese, Indian and other international investors to finance the endeavor – should include the construction of deep-sea ports, gas and oil pipelines and extensive logistics infrastructure.²⁷ China has expressed interest in such projects, as it would provide a terrestrial alternative to the heavily congested Malacca Strait, thus offering a faster, more secure trade route between the Indian and Pacific Oceans, reinforcing Thailand's role as a pivotal logistics hub in the region.²⁸

Additionally, China has invested heavily in other critical transport infrastructure projects across the region. In the Philippines, the Mindanao Railway – a \$1.57 billion venture – is under construction, set to transform connectivity in the southern part of the archipelago. In Cambodia, the new Phnom Penh Airport, valued at \$1.1 billion, is over halfway to completion, promising to bolster the country's aviation capacity and support the rapid growth of its tourism industry.

China has also made significant investments in the energy sector, with a strong focus on hydropower and coal. In Laos, the Nam Ngum 3 Hydropower Plant, worth over \$1 billion, is nearing completion and is currently 84% finished; the dam will have a total capacity of 480 MW and is expected to produce

²⁶ G. Stanhope e H. Buckley, "The murky waters of Cambodia's Funan Techo Canal", *The Interpreter*, 5 December 2025.

²⁷ E. Mark, "Thailand's Land Bridge: Navigating Geopolitical and Investor Concerns", *Perspective*, ISEAS Yusof Ishak Institute, 18 February 2025.

²⁸ H. Nan, "Bypassing Malacca? China, India and the UAE vie for Thailand's land bridge", *ThinkChina*, 14 April 2025.

2,345 GWh of electricity annually.²⁹ A similar project in the country, the Pak Lay Hydropower, valued at \$2.13 billion, is in its early stages and is expected to produce 770 megawatts of electricity.³⁰ Across Vietnam, Indonesia, and Laos, numerous other coal and hydropower plants are either under construction or have recently been completed, reflecting China's strategic focus on securing energy supplies for its rapidly growing industrial base.

Thus, for many Southeast Asian countries, China has become the primary financier of infrastructure projects, underscoring the importance of the country for regional growth. According to a report by the Lowy Institute, out of 34 major infrastructure projects in the region, 24 are sponsored and financed by the PRC.³¹ Of these, the majority focus on energy generation, with a strong emphasis on fossil fuels, while the remainder primarily involve transport networks. Notably, only about a third of these projects have reached completion, highlighting the significant gap between planned and realized investments.

Indeed, despite these substantial investments, a considerable gap between China's ambitious commitments and actual project execution persists. Numerous projects have faced delays, cancellations, or scaling down due to political instability in the partner country, as well as leadership changes and subsequent shifting national priorities. For example, the Thailand-China high-speed railway project has encountered multiple delays due to political turnover in Thailand, while political upheaval and the 2021 military coup in Myanmar have hindered the progress of the Kyaukphyu deep-sea port and the *China-Myanmar Economic Corridor*. Similarly, leadership changes in the Philippines have shifted priorities away from earlier

²⁹ "Nam Ngum 3 Hydropower Plant to Begin Power Generation in Early 2027", *LAO News Agency*, 6 January 2025.

³⁰ "Pak Lay Hydropower Project", Mekong River Commission for Sustainable Development (online).

³¹ <https://interactives.lowyinstitute.org/features/mind-the-gap-chinas-bri-south-east-asia/>

Chinese-backed projects, reflecting the complex political dynamics that can disrupt infrastructural ambitions.

Moreover, the region is often marked by high levels of corruption, opaque decision-making, and fragmented governance, further complicating project implementation. These factors have significantly slowed the pace of Chinese infrastructure investment in recent years, reinforcing the need for more strategic, politically sensitive approaches if Beijing hopes to maintain its influential role in Southeast Asia's economic future.

Connectivity and Digital Infrastructure

While China's investments in physical infrastructure have reshaped much of Asia's connectivity landscape, an equally strategic shift is unfolding in the digital realm. Digital infrastructure is now at the heart of the global economy and technological advancement, serving as an "engine" for growth and innovation. Indeed, a vast network of submarine cables featuring high-speed, low-latency connectivity enables the efficient transfer of large volumes of data between businesses and end-users, while also providing access to distributed computing and cloud services around the world.³²

The expansion of connectivity infrastructure in the Asia-Pacific region is not only driving economic development but also helping to bridge the digital divide.³³ From a macroeconomic perspective, a strong digital infrastructure network enhances competitiveness, attracts foreign investment and promotes high-tech industries, while ensuring greater integration between urban and rural areas. Southeast Asia, in particular, is a prime example of this trend, with several countries in the

³² A. Mauldin, "Do Submarine Cables Account For Over 99% of Intercontinental Data Traffic?", *TeleGeography*, 4 May 2023.

³³ "Digital Transformation: Confronting Challenges, Closing the Connectivity Divide", *Telecom Review Asia Pacific*, 22 June 2023.

region embracing the concept of digitization as a “strategic priority”.³⁴ It is estimated that the Internet-based economy of this part of Asia will reach \$1 trillion by 2030, driven by a rapidly expanding base of digital consumers and businesses.³⁵

In addition, submarine cables are critical to the ongoing AI boom, serving as the backbone for data centres. These infrastructures have extraordinary computing power, enabling them to store, process and distribute vast amounts of data. Although the United States currently leads in the number of data centres (5,426 in 2025),³⁶ the Asian continent is experiencing a rapid increase in investments aimed at building ad-hoc facilities capable of supporting the growing demand for digital services, cloud computing, and AI applications.³⁷ China currently dominates the regional market, with 449 facilities and an additional 122 in Hong Kong as of April 2025.³⁸ In addition, the APAC data centre market is estimated to grow at a compound annual growth rate of 12.6% between 2024 and 2032, potentially reaching a market value of \$71.7 billion by 2032.³⁹

Digital infrastructure projects

Since the late 1990s, the Asian continent has witnessed an increase in the number of submarine cable projects. In particular, the Asia-Pacific Cable Network (Apcn) is considered one of the most important installations, both in terms of the timeframe in which it was built and the pool of countries it connects.

³⁴ S. Lin, “3 strategies for delivering digital transformation in the Asia-Pacific”, World Economic Forum, 30 January 2023.

³⁵ “Southeast Asia internet economy to hit \$1 trln by 2030, report says”, *Reuters*, 10 November 2021.

³⁶ P. Taylor, “Leading countries by number of data centers as of March 2025”, Statista, 21 March 2025.

³⁷ G.A. Casanova, and L. Favarotto, “Data Centers: The Indo-Pacific’s Hottest Trend”, *ISPI*, 6 August 2024.

³⁸ K. Tran, “Number of data centers in the Asia-Pacific region as of April 2025, by country or territory”, *Statista*, 11 April 2025.

³⁹ “Asia Pacific Data Center Market Analysis”, Renub Research, 26 July 2024.

Launched in 1997, it enables data transmission between Japan, South Korea, Taiwan, Hong Kong, the Philippines, Thailand, Indonesia, and Malaysia.⁴⁰ In 1999, it was the turn of South East Asia-Middle East-Western Europe 3 (SEA-ME-WE 3), a project that resulted in a network of more than 40,000 km, with the aim of connecting more than 30 countries.⁴¹ Over the years, this submarine cable has been complemented by new upgrades – mainly geographical and technological – making it the longest in the world. After 25 years of operation, it was announced that the project had reached its “end of life” (EOL) in December 2024.⁴² With the retirement of SEA-ME-WE 3, connectivity between the different regions of the world is now entrusted to the more recent projects of the series (SEA-ME-WE 4, SEA-ME-WE 5 and the upcoming SEA-ME-WE 6). The Sea-ME-WE 6 cable, scheduled to be operational in 2026, will connect Singapore to Marseille, passing through countries such as Italy, Greece, Egypt, Saudi Arabia, Djibouti, Pakistan, India, the Maldives and Sri Lanka.⁴³ The project involves laying a 21,700 km cable at a cost of about \$500 million. Although several Chinese companies had initially submitted a lower bid for the consortium behind these underwater pipelines, the contract was ultimately awarded to the US-based SubCom. This was due to favourable economic incentives from Washington, as well as the threat of sanctions if Chinese companies were involved in the project.

Overall, the Asia-Pacific region leads the world in terms of investment in this industry, with projected spending for the 2024-2026 biennium exceeding that of any other part of the world.⁴⁴ In this scenario, Southeast Asia is emerging as a leader

⁴⁰ “APCN Cable System Overview”, *Submarine Cable Networks*, 21 September 2011.

⁴¹ Submarine Cable Networks, *SEA-ME-WE 3*.

⁴² N. Yadav, “SeaMeWe-3 cable retired after 25 years in service”, *Data Center Dynamics*, 4 December 2024.

⁴³ Submarine Cable Networks, *SEA-ME-WE 6*.

⁴⁴ C. Ting-Fang, et al, “China’s undersea cable drive defies U.S. sanctions”, *Nikkei*

in digital submarine connectivity, with ongoing projects led by consortia of Western and Chinese companies. Singapore stands out as one of the most vibrant hubs, hosting no less than 26 submarine cables, with 13 more in the planning and construction phase.⁴⁵ This is a record compared to neighbouring countries (such as Malaysia, Indonesia and Japan), which have up to 20–22 submarine cables each, despite having much larger territories and populations. In addition, the city-state's government plans to double its submarine cable hosting capacity over the next 10 years as part of its broader strategy to become a “hub of globally important green data centres”. Moreover, it seeks to mitigate risks associated with the country's and region's digital connectivity by leveraging the redundancy approach within existing digital infrastructure.⁴⁶ It is expected that this move could result in investments of up to \$7.4 billion in new submarine cables, and a total of \$20 billion if data centres are included. Among the major projects underway, Meta and Google plan to complete the Echo submarine cable project, which will be the first to connect the United States directly to Singapore.⁴⁷ Added to this is the Bifrost cable system, a \$760 million cable connecting Singapore and the United States via Indonesia.⁴⁸ In May 2025, it was announced that the project, which is also co-funded by Meta and Amazon Web Services, was “ready for service”.

Among the subsea infrastructure projects passing through Singapore is Sparkle's infrastructure, which reaches the country via SeaMeWe 4 and SeaMeWe 5.⁴⁹ From there, the undersea system extends to Malaysia, where it supports connectivity

Asia, 26 June 2024.

⁴⁵ Z. Abdullah, “Singapore to double capacity for subsea cable landings to enhance digital connectivity”, *The Straits Times*, 21 November 2024.

⁴⁶ “Green Data Centre Technology Roadmap”, *iDA Singapore*, 2023

⁴⁷ T. Suruga, “Singapore to double subsea cable landings in digitization push”, *Nikkei Asia*, 5 June 2023.

⁴⁸ *South China Morning Post*, *US\$760 million Singapore-America undersea cable nears finish line*, 24 January 2025.

⁴⁹ Sparkle, *Corporate Presentation*, 20 June 2019.

requests to local data centres built to meet Singapore's growing demand for data storage services after the government decided to pause construction plans in 2019-2022 due to limited energy resources.

China's investments and its confrontation with the US

Over the past 15 years, China's capacity to manufacture, lay and operate global submarine cables has developed rapidly: in 2012, HMN Technologies (formerly Huawei Marine) had a 7% share of the global submarine cable market, rising to 18% by 2019.⁵⁰ Additionally, between 2021 and 2026, more than 20 cables have been commissioned or are planned in the Asia-Pacific region.⁵¹ All of these investments are being made by Chinese firms, including FiberHome, which has emerged in recent years as an alternative to Huawei. According to the China Academy of Information and Communications Technology (CAICT) – the country's leading telecom think tank – Chinese companies will account for 45% of the 770,000 km of cables to be installed between 2023 and 2028.⁵² HMN Technologies and Hengtong Group (China's largest manufacturer of electrical and fibre optic cables) have laid more than 90,000 km of submarine cables in recent years, a result largely made possible by generous subsidies provided by Beijing to support local companies.⁵³ Since 2015, the PRC has adopted a strategic approach to offset Washington's actions: on the one hand, it provides money to improve communications infrastructure, increase surveillance, and promote e-commerce in developing partner countries;

⁵⁰ J. Brock, "U.S. and China wage war beneath the waves – over internet cables", *Reuters*, 24 March 2023.

⁵¹ P. Basu, "Multilateralism key for de-risking Indo-Pacific subsea cables", *Pacific Forum*, 19 July 2024.

⁵² C. Ting-Fang, L. Li, T. Suruga, S. Tabeta, [China's Subsea Cable Drive Defies US Sanctions](#), *Nikkei Asia*, 26 June 2024.

⁵³ S. Patil e P. Gupta, "The Digital Silk Road in the Indo-Pacific: Mapping China's Vision for Global Tech Expansion", Observer Research Foundation (ORF), Issue N. 683, January 2024.

in return, it increases its economic, strategic, and diplomatic influence in the region.⁵⁴

Currently, there are at least three major projects underway, led by Beijing, aimed at connecting mainland China and Hong Kong with several Southeast Asian countries, including Vietnam, Cambodia, the Philippines, Malaysia, Singapore and Indonesia. The Asia Link Cable (ALC) is a 6,000 km submarine cable system designed to enhance connectivity between China and the southern part of the region. It is currently under construction and is expected to be operational by the third quarter of 2025.⁵⁵ Additionally, the Southeast Asian Hainan–Hong Kong Express Cable System (SEA-H2X) is also scheduled for completion during the same timeframe.⁵⁶ This project will span 5,000 km, connecting Hong Kong to approximately seven Southeast Asian countries to strengthen digital infrastructure. Lastly, the Asia Direct Cable (Adc), which will cover 9,400 km, was completed in November 2024. This undersea cable system will provide high-capacity and low-latency connectivity across East and Southeast Asia.⁵⁷ Previously, HMN Technologies was awarded the Pakistan East Asia Africa Cable Express (“Peace”) project, which is China’s longest transcontinental digital cable with a total length of approximately 25,000 km.⁵⁸ Peace’s route, which began construction in 2018 and has been in operation since 2022, is similar to that of SEA-ME-WE 6, making it its *de facto* “geopolitical competitor”.⁵⁹ All these projects are key components of China’s Digital Silk Road initiative, which aims to enhance digital connectivity and infrastructure while

⁵⁴ J. Sherman. “Cyber defense across across the social floor: the geopolitics of Submarine cable security”, Atlantic Council, 13 September 2021.

⁵⁵ Submarine Cable Networks, *ALC*.

⁵⁶ “SEA Hainan-Hong Kong Express undersea fiber-optic cable network in Sarawak set for completion by 3Q 2025”, *The Borneo Post*, 18 December 2024

⁵⁷ “The Asia Direct Cable System and Its Role in Shaping the Region’s Digital Future”, *Telecom Review*, 23 January 2025.

⁵⁸ J. Brock, “U.S. and China wage war beneath the waves – over internet cables”, *Reuters*, 24 March 2023.

⁵⁹ *Ibidem*.

expanding China's influence and presence in the Asia-Pacific region.

Nevertheless, the growing technological de-risking between China and the United States has also affected undersea connectivity, leading to delays and, in some cases, even the total shutdown of several projects. In total, China has invested in constructing more than 65 submarine cables since 2010, although at least six projects have been impacted or delayed due to tensions with Washington. In 2019, the Trump administration effectively halted the direct connection between the United States and Hong Kong via the Pacific Light Cable Network (PLCN), which was designed in 2016 through a collaboration between Facebook and Google. The final result, which is now operational, terminates in the Philippines and Taiwan, leaving out Hong Kong altogether.⁶⁰ Even more emblematic is the case of the Hong Kong-America cable system (Hka), which was supposed to connect Hong Kong to California through investments from both China (including China Telecom) and the United States (such as Meta). However, despite being launched in 2018, the project was delayed for three years when the international consortium behind its construction withdrew its application; the rectification came at a time when more than 85% of the cable connecting mainland China to the US territory had already been laid.⁶¹ Furthermore, the "Bay to Bay Express" (BtoBE) cable system, an international collaboration between major communications giants – including China Mobile, Meta and Amazon – has also suffered setbacks. Originally planned to connect Hong Kong to Southeast Asia and California, it has been rerouted to avoid a direct connection to the Chinese metropolis. The new plan – renamed Cap-1 – only links the Philippines with the United States.⁶²

⁶⁰ Submarine Cable Networks, *PLCN*.

⁶¹ W. Qiu, [HKA Consortium Withdraws Application for Submarine Cable Landing License in the US](#), *Submarine Cables*, 12 March 2021.

⁶² Submarine Cable Networks, *Bay to Bay Express Cable System (BtoBE)*.

Although the U.S. strategy appears to have been successful in reducing the share of HMN Tech in global supply (around 10% in 2025),⁶³ Beijing has continued to enhance its technological capabilities in the sector and has demonstrated its ability to independently manage the entire value chain of submarine cable projects.

Conclusion

Asia, particularly China, is at the forefront of investment in infrastructure for national and regional development, whether in transportation, energy or digital connectivity. The massive influx of capital and the rapid pace of projects underway are driven by the need to address existing gaps in logistic networks. Infrastructural projects are essential for the economic and technological advancement of the countries involved, China included, and their implementation may also contribute to speed up achieving higher levels of sustainability in the future. High-quality technological development is thus no longer merely the objective of such investments – it has become both the catalyst and driving force. What these large-scale infrastructures investment plans ultimately reveal is a “shifting paradigm”: emerging countries and private companies are stepping onto the global stage, reshaping the current geopolitical landscape through increasing complex, interconnected projects and strategic alliances.

⁶³ A. Gross et al., “[How the US is pushing China out of the Internet’s plumbing](#)”, *Financial Times*, 13 June 2023.

22. The Geoeconomics of Connectivity: New Corridors from Europe to Africa and Asia

Alberto Rizzi

International transport corridors – networks of infrastructure such as roads, railways, and shipping lanes – are much more than mere conduits for goods; they are pivotal instruments in global trade, geopolitical strategy, and economic development. Through the connection of disparate regions and the facilitation of movement of goods and people, these corridors have become central to international relations. Two forces in particular are strengthening the relevance of transport corridors: multipolarity and interdependence. On the one side, the end of the American multipolar order, especially geoeconomically, is bringing about a new situation with looser ties between countries where economic corridors play a key role in keeping partners together. Infrastructure and trade routes, in fact, prevent actors that do not belong to the same international alignment from drifting too far apart. This is crucial when it comes to the Global South, the group of non-Western developing economies: caught in the US-China rivalry, they seek cooperation with all major powers but do not wish to take sides. As those developing economies wish to move up the value chains and strengthen their integration in global markets, transport infrastructure ranks at the top of their requests, while major powers are interested in those countries' natural resources, industrial capacity, and expanding markets.

The other force shaping international transport corridors is the interdependence of the global economy. Even if the globalisation experienced until the late 2010s is arguably over, interdependence in industry, trade, and finance remains high and extremely complex.¹ Supply chain disruptions witnessed during the Covid-19 pandemic are a testament to this, as is the number of components from different countries used to manufacture electronic goods like Apple's iPhone.² This complexity requires a smooth and rapid flow of goods, allowing manufacturers to source easily raw materials and inputs, as well as reliable routes to bring their products to export markets.

The contemporary emphasis on transport corridors is largely driven by the rise of the rebalancing of the economic centre of gravity towards Asia, and by Africa's growing importance in the global economy and demographic boom. The African continent also holds massive reserves of critical raw materials (CRMs) essential to build hardware for artificial intelligence, electric vehicle batteries, and defence equipment.³ Transport corridors allow easier access to those resources, facilitating trade and overcoming bottlenecks or obstacles by rival powers.

Europe at the Forefront of Mediterranean Corridors

Access to mineral resources and commodities, however, is only one of the reasons why the European Union is investing in the development of transport corridors. Brussels aims, in fact, to reach different economic security and foreign policy goals through those connectivity initiatives, starting from its immediate neighbourhood and reaching out as far as India

¹ E. Braw, *Goodbye Globalization: The Return of a Divided World*, New Haven, Yale University Press, 2024.

² S. Joiner et al., "Why Trump can't build iPhones in the US", *Financial Times*, 28 April 2025.

³ A. Lemma, "Critical minerals, critical moment: Africa's role in the AI revolution", *ODI Global*, 10 February 2025.

and sub-Saharan Africa. In the Mediterranean dimension, Europe is primarily concerned – besides energy imports – with extending its Trans-European Transport Network (TEN-T) to the southern shore and to reduce the length and vulnerability of its supply chains. After the pandemic shock and willing to diversify away from China as the main supplier of inputs and manufactured goods, European countries and firms are looking south, especially towards the Maghreb region to establish production facilities, leveraging the geographical proximity and local industrial capabilities.⁴ In the Western Mediterranean, Morocco has rapidly emerged as a key hub for automotive manufacturing, exporting both components and finished vehicles to EU countries like Spain, France, Italy, and Germany also thanks to its lower labour costs compared to central and eastern Europe. The same progressive integration of value chains is happening with other two Maghreb countries, Tunisia and Algeria, albeit the latter proceeds at a slower pace due to Algier's economic closure and growing tensions with the EU over trade and migration⁵. Parallel to the European Mediterranean Corridor, which is part of the TEN-T network and extends from the Southern Spain port of Algeciras to Ukraine through France, Italy, Slovenia and Hungary, another key corridor is progressing on the North African shore. Initially imagined in 2008, the Trans-Maghreb Multimodal Corridor seeks to improve the transport connectivity between Morocco, Algeria, Tunisia and Libya. A key component of this is the Trans-Maghreb Railway, a project to refurbish and renovate existing lines to connect Casablanca with the Tunisian capital, drastically reducing the travel times for people and freight. Despite the political problems it faces, such a corridor would provide a key development in the region, filling a crucial gap

⁴ M. Tanchum, “Africa-to-Europe value chains: How nearshoring can mitigate Europe's migration crisis and aid energy transition”, International Centre for Migration Policy Development (ICMPD), 8 February 2024.

⁵ D. Ghanem, “Rocky Road Ahead: The Challenges of Eu-Algeria Relations”, Commentary, ISPI, 23 July 2024.

in Mediterranean connectivity. Infrastructure and connectivity in the region have in fact been primarily promoted, especially from the European side, on a vertical dimension, seeking to improve links on a north-south axis and giving little attention to the horizontal component on the North African coast. While the Moroccan Algerian standoff constitutes a major obstacle to cross-border links, the establishment of such a network would be of crucial importance in supporting economic growth, industrial development, and cross-border connectivity.⁶ On the one hand, the region represents the obvious destination for European nearshoring, the practice of relocating industrial production facilities closer to the EU to reduce disruption risks; on the other one, it drastically lacks connectivity and economic integration, thus making such a relocation inherently difficult on a regional basis. This is why several connectivity projects proceed on a mini-lateral basis, connecting a single Maghreb country with one European partner or a third country. This is the case of the Turkey-Italy-Tunisia corridor, which leverages the Italian geographical position, its ports facilities, and its high-speed railway network, to simplify the intermodal movement of goods in a triangle centred on Southern Italy, Tunis and Rades, and Mersin port on Turkey's Aegean coast.⁷ Further East in the Mediterranean, Greece is developing the port of Alexandroupolis – with significant support from the US – as a regional hub to serve both strategic deterrence against Russia, and to facilitate trade flows of the TEN-T corridors. The port will in fact facilitate trade from Egypt and the Suez Canal to Bulgaria and Romania, linking Greece with existing

⁶ L. Danese and A. Rizzi, "The Impact of Algeria-Morocco Rivalry in the Transport Sector and Why Connectivity Matters", in E. Cohen-Hadria and C. Limon (eds.), "Morocco and Algeria Beyond the Divide: From Costs of Non-Engagement to Pathways for Cooperation", *Diplomeds*, January 2025.

⁷ M. Tanchum, "Italy and Turkey's Europe-to-Africa Commercial Corridor: Rome and Ankara's Geopolitical Symbiosis Is Creating a New Mediterranean Strategic Paradigm", AIES, October 2020.

Eastern European and Black Sea networks.⁸ If any effort that improves connectivity in the region and strengthens the European position in Mediterranean infrastructure and transport landscape is to be welcomed, uncoordinated efforts are hardly ideal when it comes to corridors. Interoperability, interminability, and the ability to build effective networks are essential to avoid duplication, inefficiency and to establish an effectively integrated system within the region.

The Struggle for African Connectivity

Corridors along the North African coast do not only hold strategic value for Europe in themselves, but also as the gateway to the African continent. It is not by chance that the EU has decided to allocate through the Global Gateway Investment Package half of the initiative resources, €150 billion, to Africa. Sub-Saharan Africa has witnessed in the last decade a growth of infrastructural investments, paired a diversification of external actors involved in the construction and management of transport corridors and facilities. Major and middle powers are in fact targeting Africa with key investments, attracted by the continent's vast mineral riches that are essential to the production of electronic goods, green energy components, and the defence industry. Beyond its underground resources, African countries are also experiencing a demographic boom that would bring the continent's population to account for 28% of the world total in 2050, substantially doubling the number of working-age Africans compared to today.⁹ Coupled with the progressive establishment of an African Continental Free

⁸ A. Marghelis, "The port of Alexandroupolis: a strategic and geopolitical assessment", *Fondation pour la recherche stratégique*, no.18/2024, 1 August 2024.

⁹ S. Sinha and M. Getachew, "[As Africa's Population Crosses 1.5 Billion, The Demographic Window Is Opening; Getting The Dividend Requires More Time And Stronger Effort](#)", UN Economic Commission for Africa, 12 July 2024.

Trade Area (AfCFTA), the continent could boost its growth perspectives. Yet, the reduction of tariff and non-tariff barriers can only improve cross border trade if it is accompanied by the hard infrastructure components, and Sub-Saharan Africa suffers from significant infrastructure deficiencies, further aggravated by the difficult geography of the continent. In this regard, electricity interconnections are equally important to transport infrastructure, addressing the significant challenge of limited energy access in Africa. The progressive integration of national grids will also support the development of pan-African energy market, allowing surplus nations to export to neighbouring countries. Notable examples include the transmission line connecting Côte d'Ivoire, Guinea, Liberia, and Sierra Leone (CLSG), as well as the North Core/Dorsale Nord Regional Power Interconnector Project, aiming to increase capacity and cross border electricity trade between Nigeria, Niger, Benin and Burkina Faso.¹⁰

Regional corridors have featured prominently in the 2025 Annual Meeting of the African Development Bank, which has invested more than \$50 billion in infrastructure over the last decade to boost connectivity.¹¹ Transport corridors are crucial for unlocking Africa's potential, integrating it into the global economy, and facilitating trade with both Asian and European markets. A key example is the Trans-Saharan Road Corridor, a 4,500 km network of highways linking the North African ports of Gabes, Algiers, and Tunis with the Lagos Port Complex in Nigeria, a major trade hub in Western Africa, through Niger.¹² The corridors, which is nearing completion, will also strengthen the role of Sahelian economies as transit hubs and allow them

¹⁰ West African Power Pool, "[Eighth Meeting of Joint Supervisory Committee of the NorthCore Project: A Step Forward towards Regional Energy Integration](#)", 26 February 2025.

¹¹ African Development Bank, "[2025 Annual Meetings: Regional corridors as drivers of continental integration](#)", ADB, 19 March 2025.

¹² UNCTAD, "The Trans-Saharan Road Corridor Towards an Economic Corridor: Commercializing and Managing the Trans-Saharan Road", 2022.

to alleviate their landlocked status by providing better access to the Mediterranean and Atlantic coasts.

While roads remain the preferred transport option in Africa, carrying roughly 80% of freight in the continent, railways are being increasingly developed – primarily thanks to foreign investments – thanks to their greater cost efficiency and greater ability to move goods at long distances.¹³ Yet, the African continent suffers from a chronic lack of efficient railways and transnational lines. Most of the countries possessing extensive and functioning railway networks are in fact located north of the Sahara, like Egypt, Morocco, and Tunisia. The latter two have embarked on substantial upgrades of their infrastructure and rolling stock. Morocco is partnering primarily with France, while Algeria's 6,000 km of new rail lines are being built by Chinese firms.¹⁴ Yet, the two countries are locked in harsh rivalry that prevents the construction of any cross-border link between the respective national networks, thus limiting the potential benefits and furthering the lack of horizontal connectivity in North Africa. Egypt is also modernising its railway system, creating high-speed lines, electrifying vast sections of the network and improving freight transport capabilities. This plan is essential to Egypt's role as a node in connectivity initiatives between Africa, Europe, and Asia. In East Africa, a project first proposed in the early 2000s is now gaining new momentum: the East African Railway Master Plan seeks to substantially upgrade standard gauge railway connections between Tanzania, Kenya, Uganda, Rwanda, Burundi, and South Sudan, providing cross-border interoperability. Negotiations are ongoing about the inclusion of Ethiopia, Africa's fifth-largest economy by GDP and a landlocked country that would greatly benefit from transnational rail connectivity.

¹³ J.M. Vilardell and M. Espinosa Mateo, "Reform schemes for African railway and road networks", *ALG Global*, 2 October 2023.

¹⁴ "Algeria partners China for construction of 6,000km railway lines", *AfricaNews*, 13 August 2024.

Railways are advantageous over roads, especially to move bulk cargo like minerals over long distances, and this plays a key role in what is arguably the most significant Western-led transport corridor in Africa, the Lobito Corridor. The project launched by the G7's flagship infrastructural initiative Partnership for Global Infrastructure and Investment (PGII) in 2023, aims at connecting the Angolan port of Lobito with the mining regions of Zambia and the Democratic Republic of Congo (DRC). Relying partly on the renovation of colonial railways and partly on the construction of new links, the Lobito Corridor holds strategic value to its promoters for different reasons. First, the route will grant access to the commodities of the Copper Belt between Zambia and the DRC, which a major mining basin for copper, cobalt, and lithium and connect easily connect the area with port facilities for export. Access to critical minerals is essential not only to support the European pathway to net-zero by 2050 but also to reinforce the economic security of the continent, diversifying the supply of raw materials necessary to the manufacturing sector. At the same time, the corridor represents a major effort by the G7 to push back against Chinese influence in the region, largely gained through the Belt and Road Initiative (BRI) and its massive infrastructural investments in Africa. Europe and the US are thus offering alternatives to the Chinese model for infrastructure financing, seeking to regain influence in the region and to weaken Beijing's monopoly over critical minerals in the developing world. Supported by the EU Commission, the US, the African Development Bank and the Africa Finance Corporation, the project shows a remarkable unity of intent by the G7 and transatlantic support to the initiative. This is crucial to avoid fragmentation of efforts and to present African partners with a credible offer for infrastructural development alternative to China's. The Lobito Corridor is therefore the first major test about the seriousness and feasibility of Western-led transport corridors in Africa, and two key determinants of such a success are the ability to include the private sector

and to grant market access to African minerals to both the EU and the US.¹⁵ If the Trump administration's pledge to support politically and financially the corridor shows a rare – and welcome – sign of continuity with Biden, the Lobito corridor faces several other challenges.¹⁶ First, the corridor needs to provide tangible benefits to African partners and not just for foreign investors: the creation of local quality jobs, value added, and the support of the diversification of local economies. While it might seem absurd at a first glance that a railway built to move minerals could support economic diversification, the Lobito corridor could indeed help the development of other economic activities, better connecting actors along the axis. It can offer an avenue for agricultural and non-mineral exports and the emergence of logistics hubs can play a major role once those countries move up the value chain, for instance in electric vehicle batteries.¹⁷ Beyond local benefits, participants to the Lobito corridor should also invest in processing facilities for cobalt and copper, as the real Chinese hold over minerals does not lie in extraction but in the refining phases, where Beijing maintains most of the world's capacity. China's share in global cobalt refining was 68% in 2022 and is projected to decline only to 66% by 2030.¹⁸ A transport initiative such as the Lobito Corridors thus is not enough in itself to challenge the Chinese monopoly over mineral processing.

The creation of local added value is a key component of Europe's new type of trade deals, clean trade and investment partnerships (CTIPs) and not by chance the first one has been launched in March 2025 with an African country, South Africa. The deal focuses on the clean energy transition and

¹⁵ E. Castellet Nogués, "Confronting the China Challenge in Africa: The Lobito Corridor", Center for European Policy Analysis (CEPA), 2 April 2024.

¹⁶ M. Gomes, "[US committed to funding Angola's Lobito rail corridor despite spending cuts, diplomat says](#)", *Reuters*, 3 April 2025.

¹⁷ OECD, *The Lobito Corridor: Background note*, 12 April 2025.

¹⁸ D. Quiggin and R. King, "[Cobalt refining power gives China an advantage in the race for EV battery dominance](#)", *Resource Trade – Chatham House*, 4 July 2023.

seeks to develop new supply chains for strategic industries in net-zero technologies.¹⁹ This new tool provides the EU with a more flexible instrument to enhance economic partnerships with African countries and constitutes the external arm of the Clean Industrial Deal: by building effective international cooperation along entire value chains, Europe can reduce external vulnerabilities of its transitioning industries while also offering industrialization opportunities to developing countries.

In Africa, Beijing proceeding with its own alternative to the Lobito corridor, strengthening another avenue for mineral exports from the Copper Belt region: China has agreed to the reconstruction of the “Tazara line”, a 1970s railway linking Zambia with the port of Dar es Salaam in Tanzania. The port facility already registers a significant Chinese presence, and Chinese companies have recently upgraded the harbour to increase cargo handling capacity. Although Chinese BRI investments in Africa are declining, same as loans, the country still plays a major role in providing connectivity to African countries and transport corridors are a key part of Beijing’s strategy to consolidate its economic and political foothold on the continent.²⁰ Yet, beyond China, rising middle powers are also consolidating their presence in African connectivity: Gulf actors, and the United Arab Emirates in particular, are rapidly emerging as key investors in port and maritime corridors. Seeking to consolidate its position as a gateway for African trade, the UAE has been acquiring port facilities all around the African continent to build shipping corridors. Abu Dhabi’s interest in African logistics and connectivity depends both on growing trade relations and on the country’s growing geopolitical ambitions, both within the Red Sea Basin and beyond. Although a distant second to the UAE in terms of

¹⁹ M. Juetten, “Clean trade and investment partnerships A new instrument in the EU’s trade policy toolbox”, European Parliamentary Research Services, April 2025.

²⁰ C. Munyati, “[Why strong regional value chains will be vital to the next chapter of China and Africa’s economic relationship](#)”, World Economic Forum, 25 June 2024.

trade and economic presence, Saudi Arabia is also strengthening its role in African transport facilities, mining facilities and air connectivity. Yet, Riyadh's African approach remains more cautious than its neighbour's, reflecting the country's balancing between its economic imperatives and internal constraints.²¹

Africa's Transport corridor landscape is increasingly complemented by the establishment of digital corridors and crucial undersea cable infrastructure. From a European point of view, this evolution presents a complex mix of opportunities and challenges, addressed in part by the EU's Global Gateway strategy and its support for the continent's digital transformation. This surge in connectivity, driven by substantial investments in subsea cables like 2Africa – which circumnavigates the continent – and Equiano, on the Western coast. Those infrastructure are providing key links to global networks, fostering African economic growth and helping its integration in global markets. Economic and demographic growth would further increase the demand of digital connectivity and European telecommunications companies, with their established expertise, play a significant role in the development and maintenance of undersea cables. The improvement in digital connectivity, facilitated by these cables, supports smoother business transactions, the growth of e-commerce, and greater participation in the global digital economy for African nations. However, this digital transformation also brings forth new strategic considerations. The security and resilience of these undersea cables, vital arteries of global communication, are of growing concern in an increasingly contested digital environment. For instance, the West Africa Cable System (WACS) is crucial for West African connectivity, and its protection is paramount. Ensuring the protection of these and other cables against both natural disruptions and potential malicious acts, including those by

²¹ M. Procopio and C. Cok, "[Diversification nations: The Gulf way to engage with Africa](#)", European Council on Foreign Relations (ECFR), 24 March 2025.

state and non-state actors, is essential. Moreover, as Europe aims to be a key partner in Africa's digital transformation, it faces other global players, notably China and the US, who are also investing heavily in Africa's digital infrastructure. This necessitates a nuanced approach, balancing competition with collaboration, to secure Europe's interests and promote a stable, just, and interconnected digital future for the continent.

IMEC: From the Mediterranean to the Indo-Pacific

Beyond Africa, Gulf countries and Europe are key players in another major transport corridor project, the India-Middle East-Europe Economic Corridor (IMEC). The project, unveiled at the G20 in Delhi in 2023, envisages the construction of a new trade route between India and European countries through the Arabian Peninsula to facilitate the movement of goods and boost economic integration along the corridors. IMEC will see two maritime transport corridors and an overland one: the first in the Arabian Sea, linking Western Indian ports with Saudi and Emirati ones, and one in the Mediterranean from the Israeli port of Haifa to Italy, France, and Greece. While detailed plans have not been presented yet, the corridor project plans to rely on the Gulf Railway, the Gulf Cooperation Council regional connectivity masterplan (currently under construction) to streamline the movement of goods from the Persian Gulf to the Mediterranean, through Jordan and Israel. This rail corridor, while undoubtedly ambitious, carries significance beyond linking the different Gulf monarchies with fast and efficient trains: it represents an asset for regional competitiveness and a powerful tool to reinforce the Gulf geoeconomic position in global trade routes.²² The IMEC route serves different strategic goals for the countries involved and it would be essential to its success that convergence is maintained throughout the planning

²² S. Vij, "The Gulf Railway Project: Bridging the Gaps between Vision and Reality", Observer Research Foundation (ORF), 29 April 2025.

and development phases. European countries and institution see the project primarily to diversify their economic relations away from China and to build a solid strategic partnership with India: Delhi's booming economic, growing population, and industrial might make it a very attractive partner for Europe.²³ IMEC also helps in making sure that India's multi-alignment maintains a solid link with Europe, preventing it from drifting too far away. India, on the other hand, relies on IMEC's transport corridor to bypass Pakistan's roadblock over Delhi's connectivity with Europe and to consolidate its rising role in global value chains. A successful IMEC would also massively help India's bid for global south leadership and reinforce the country is its historical rivalry with China. If both India and Europe look at IMEC to counter the BRI – albeit from very different perspectives – Gulf powers do not see the two as mutually exclusive but as complementary.²⁴ Both Saudi Arabia and the UAE seek to make use of IMEC to emerge as they key logistic hubs in Europe-to-Asia trade, adding to the transport corridors essential services from shipping to trade insurance and finance. This represents an essential component in their quest to diversify their economies and reduce the reliance on fossil fuel exports.

The degree of their success in this quest, and of IMEC's overall fortunes, however, would largely depend on their ability to put aside their bitter rivalry for the benefit of the corridor.²⁵ The two monarchies are in fact competing for regional prominence and the transport infrastructure domain is highly salient in this rivalry: they both see the corridor as a zero-sum game, where each one pushes for the use of its ports over the rival's one.

²³ A. Rizzi, “[The infinite connection: How to make the India-Middle East-Europe economic corridor happen](#)”, European Council on Foreign Relations (ECFR), 23 April 2024.

²⁴ A. Hess, “New India-to-Europe ‘spice route’ gains traction amid global tensions”, *Euronews*, 5 May 2025.

²⁵ A. Reisinezhad, “The Hidden Rivalry of Saudi Arabia and the UAE”, *Foreign Policy*, 25 January 2024.

Added to the tariff and non-tariff barriers the two countries have between each other, this rivalry threatens the effectiveness of the corridor, since it would benefit more from a network structure. Instead of relying on a single terminal on the Gulf, it would best be served by a set of different ports, creating multiple entry points connected by railways, maximising opportunities and reducing vulnerability to localised disruptions. The same reasoning also applies to the Mediterranean stretch of IMEC: while initial designs have indicated the port of Haifa, acquired in January 2023 by a consortium led by India's Adani Group, as the main hub on the Mediterranean side, there are valid reasons to extend the corridor to other partners. First, it would be a risky bet to place all the traffic of the corridor in a single harbour, making the supply chains promoted by IMEC vulnerable. Most importantly, however, the project should be inclusive towards neighbouring countries that can extend the transport network and increase its resilience. Egypt is the perfect candidate, as the country is scared that the corridor would take trade away from the Suez Canal, whose revenues are essential to Cairo's public finances. French envoy for IMEC, Gerard Mestrallet, has signalled President Macron's desire to include Egypt in the corridor, integrating the new route with existing ones between Europe and Asia and relying also on the port of Alexandria.²⁶ Europeans are also competing to intercept trade flows from the corridor: in February Indian Prime Minister Modi visited Marseille, while Italy seeks to position Trieste leveraging the port's connectivity with Central Europe, and Greece counts on the geographical proximity of Piraeus. Europeans should develop all three of them as IMEC's terminal, ensuring the corridor relies on multiple entry points. The crucial difference with the situation in the Gulf is that all three ports are major transport hubs within the European TEN-T network, and therefore they help integrating the corridor with the EU's domestic system.

²⁶ S. Rose, "French envoy eager for Europe to strengthen trade with UAE and India", *The National News*, 12 April 2025.

IMEC does not merely seek to overturn the narrative about transport corridors, it also represents a key test about the ability of Europeans to effectively cooperate with new powers on the global stage in an initiative that spans three different continents. If successful, it can become the blueprint for further transport initiatives that overcome political and geographical boundaries. Yet, transport corridors are long-term initiatives that require continued coordination among participants even in the face of a changing global order, allowing the establishment of new integrated supply chain and supporting with the soft infrastructure component the seamless movement of goods, services, and people. In an increasingly interdependent world, in fact, effective connectivity represents a major investment for economic security.

Europe's Efforts to Navigate a Shifting Global Economy

In today's world, international transport corridors represent critical infrastructure assets whose strategic importance is amplified by prevailing trends in global economic architecture, notably the shift towards multipolarity and the enduring complexity of international production networks. These corridors transcend mere logistical conduits, functioning as pivotal determinants of trade flows, market access, and ultimately, economic growth trajectories. The imperative for upgraded transport infrastructure is particularly acute for developing economies in the Global South, to support their integration into global value chains and economic growth.

The inherent interdependence of the contemporary global economy, underscored by supply chain vulnerabilities and intricate manufacturing processes, necessitates efficient and resilient transport networks. The economic ascendance of Asia and Africa's demographic dividend and resource endowments further accentuate the strategic value of corridors facilitating access to burgeoning markets and essential raw materials.

The European Union's engagement in corridor development reflects a strategic calculus aimed at diversifying supply chains, enhancing economic security through nearshoring opportunities in the Maghreb, and fostering regional integration. Ambitious projects like the IMEC initiative underscore the strategic intent of major economic players to reshape trade linkages and counter emerging competitive pressures. However, the realisation of the economic potential inherent in these corridors necessitates the mitigation of regional rivalries and the implementation of interoperable and interconnected infrastructure networks. Ultimately, strategic investments in transport corridors, coupled with policy frameworks promoting trade facilitation and regional cooperation, are indispensable for unlocking economic potential and fostering sustainable development in an increasingly interconnected global economy.

23. The Energy Nexus between Security and Transition: The Strategic Role of Italy

Domenico Maggi

In recent years, Italy's energy strategy has focused on expanding access to energy supply routes. This is a crucial objective given the country's reliance on imported energy resources, particularly natural gas (which accounts for 95% of total consumption). Like many European economies, Italy depends on energy resources it does not produce domestically, with gas constituting roughly 40% of its overall energy mix. Hence, the national gas infrastructure is essential for ensuring energy security and diversification, and recent events have underscored that, in the absence of domestic resources, supplier diversification is the only viable path.

Italy's transition away from Russian supplies has been particularly striking. In 2021, Russian gas accounted for nearly 40% of total imports, but by January 2025, pipeline flows from Russia were completely phased out. Replacing approximately 30 billion cubic metres (bcm) of gas previously sourced from Siberian fields required a substantial effort, but Italy achieved this goal, primarily by leveraging its strategic position in the Mediterranean.

For decades until 2021, Italy operated as a downstream recipient, with gas entering Central Europe and then flowing southward into the Italian market. The existing infrastructure was tailored to a north-to-north transit model, channelling

supplies into north-east Italy, where the majority of industrial activity is concentrated. However, the crisis necessitated a rapid reconfiguration of supply routes, with an emphasis on diversification through alternative suppliers – most of which are connected to the peninsula via the Mediterranean basin.

By 2024, over 50% of Italy's imported gas – vital for both industrial production and household consumption – was sourced via Mediterranean pipelines. Specifically, Algeria contributed approximately 36% of total imports, while Azerbaijan supplied around 17%. Before the conflict, a significant share of Italy's gas was routed from the north-east to meet concentrated industrial demand. Since February 2022, however, the supply landscape has changed dramatically. The substantial increase in flows from the Trans Adriatic Pipeline (TAP) and the five parallel lines of the Transmed pipeline has prompted extensive infrastructure upgrades, particularly the expansion and reinforcement of compression stations, to bridge the distance between southern entry points and the industrial heartland of Northern Italy. Moreover, the new "Linea Adriatica" is under construction, with the aim of unlocking further south-north transport capacity for 10 bcm of natural gas per year.

In parallel, Italy has expanded its regasification capacity significantly, enhancing its ability to reinforce its position in the liquefied natural gas (LNG) market and obtaining new flows from the Mediterranean and beyond. In 2024, LNG accounted for a quarter of total national imports – almost doubling its share since 2021. Qatar has emerged as a stable LNG supplier, complementing pipeline imports, while the United States has also contributed, albeit at a lower level than the European average. The addition of 10 bcm in regasification capacity over the past two years – through the Italis LNG Floating Storage Regasification Unit (FSRU) in Piombino and the BW Singapore FSRU in Ravenna – has further bolstered Italy's energy security. These strategic investments have not only strengthened Italy's supply resilience but also positioned the country as a resource for neighbouring European countries. In

fact, during the crisis, Italy emerged for the first time as a key energy gateway, exporting more than 4 bcm to Central Europe in 2022 – a record volume three times higher than in 2021 and more than ten times higher than in 2005.

These developments confirm that Italy's strategic reorientation – leveraging its privileged Mediterranean position and flexible infrastructure network – has effectively transformed it from a downstream energy recipient into a central gateway for energy flows across Europe.

While the European and Mediterranean energy landscapes are now more closely linked than ever, the region's energy future will be even more interconnected. Nonetheless, while the potential for renewables is undeniable, there remains a significant spatial mismatch between regions abundant in renewable resources and those with high energy demand – a disparity that often mirrors traditional North-South global divides.

The most challenging demand centres for decarbonisation are located in Europe's industrial core, while the necessary resources are not always close by. For instance, Africa is one of the world's richest renewable energy regions and holds 60% of global solar generation potential. Within this framework, Italy's strategic position enables it to serve as a gateway for the European energy transition, bridging the distance between supply and demand. This vision can extend even further. The key energy corridors – South-North and East-West – are not only critical for energy security but will also drive economic development in Europe's neighbouring emerging economies. Only by fostering synergies between the energy transition and economic growth can the goal of a just transition be achieved.

The SoutH2 Corridor exemplifies this approach, embodying the win-win logic behind several recent institutional initiatives focused on the Mediterranean – from the Italian government's Mattei Plan for Africa to the European Global Gateway. This project envisions a large-scale green hydrogen transport infrastructure linking North Africa to Europe, connecting

Algeria, Tunisia, Italy, Austria and Germany. With construction works expected to start in the early 2030s, it aims to secure a stable, sustainable energy flow, leveraging the most competitive energy sources for European industry, while stimulating industrial development in North Africa's clean energy sector.

The SouthH2 Corridor is an important energy partnership opportunity, especially in view of the role of hydrogen as a cost-effective solution for decarbonising Europe's hard-to-abate sectors, while driving significant economic opportunities in North Africa. The ability to repurpose existing gas pipelines – which are estimated to account for around 60-70% of the corridor's overall reach – significantly reduces transportation costs, making large-scale hydrogen imports economically viable. At the same time, North Africa's abundant and low-cost renewable resources enable competitive hydrogen production through electrolysis, turning the region into a key supplier for Europe.

Infrastructure is crucial to creating both upstream and downstream markets. In the energy sector, as in other industries, networks and storage sites enable the necessary match between supply and demand for a market to work effectively. While North African countries boast enormous renewable energy generation potential, which is instrumental to unlocking the hydrogen production process, large-scale investments in these regions often depend on the presence of external demand. The SouthH2 Corridor addresses this challenge by establishing a critical link between producers and reliable off-takers, thereby creating a market case for clean energy investments in North Africa and supporting local industrial development in key sectors.

Spanning 3,300 km of pipelines in its European section alone, the Corridor – designated a Project of Common Interest (PCI) by the European Commission in April 2024 – has gained strong institutional backing from all countries along its route, and aspires to become the central hub for green hydrogen flows across the Mediterranean.

Italy's strategic geographical position equips it to provide another key tool for the industrial sector's energy transition: Carbon Capture and Storage (CCS). The ability to capture CO₂ directly at the emission source, transport it, and store it safely is widely recognised as a fundamental pillar of any credible decarbonisation strategy. Off the coast of Emilia-Romagna, the Ravenna CCS project – jointly developed by Eni and Snam – is under development as the Mediterranean's primary CO₂ storage hub. With an annual injection capacity expected to reach 16 million tons in the 2030s, Ravenna CCS will play a pivotal role in advancing Mediterranean regional integration – a priority reflected in the political agenda of the European Commission led by President Ursula von der Leyen. Notably, for the first time, the Commission has appointed Dubravka Šuica as Commissioner for the Mediterranean and established a dedicated Directorate-General for the Middle East, North Africa and the Gulf, both specifically focused on enhancing regional energy integration.

The past few years have been marked by continuous geopolitical and economic upheavals, fundamentally reshaping the energy landscape. Looking ahead, accelerating the integration of the energy markets of all countries overlooking the Mediterranean will be crucial to ensuring long-term development and sustainability for the entire region. Indeed, while different actors may pursue distinct interests, energy can serve as a unifying platform, aligning them within a common, mutually beneficial framework. As industrial and institutional initiatives increasingly highlight the potential of cross-border collaboration, achieving a truly interconnected Mediterranean energy system will require deeper regulatory alignment between countries on both shores, enhanced intra-regional investment frameworks and tailored multilateral financing mechanisms. Strengthening regional fora to facilitate dialogue and fostering coordinated planning will further solidify the Mediterranean's strategic role, thus transforming today's challenges into opportunities for shared economic growth and climate leadership.

24. The Role of North African Energy in Europe's Energy Transition

Riccardo Dutto

In the new global context of geopolitical shifts, military conflicts, competition for resources and looming trade wars, Europe must find a new business model to preserve a competitiveness and meaningful industrial base and to create sustainable economic growth. The new European Commission strategy that emerges from the Clean Industrial Deal just published is in line with the recommendations of the Draghi report. The document targets investments in building European leadership in green technologies and a competitive and decarbonised European industrial system. The electricity grids, LNG terminals, hydrogen-ready pipelines and CCS infrastructure scheduled to be laid down in the coming years will shape the cost structure of our energy mix and our relationships with neighbouring countries for the next 50 years.

What is the role of the MENA region in this? Is there value in jointly designing interconnected EUMENA green infrastructure in terms of cost optimisation and system resilience? What about security for any potential future infrastructure? Can an alignment of interests between Mediterranean Countries and a systemic view improve the resilience of our interconnections?

These themes are overlooked in the most recent European energy strategy. Many aspects of the RED II Delegated Act, the ETS Regulation, the Carbon Border Adjustment Mechanism, and Waiver Schemes for State Aid Rules create obstacles to

smooth dialogue with the MENA Region, not to mention the planning of integrated infrastructure. The Global Gateway scheme seems to go in the right direction, but with a deal-by-deal approach that lacks a systemic view. Only the Italian “Mattei Plan” seems to have the right approach, especially now that a focus on infrastructure has been considered part of a broader picture.

Since the start of the war in Ukraine, Europe has been trying to accelerate its green strategy to match the challenging ambition of switching its 98% dependence on imported oil & gas to a more domestic production of renewable and low carbon electricity in an attempt to combine decarbonisation with energy security. After 3 years, however, we are still seeing a lack of diversification in renewable generation; offshore wind projects remain unreliable in terms of time to market and cost; and multiple grid bottlenecks are skyrocketing system flexibility costs (curtailment, re-dispatching and capacity costs). The solution seems to be huge investment in storage (mainly batteries) as well as more robust transmission grid interconnections, and an electricity market review to give long-term signals to investors and promote demand response as a cheap balancing tool.

The Draghi report focused the spotlight on the competitiveness of our expectedly green “autarkic” system, challenging European decision makers to not just make incremental moves but to be more “strategic” in their view of the system. So, is it time to look at our southern borders? Is there value to be had from investments in solar power in the MENA region given its low complexity and the regular high yields typical of solar resources at these latitudes? What is certain is that the time window for our MENA neighbours to become part of the design of future green energy grids is open now. Putting ourselves in their shoes, we can see that they are relying on the export of fossil fuels to Europe to provide a significant share of their GDPs. At the same time, though they are aware of their countries’ potential for renewable energy, they perceive Europe as a “fortress of

rules” that frustrate this export potential due to a lack of green infrastructure.

The Vision We Need to Share: Where Is the Value in Building an Integrated EUMENA Electricity Grid?

Electrification is the priority in every energy transition pathway. Electricity is a complex real-time market where electrons only have value if they are ready to be used in the quantities, volumes and timeslots requested by users. Renewables are green but unpredictable, so when they become the main source of electricity in our grids, a back-up source like gas, nuclear or storage (batteries or pumped hydro) is needed for system reliability. A decarbonised energy system is therefore all about the availability of grid infrastructure with the right capacity and daily, weekly, and seasonal balancing solutions to provide the necessary resilience to power load volatility.

A competitive and affordable green energy system will no longer depend on making cheap fuels available but will be all about minimising capex per unit of renewable generation output and the fixed grid costs (cable size and balancing solutions) necessary to achieve a reliable grid. Energy security will be achieved through defending grid integrity, redundancy, and the diversification and flexibility of power sources.

Technically, you can oversize renewable capacity and store excess electricity when available, ready for use when a production peak occurs or a “Dunkelflaute” – a simultaneous lull in solar and wind resources typical of northern latitudes – reduces local energy production. Electrochemical storage is not an easy option because it is still expensive, short term and low in energy density. Hydrogen and green molecules are a viable option for the seasonal storage of excess electricity, but roundtrip efficiency needs to be improved to make this a feasible solution for grid balancing in the medium/long term. Green molecules that use green hydrogen as a feedstock are key for hard-to-abate (HTA) sector decarbonisation (aviation,

maritime, steel, cement, fertilisers, chemicals etc.) and can be deployed to make better use of curtailed energy (peak eating) or dedicated off-grid renewable projects.

Grid balancing comes for free if you use a sizeable and diversified renewable generation fleet. Is the MENA region suitable for this purpose? Size matters because through the interconnection of different grids and markets you can statistically offset uncorrelated peaks with supply; diversification in geography, renewable generation technology and time zones helps mix and flatten load curve profiles, offering a steady and reliable flow of available electricity.

A critical advantage for North Africa is the vast availability of desert land, much of which is suitable for utility-scale PV installations (ENEMED-Plat, 2023). Recent feasibility studies in regions such as Tebessa (Algeria) and Buhayra (Egypt) have demonstrated that only a fraction of these deserts is required to meet domestic electricity demand, leaving a substantial surplus available for export, potentially exceeding annual European electricity consumption in 2024 (2,700 TWh) and forecast consumption in 2050 (7,500 TWh – JRC estimates).

Region	Country	Surface (Km²)	Surface available for PV (Km²)	Share over total surface	Annual electricity generation (TWh/h)
Tebessa	Algeria	2,381,741	4,231	0.18%	6,487
Tlemcen	Algeria	2,381,741	1,204	0.05%	1,818
Buhayra	Egypt	1,001,450	2,430	0.24%	4,149
Tanger-Tetoun	Morocco	446,550	3,025	0.68%	4,319

Source:
SRM 2024 - MED & Italian Energy Report

The potential value of these resources lies in efficiency (at North African latitudes solar energy yields 100% more electricity than in continental Europe) and flexibility (normally an overlooked item). Let us see why. North African solar is stable in winter

with no seasonal variation, so complements North European offshore wind. This synergy is especially valuable given that the southern shores of the Mediterranean typically do not experience “Dunkelflaute”. In addition to south-north routes, east-west interconnections can further optimise energy flows across the Mediterranean. A network of offshore (shallow water) submarine cables linking Morocco and Spain with Sicily, Egypt, Saudi Arabia, and the UAE would cover 4 time zones and so would extend peak production hours and facilitate 12-hours-a-day solar power trading among multiple countries, with Sicily in the middle as the natural barycentre of these flows. This approach diversifies energy sources, improves resilience, and enables more efficient balancing of supply and demand.

SOLAR PANEL @ LATITUDE 50° (Paris)

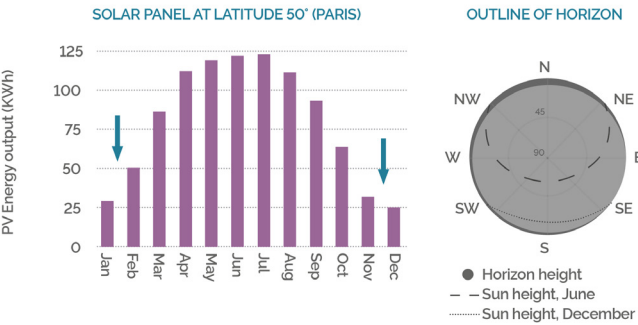
SUMMARY

PROVIDED INPUTS:

Location (lat/lon): 50.955,8.228
Horizon: Calculated
Database used: PVGIS-SARAH3
PV technology: Crystalline silicon
PV installed [kWp]: 1
System loss [%]: 14 Outline of horizon

SIMULATION OUTPUTS

Slope angle [°]: 35
Azimuth angle [°]: 0
Yearly PV energy production [kWh]: 915.39
Yearly in-plane irradiation [kWh/m²]: 1212.13
Year-to-year variability [kWh]: 57.64
Changes in output due to:
Angle of incidence [%]: -3.17
Spectral effects [%]: 1.92
Temperature and low irradiance [%]: -5.19
Total loss [%]: -19.53



SOLAR PANEL @ LATITUDE 35°

SUMMARY

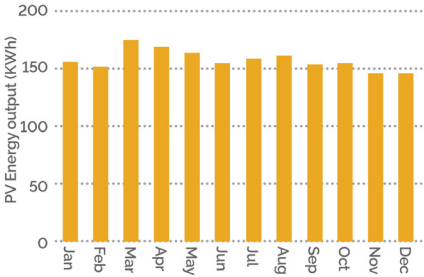
PROVIDED INPUTS:

Location (lat./lon): 32.246,5.254
Horizon: Calculated
Database used: PVGIS-SARAH3
PV technology: Crystalline silicon
PV installed [kWp]: 1

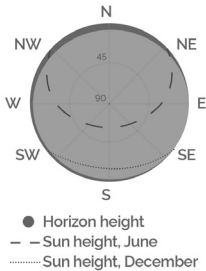
SIMULATION OUTPUTS

System loss [%]: 14
Slope angle [°]: 35
Azimuth angle [°]: 0
Yearly PV energy production [kWh]: 1890.58
Yearly in-plane irradiation [kWh/m2]: 2483.53
Year-to-year variability [kWh]: 25.04
Changes in output due to:
Angle of incidence [%]: -2.51
Spectral effects [%]: 0.3
Temperature and low irradiance [%]: -9.47
Total loss [%]: -23.68

SOLAR PANEL AT LATITUDE 35° (TUNIS)



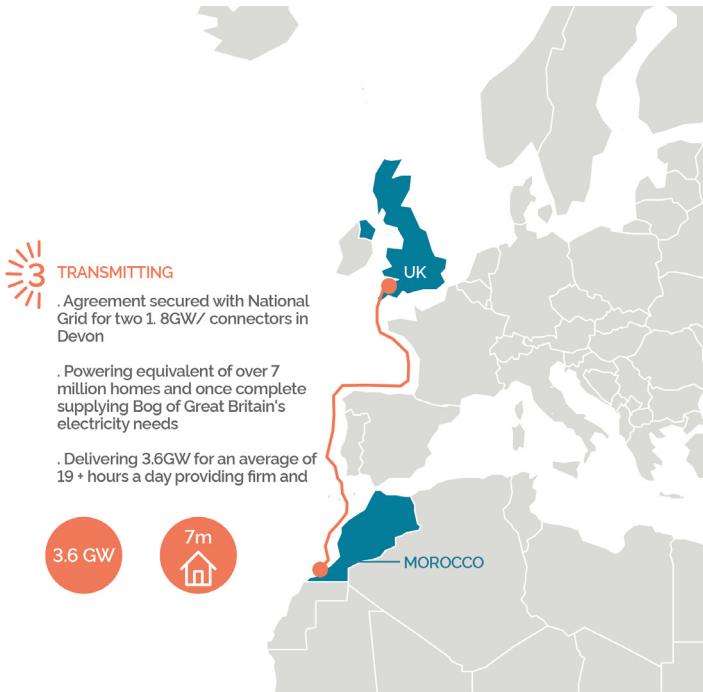
OUTLINE OF HORIZON



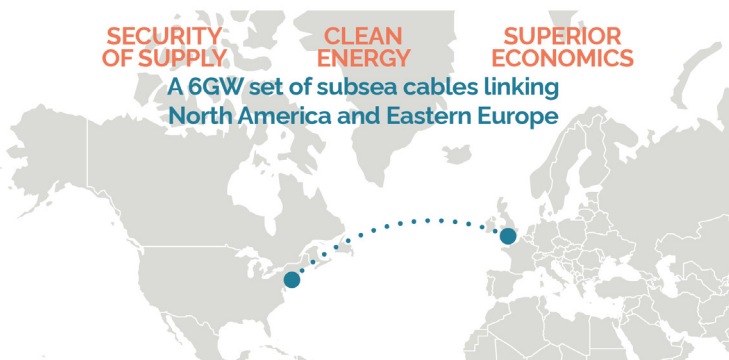
Furthermore, North African solar can be complemented with local coastal onshore wind, harvesting steady thermal wind in the morning and in the evening, further stretching the load curve coverage to 16/18 hours a day. We simply lack the infrastructure to interconnect all these resources to monetise their intrinsic resilience and complementarity with, for example, European offshore wind, nuclear and hydropower resources, thus reducing the need for large-scale storage solutions. Such infrastructure could also be the backbone needed to power a fleet of desalinisation plants with green electricity, a critical asset that, with state-of-the-art technologies, could operate in a modular manner, acting as a further resource for modulating the supply grid and providing abundant, green, fresh water for the MENA region. These are small examples of how investments in renewable energy infrastructure across the Mediterranean Sea can forge an integrated and resilient EUMENA energy network, with mutual benefits in terms of efficiency, reliability, redundancy and flexibility.

Does This Sound Crazy or Too Ambitious?

Projects such as the 4,000+ km long UK-Morocco *Xlinks* submarine cable demonstrate that interest exists in large-scale transmission systems designed to interconnect solar and wind power over long distances.



A similar project is the NATO-L (North Atlantic Transmission One - Link) Project, a 3,500 km, 6 GW subsea cable interconnecting North America with Europe (www.nato-l.org).



Imagine what could be feasible if we succeed in mobilising European Global Gateway funds and MENA region sovereign wealth funds in a joint effort to build an EUMENA infrastructure aligning all our interests? The “Mattei Plan” offers the ideal framework to deliver this vision.

By linking North Africa directly to European demand, Europe can reduce its reliance on fossil fuels while cutting the overall cost of energy transition. At the same time, MENA countries can transition from exporting oil to a more diversified and resilient green economy. Such interconnections not only lower the capital needed for storage facilities but also enhance system resilience by providing access to a wider range of renewable resources and consumption markets.

A second vision we need to share: fossil energy security and decarbonisation are not two conflicting objectives but can be promoted at the same time. What is the role of natural gas in the Mediterranean Sea?

Building integrated EUMENA electricity grids and interconnections will take years. How can we achieve energy security while ramping up this infrastructure? Since the start of the war in Ukraine, North Africa has emerged as a crucial partner in Europe's pursuit of energy security. Algeria, Egypt, and other regional players ramped up natural gas exports at the peak of the Ukrainian crisis, filling gaps in Europe's supply and mitigating geopolitical vulnerabilities. In the near future, however, a growing part of their local gas production will be used for domestic electricity generation, threatening to reduce their ability to export gas. One potential opportunity for these nations is to accelerate renewable deployments. This can significantly decarbonise their domestic grids and, by substituting solar and wind power for gas, free up gas for export to Europe, thereby addressing two crucial objectives in parallel.

How much natural gas can be freed up in this way?

A broad estimate indicates that 10-12 bcm could be made available for export if renewables reach a 40% share in the local power mix. This figure is compatible with the existing pipeline and the still huge spare capacity of LNG export terminals. This, however, will not be enough to bridge the gap in Europe's demand for natural gas.

Natural gas is a strategic transition fuel and even in the most aggressive decarbonisation scenario will still play a major role in the energy mix of 2050. So, what is the best way to make it available to EUMENA countries in a secure and efficient way? The Mediterranean Sea is conditioned by geopolitical themes because it is accessible only through three highly vulnerable maritime chokepoints (Gibraltar, Suez, and the Dardanelles) that could limit the potential for LNG imports. There is therefore value in securing gas from wells within the Mediterranean Sea, also because of huge spare capacity in existing transport infrastructure (pipelines and LNG) within the shores of the Mediterranean.

Many strategic investments are needed to capitalise on infra-Mediterranean gas sources that are resilient to geopolitical crises. These include the Adriatic Backbone pipeline in Italy and the EastMed pipeline/LNG to exploit the giant gas fields off the shores of Israel (Leviathan, Tamar etc.), connections to Egypt, Greece, Cyprus and Turkey (an area where many well-known geopolitical problems need to be solved) and the Barcelona-Marseille interconnection to debottleneck Spanish LNG import infrastructure and exploit the huge hydrogen potential of the Iberian peninsula. These investments could create flexibility, optionality to react to crises and more in general – if done using H2-ready technologies – could enable a future Mediterranean market for new green molecules.

While oil and gas are global markets, green molecules will remain regional markets (like the Mediterranean Sea) for many decades because of their high liquefaction costs, the cost of long-distance transport using dedicated ships and the lack of

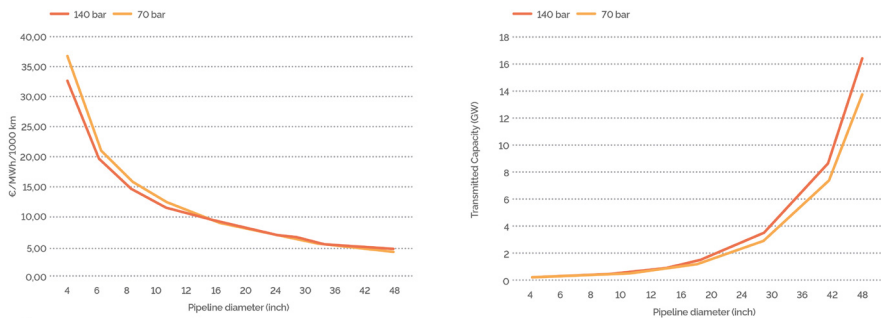
dedicated infrastructure. Hydrogen pipelines are the cheapest transport solution over “regional” Mediterranean ranges. Provided new gas assets are built or retrofitted to be “hydrogen ready” they will benefit from a long useful life (and not become stranded assets) and will enable future green markets while supporting short-term security and resilience. A good example of market cooperation is the SouthH2 Corridor, a 3,300 km dedicated hydrogen pipeline connecting North Africa, Italy, Austria and Germany which is expected to come online in the early 2030s, enabling cost-effective transportation thanks to a high proportion of repurposed natural gas pipeline (60-70%). Another point in favour of pipelines is their efficiency in transporting huge amounts of energy compared to cables as well as the optionality of long-term molecular electricity storage.

Optionality and high-energy-density transport infrastructure are key to a successful energy transition.

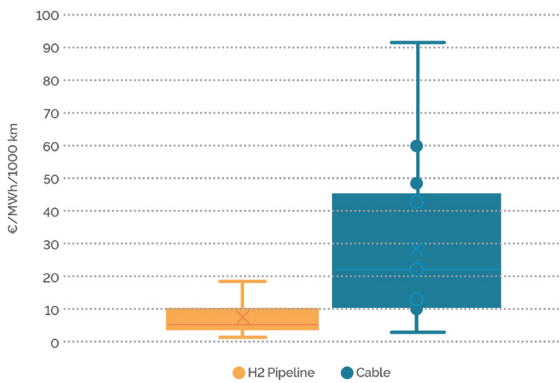
Conclusion and Outlook

The Mediterranean region is poised to become a linchpin in Europe's journey towards a low-carbon future. Through strategic investments, North Africa can harness its abundant solar and wind resources to supply with green energy and fresh water not only its own populations but also partner countries across the Mediterranean. Meanwhile, Europe benefits by reducing its dependence on volatile fossil fuel markets and accelerating its 2050 climate-neutral ambitions.

PIPE DIAMETER AND PRESSURE LEVEL AGAINST THE COST OF DELIVERED HYDROGEN AND TRANSMISSION CAPACITY



SPECIFIC COST RANGES FOR ENERGY TRANSPORT BY HYDROGEN PIPELINES AND DVDC LINES



Source:
"Hydrogen pipelines vs. HVDC lines: Should we transfer green molecules or electrons?",
Oxford Institute for Energy Studies, November 2023.

However, unlocking this potential requires immediate action. Large-scale infrastructure projects, particularly those involving cross-border and offshore interconnections, can take over a decade to plan, finance, and build. Policymakers, industry stakeholders, and international organisations must work in

tandem to address technical, regulatory, and financial barriers. By combining forward-looking strategies, robust investments, and effective diplomatic engagement, the Mediterranean Basin can evolve into a vibrant clean energy corridor, delivering economic, environmental, and social benefits to millions of people on both sides of the sea. The “Mattei Plan” is the ideal framework to deliver this: we just need to be ambitious and support this visionary plan for Mediterranean communities, which complements European Global Gateway resources with MENA region sovereign wealth fund resources.

Now is the time to act and plan an integrated EUMENA network of energy infrastructure.

25. The Economic Challenges of Connectivity in Latin America and the Caribbean

Lian Allub, Walter Cont

In Latin America and the Caribbean, connectivity is fundamental for economic growth, social cohesion, and regional and global integration. Over the past 30 years, most countries have implemented trade liberalisation policies that reduced tariffs and non-tariff barriers, leading to increased trade and investment. However, these gains have been modest and fall short of expectations regarding their impact on growth and welfare. A key reason is that liberalisation measures did not lead to significant, sustained intraregional trade – unlike regions such as East and Southeast Asia, Europe, or North America, with infrastructure playing a relevant role.

Connectivity as a Structural Challenge

Transport infrastructure for goods has distinctive features. First, it has a network structure, meaning that changes in one part can not only affect the segments directly affected, but also significantly impact other segments not directly exposed to the change. For example, building a new highway can reduce traffic on alternative routes and shift movement patterns, influencing overall travel time and costs. Second, transport systems involve multiple modes; optimal networks often utilise different vehicles depending on the goods and distances involved. Third,

networks consist of links and nodes, so total costs – whether in time or money – depend on both. For instance, improving roads connecting to border countries offers limited benefits if border procedures are inefficient, as delays at borders can offset travel time savings.¹ Additionally, both the quantity and quality – and the placement – of infrastructure matter. Ultimately, the value of infrastructure depends on the services it provides, including connectivity, travel time, and security.² However, despite rising demands for mobility, energy, and trade, the region's infrastructure remains fragmented, unequal, and often outdated, with networks that do not connect with each other, corridors that end at borders without continuity, and energy systems that do not communicate between countries.

Performance in transport infrastructure depends on several determinants, including the availability and quality of roads and other ways (pavement, highways, railways, etc.), nodes (ports and airports), topography, and connections between nodes and links. For example, the quality and congestion of the road network influence travel time volatility, which is crucial for supply chain logistics. In Brazil, only 13% of the road network is paved. In Guatemala, the CA-2 West – a key artery for trade with Mexico and El Salvador – has sections with average speeds that reach 14 km/h (Bid Invest, 2025).³ This situation affects not only logistics but also access to basic

¹ For example, cross-border time and costs – excluding tariffs – for exporting and importing goods estimated by World Bank via questionnaires from freight forwarders, port authorities, and traders, shows that, for land border crossings, border compliance accounts for 31-64% of export time (36-59% for imports) and 8-23% of export costs (29-35% for imports). Domestic transportation also significantly impacts trade costs and time. See details in Cont et al. (2024).

² With minor changes, the same statement applies to electricity. In the case of natural gas, energy source went through a transition, from local good transported regionally through pipelines (within a country or, at most, among border countries) to a commodity with international reach, after the technology for liquefied natural gas (LNG) became economically available.

³ BID Invest, “*Xochi, un corredor de flores que alivia el tráfico en Guatemala*”, 2025.

services, labour mobility, and social integration. In the 2021 Report on Economic Development (RED), we analysed travel times within main cities of a country and between these cities and those in neighbouring countries to assess potential gains in market access – the population reachable – if vehicles could travel at a consistent speed of 90 km/h across the network. Improving speed would notably enhance domestic market access, more than doubling it in countries like Colombia and Bolivia, while having minimal impact in developed economies such as the US or Spain. External market benefits are especially significant for small countries bordering large neighbours.⁴ The “Xochi, Corredor de las Flores” project consists of a 31-km road that will allow to reduce travel time from 3 hours to 25 minutes bypassing the Suchitépquez department. This is an interesting example of private initiative that engages local communities as shareholders, employers, and suppliers, incorporating sustainability, gender and indigenous groups, and climate resilience criteria.

In the railroad sector, the situation is even more critical. The network is limited, fragmented, and, in many cases, abandoned. Although initiatives are underway – such as the Central-West Integration Railway (FICO) in Brazil or the Commuter Train in Colombia – investment remains insufficient given the magnitude of the challenge.

Shipping is key for Latin America and the Caribbean, enabling regional trade, connecting markets, and supporting economic growth through the efficient movement of goods across diverse coastal and inland regions. 95% of trade in goods in South America is through shipping. Two cases are worth mentioning. The Panama Canal remains a strategic axis of global trade. However, recent developments pose new challenges. Increased tensions over the Canal itself and foreign investments ports located in Panama have renewed public opinion on sovereignty and international

⁴ P. Sanguinetti et al., *RED 2021: Pathways to integration: Trade facilitation, infrastructure and global value chains*, Caracas, CAF, 2021.

relationships (see, for example, *The Economist* note on 13 March 2025, or *Financial Times* note on 7 April 2025).⁵ Additionally, climate events have disrupted logistics. According to Autoridad del Canal de Panamá (2024), irregular rainfall in 2023 lowered the Gatun reservoir levels, forcing the Authority to reduce ship drafts and innovate with pricing schemes.

The Port of Chancay in Peru, developed by Cosco Shipping, aims to position the country as a logistics hub of the South Pacific as well as develop the Chancay region. With an investment of over \$1.3 billion, the project promises to transform the region's maritime connectivity. However, it is not exempt from legal disputes over competition policy, as interventions by INDECOPI (the Antitrust agency) and OSITRAN (the transport regulator) indicate.⁶

Finally, although it has been improving over time, air connectivity is also lagging in the region. According to the air connectivity index, the per capita air connectivity of Latin America in 2019 was around 8% that of the United States.⁷ This is important not only for better access to individuals but also for air cargo transport, since up to 40% of the cargo holds of passenger airplanes are used for shipping goods.

Energy: Between Pipelines, Gas, and Geopolitics

The energy sector faces complex challenges for regional connectivity. Hydrocarbon transport infrastructure – oil ducts, gas pipelines, LNG terminals – faces dual pressures: adapting to new sources like natural gas and responding to the urgent energy transition.⁸

⁵ *Financial Times*, “Panama to file criminal complaint over canal concession”, 7 April 2025; *The Economist*, “Panama's giveaway game”, 13 March 2025.

⁶ BNAméricas, “Megapuerto peruano de Chancay avanza más rápido que su propia realidad”, 20 April 2025.

⁷ Sanguinetti et al. (2021).

⁸ L. Allub et al., *RED 2024: Renewed Energies: A just energy transition for sustainable development*, Caracas, CAF, 2024.

The Vaca Muerta shale gas and oil formation in Argentina exemplifies a transformative energy development in the Southern Cone. On the one hand, financing is at the front of challenges. YPF, Argentina's main oil company, is seeking external funds to finance the \$2.9 billion Vaca Muerta Sur oil duct project, after having been accepted in the Incentives Regime to Large Investments (RIGI). This case requires coordination between public investment, international financing, and strategic alliances. Also, the exploitation of the gas formation provides a low hanging fruit to reengage in exports of natural gas to Chile, as the existing transport infrastructure is available, and reserves exceed the required limits for self-supply in Argentina. On the other hand, projects like the reversal of the Northern Gas Pipeline (a pipeline that used to transport natural gas from the northwest basin and from Bolivia to consumption centers), the Perito Moreno pipeline, and Argentina LNG projects aim to position the country as a key regional supplier. However, these efforts face technical, financial, and diplomatic challenges, such as tariff negotiations with Bolivia, improved compression infrastructure, and the reengagement of binational agreements. At the same time, the rise of LNG shifts connectivity from traditional physical integration to global trade. Countries like Mexico, Brazil, and Colombia are investing in regasification and liquefaction plants, increasing flexibility but also heightening technological dependence on this energy source.

Note that LNG advancements enable tailored distribution for small markets like the Caribbean. Floating storage and regasification units offer an attractive, cost-effective solution for coastal countries, eliminating the need for fixed infrastructure investments.⁹

Connectivity in the electricity sector has another meaning. In the discussion on connectivity in Latin America, electrical infrastructure has historically been underestimated. However, in

⁹ International Group of Liquefied Natural Gas Importers (GIIGNL), *GIIGNL releases 2023 annual report*, GIIGNL, 2023.

the context of energy transition, electrification of the economies, and rising demand, cross-border electrical interconnection re-emerges as a strategic component for regional integration, energy security, and sustainability.

The uneven pace of regional integration in Latin America shows that, despite its potential benefits, certain conditions are necessary for countries to adopt this strategy. The key is the national grid's ability to support electricity trade without disrupting each country's supply, even in emergencies.

STATUS OF CONNECTIVITY IN ELECTRICITY IN LATINA AMERICA

SIEPAC AND MER: THE CENTRAL AMERICAN MODEL

The most advanced example of regional electrical integration is the Central American Electrical Interconnection System (SIEPAC), which connects six countries via an 1,800 km network with an initial capacity of 300 MW. Together with the Regional Electricity Market (MER), it has increased energy transactions from 700 GWh in 2013 to over 3,100 GWh in 2022, involving more than 300 agents. SIEPAC's success relies not only on its infrastructure but also on its institutional framework: the Network Owner Company (EPR), the Regional Operating Entity (EOR), the Regional Interconnection Commission (CRIE), and the MER Governing Council (CDMER) form a regulatory and operational ecosystem that has established a functional regional market.

The MER's "Vision 2050" projects a significant expansion of variable renewable energy – mainly solar and wind – in the region, alongside investments in transmission and storage, including new interconnections with Mexico, Belize, and Colombia.

The Colombia-Panama interconnection is the pending link between South and Central America, enabling access to a continental electricity market. This emblematic project involves a 500 km HVDC line (including 130 km submarine) with a 400 MW capacity. Despite feasibility studies and support from MDBs like the IDB and CAF, it has faced persistent technical, environmental, and social challenges, particularly in the Darién region.

SINEA, SIESUR, and Arco Norte: South American Integration Initiatives. Currently, three regional initiatives are developing at different stages. The Andes Electrical Interconnection System (SINEA), led by Colombia, Ecuador, Peru, Chile, and Bolivia, aims to replicate the Central American model. Progress has been slow, but interconnections are operational between Colombia-Ecuador and Peru-Ecuador, with planned lines between Peru-Chile and Bolivia-Argentina. Additionally, regulations for the regional Andean Electricity Market (MAER), established in 2017, were recently enacted in 2024.

The Southern Cone Electrical Interconnection System (SIESUR), led by Argentina, Brazil, Chile, Paraguay, and Uruguay – with potential inclusion of Bolivia – has outlined a roadmap to establish institutional and regulatory frameworks for effective interconnection by 2032.

Meanwhile, the Arco Norte project proposes connecting Roraima (Brazil) with Guyana, Suriname, and French Guiana, creating an Amazonian energy corridor. Although still in early stages, it highlights the potential for broader, diversified energy integration in the region.

Interconnection infrastructure relies on specialised, costly assets with long-term investments, distinguishing electricity markets from other goods and services. Consequently, electricity trading is typically bilateral – such as in Southern Cone countries – and expands regionally only when successful, as in Central America.¹⁰ Effective regulation – including standards, tariff harmonization, and remuneration mechanisms – is essential for managing operations and trade across the region.

Beyond these requirements, obstacles can impede investment and integration. A key factor is each country's approach to energy security; energy-deficient nations may prioritise self-sufficiency to avoid external shocks, driven by volatility, scarcity,

¹⁰ Sanguinetti et al. (2021), ch 5.

or geopolitical risks. Additionally, institutional weaknesses and the lack of reliable dispute-resolution mechanisms within regional trade blocks pose significant challenges. In South America, establishing stable, predictable rules that ensure legal security remains particularly difficult.

Regional Initiatives: Between Ambition and Fragmentation

The region is not lacking in plans or resources. Moreover, most of the trade agreements like MERCOSUR, Andean Community or SICA have considered infrastructure as a main barrier for integration and have particular divisions to developed regional plans. Moreover, MDBs have also developed agendas to finance multi-country infrastructure projects. Probably the most iconic one is the Initiative for the Integration of Regional Infrastructure in South America (IIRSA), initiated in 2000, that aimed to improve connectivity across the continent through transportation, energy, and telecommunications projects. Its strengths included fostering regional cooperation and infrastructure development. However, it faced challenges like financial constraints and environmental concerns, leading to its stagnation. The Integrated Latin American Transport Alliance (ILAT) has since emerged, building on IIRSA's goals by promoting sustainable infrastructure and enhancing trade connectivity with modern solutions, addressing previous limitations by integrating environmental considerations and innovative financing models for regional development.

At the country level, Brazil launched the Novo PAC program with investments of \$62 billion in transportation. Chile has a concessions plan worth \$17.6 billion. Peru plans to award projects totaling \$9 billion in 2025. Mexico promotes logistics corridors and LNG projects. This is just to illustrate that infrastructure planning is common across countries. However, most of these initiatives are national, lacking an articulated regional vision.

For example, energy integration remains an unfulfilled promise. Cross-border pipelines face regulatory, technical, and political obstacles. LNG infrastructure is advancing, but without regional coordination. Rail connectivity between countries is nearly nonexistent. And logistics corridors often stop at borders.

Towards a Transformative Connectivity

Connectivity in Latin America must move beyond isolated projects and adopt a strategic vision that integrates infrastructure, regional cooperation, sustainability, and equity. It requires stable regulation, innovative financing, citizen participation, and multilateral support.

Examples like Xochi show that infrastructure can have social impact. Vaca Muerta and LNG highlight energy potential but underscore the need for coordination. The Panama Canal and Chancay port remind us that political interference can influence infrastructure development. The Panama Canal also highlights the challenges that climate change can bring to infrastructure projects.

The region has the opportunity to redefine connectivity as a tool for territorial integration, closing gaps, and shaping a better future.

26. Japan: The Quest for Economic Security

Corrado Molteni

Faced with an assertive China, a nuclear-armed North Korea and a bleeding but still powerful Russia, in recent years Japan has adopted a more proactive defence policy to cope with the rapidly changing security environment in the Indo-Pacific Region.¹ The government is gradually but steadily implementing a far-reaching programme aimed at expanding and upgrading the country's military capabilities. The military doctrine governing the role and the deployment of the Self-Defence Forces has also evolved, and even revision of the pacifist constitution, a long coveted but unrealistic goal of the political right, is now within reach as a growing percentage of the population seems to support the idea, at least according to recent opinion polls.

In this context, in recent years, special attention has been devoted in Japanese public discourse to the issue of economic security, which is perceived as the weak side of a country geographically and politically isolated within East Asia.² The concerns regarding economic security, raised initially in the wake of Covid-19 and the consequent disruption of supply chains, have been exacerbated by soaring tensions in the Middle East and even more so by the Russian invasion of Ukraine,

¹ For a comprehensive overview see: M. Tsuruoka (ed.), *Japan in an Era of Geopolitics: A New Foreign and Security Policy Direction*, Konrad Adenauer Stiftung, October 2024.

² See <https://www.kas.de/en/web/japan/single-title/-/content/japan-s-economic-security-policy-2>

which has led to a partial halt and, in some instances, the outright cancellation of important plans for the exploitation of Siberian natural resources by Japanese companies. Then came the election of Donald Trump to the Presidency of the United States with his agenda of America First. The vagaries and the unpredictability of his administration have made the need to strengthen the basis of Japan's economic security even more pressing, as many in Japan's ruling circles fear that the country's sole and all-important ally might turn his back on them in an emergency. The Japanese government is indeed playing a difficult game with Washington, keeping the alliance as the cornerstone of the country's defence while appeasing or trying to appease the many demands and wishes of a cumbersome partner in the hope that this period will soon be over.

Aware of the need to strengthen the economic security framework, in February 2022 the Government of Fumio Kishida submitted to the Diet a bill that 3 months later became the so-called "Economic Security Promotion Act".³ This law formulates guiding principles and basic policies to ensure the stable supply of critical materials, products and services as well as the development of essential infrastructures and key technologies. The law identifies a broad spectrum of sectors deserving special attention, from major utilities (electricity, gas, oil and water) to transport, telecommunications and financial services. Activities and investment in these sectors are subject to prior notification and screening. Later, in December of 2022, the Cabinet approved a list of 11 "critical products and materials" including not only semiconductors, storage batteries, machine tools, industrial robots and fertilisers but also platforms for cloud programmes, natural gas and rare earths.⁴ Although clearly designed to keep Chinese investment in strategic sectors at bay, this decision has also raised concerns and criticisms in the

³ See [Outline of the Economic Security Promotion Act](#) (Act on the Promotion of Ensuring National Security through Integrated Implementation of Economic Measures).

⁴ See <https://www.meti.go.jp/english/report/data/wp2023/pdf/2-1-2.pdf>

domestic and foreign press, as potentially deterring investment even by foreign partners and allies.⁵ In the meantime, specific organisations have been established within the government and in the Cabinet Office, including the appointment of an ad hoc minister in charge of economic security – a post occupied by heavyweights in the Liberal Democratic Party.

In the case of Japan, economic security means, first of all, a stable and affordable energy supply. It also implies access to reliable sources of rare metals and strategic components essential to the nation's industries, from advanced semiconductors to high-value-added materials. It also concerns cyber security, a field where Japan has been conspicuously lagging behind other countries.

The policies adopted or planned by Japan in the field of economic security are the topic of the following pages, which focus on the most relevant and crucial aspects: the energy sector, cyber security and, in the final section, the industrial policy supporting the semiconductor industry.

The 7th Strategic Energy Plan: Back to Nuclear

In Japan, a country almost totally lacking domestic sources of fossil fuels, the availability of a stable supply of energy has always been a key issue in the country's foreign and economic policy. Indeed, the need to secure control of the oil fields of Southeast Asia was a major factor behind the southern advance of the Japanese army in 1941, leading to the clash with the United States and the Pacific War.

In the postwar period, the country's rapid economic growth was fuelled by cheap imports from the Middle East, at least until the 1970s, when the first and the second oil crisis caused a major shift in the country's energy policy. From that time onward, Japan developed a major programme of investment in

⁵ See <https://castasiaforum.org/2024/12/06/japans-economic-measures-are-immense-but-ineffective/>

nuclear power generation and by March 2011 had 54 nuclear reactors in operation.

Then, on 11 March, the fateful disaster at the Fukushima nuclear plant occurred, and the issue of how to secure a stable, reliable source of energy was once again brought to the forefront of the political agenda. In a major policy shift, nuclear power generation was drastically curtailed, with most of the existing reactors decommissioned or temporarily halted.

However, Russian aggression against Ukraine, conflicts in the Middle East and the concomitant need to decarbonise the economy have induced Japan to change course again and to reconsider disinvesting in nuclear power. The latest policy shift has been incorporated in the new Strategic Energy Plan, the 7th, approved on 18 February 2025 by the Ishiba Cabinet.⁶

The plan, which defines the nation's mid-to long-term policy, states that "it is necessary to maximize the use of both renewables and nuclear power", the two main carbon-neutral energy sources. In previous documents, the stated goal was to reduce dependence on nuclear power as much as possible. Clearly, the new approach marks a fundamental reversal of the policy adopted after March 2011.

The target is to achieve a self-sufficiency ratio of 30 to 40% by 2040, against 15.2% in the 2023 fiscal year. This should be achieved by adopting an energy mix comprising 40 to 50% of energy from renewable sources (against 22.9% in 2023), approximately 20% from nuclear power (8.5% in 2023) and 30 to 40% from thermal power (68.6% in 2023). Before the Fukushima nuclear disaster, the goal was to rely on nuclear power for as much as 50% of the energy mix.

The government considers nuclear power particularly suited to meet future demand from the large-scale data centres and semiconductor plants currently being built in Japan. On the plus side, the document mentions "excellent supply stability,

⁶ [The 7th Strategic Energy Plan](#), Agency of Natural Resources and Energy, February 2025.

technological self-sufficiency and cost levels comparable with other energy sources". The latter point is, however, quite controversial, considering the huge investments now required to build and manage safely and efficiently a large nuclear power plant in earthquake-prone Japan.

The government's intention, as stated in the strategic plan, is to accelerate the restart of nuclear reactors currently idle and to allow the building of new ones. At the same time, it will promote research, development and construction of next-generation reactors such as advanced light water reactors, small modular reactors, fast reactors and high temperature gas reactors. Research on nuclear fusion will also be promoted. Japan has already started an ambitious initiative to unlock the potential of fusion energy with the Fusion by Advanced Superconducting Tokamak (FAST) project, officially launched at the end of 2024. FAST is designed to tackle the final technical hurdles preventing the commercialisation of fusion energy, and aims to achieve its goal possibly by the end of the 2030s.

As for next-generation reactors, Japan is engaged in several research projects with international partners, mainly from the US, the UK and France. For example, the Japan Atomic Energy Agency (JAEA) and the British National Nuclear Laboratory are jointly developing a high temperature gas reactor (HTGR), while an agreement was signed last December for a joint project by French Framatome, JAEA and Mitsubishi Heavy Industries to develop a Sodium-cooled Fast Reactor (RNR-Na) demonstrator. The latter is considered a cutting-edge project that could maximise fuel efficiency, reduce nuclear waste and secure energy independence.

There are, however, several issues concerning nuclear energy.⁷ Although most Japanese support its use, the local communities where the facilities are located are still divided and, in several cases, opposed to the idea. The plan to rely heavily on nuclear

⁷ See the articles, in Japanese, by Professor Okamoto Koji and Professor Suzuki Tatsujiro printed in the *Nikkei* of respectively on 18 and 19 of February 2025.

energy is also hampered by safety problems in a country subject to frequent earthquakes and surrounded by non-friendly states that could target nuclear plants in case of a conflict. Yet, the most serious issue concerns the disposal of nuclear waste, a major headache for policy makers.

The strategic plan lacks specifics on this crucial aspect and refers only to the need to “accelerate back-end processes such as the nuclear fuel cycle, decommissioning, and final disposal, (including) the completion of the Rokkasho Reprocessing Plant”, a facility of crucial importance, whose construction has been affected by all sorts of problems since its start in 1993. The current goal is to have it completed by the 2026 fiscal year, but this, if achieved, will be a major feat given the long history of postponements.

As for renewable energy, the 7th plan advocates an extensive use of next-generation perovskite solar cells. Solar power is expected to cover from 23 to 29% of the country's energy needs, followed by offshore wind power (approx. 4-8%) and other sources, including geothermal power. However, in the field of renewables too there are several hurdles to overcome. A recent Nikkei article on the prospects of offshore wind farms pointed out how the envisaged expansion is facing trouble due to rising construction costs, which have caused significant losses to Mitsubishi Trading, a key operator.⁸ To make investments a viable undertaking, Japanese companies are demanding additional incentives and a revision of the contract assignment procedures, which currently is particularly risky and burdensome for potential investors.

According to the strategic plan, Japan will continue to rely partly on thermal power, but to achieve carbon neutrality, the use of hydrogen and its derivatives (ammonia, e-methane and e-fuels) is going to be actively promoted. The government, following enactment of the Hydrogen Society Promotion Act in May 2024, is expected to support the establishment of both

⁸ Nihon Keizai Shimbun, 12 February 2025

a supply chain and a distribution network for hydrogen, while contributing to the reduction of the price gap with other fuels.

As for fossil fuels, Japan is expected to remain a major consumer of liquified natural gas (LNG), imported mainly from Australia, Malaysia, the US and, even now, Russia. In future, however, Japan might have to open its market to imports of Alaskan gas, following the strong push by the U.S. President who is eager to promote the construction of a 1,290 km pipeline across the state. Trump pressed Prime Minister Ishiba on this issue during their meeting in Washington in February. According to Japanese newspapers, the President and Doug Burgun, his “energy czar”, framed the idea as a way for Japan to replace imports from the Middle East and Russia, address its trade imbalance with the US and avoid the sensitive choke points of Hormuz, Malacca and the South China Sea.⁹ So far, Japanese response has been non-committal, given the huge costs and logistical hurdles of the project, but pressure is likely to mount.

Strengthening Cyber Security

In the realm of cyber security, an essential component of national economic security, over the years, Japan, like other developed countries, has developed a complex legal framework for the protection of telecommunications and data privacy, including the Basic Act on Cybersecurity, approved by the Diet in December 2014.¹⁰ In the same year, a Cybersecurity Strategic Headquarters was established within the Cabinet for the purpose of “comprehensively promoting cybersecurity

⁹ “Trump push for Alaska’s oil & gas”, *Japan Times*, 24 February 2025, p. 1.

¹⁰ For an overview see the article by Roberto Carapeto, “[The Japanese Basic Act on Cybersecurity and the historical development of the Japanese legal framework for cybersecurity](#)”, *International Cybersecurity Law Review*, vol. 2, 31 March 2021, pp. 65–76.

policies”.¹¹ However, there is a widespread perception, both in Japan and abroad, that the country is lagging behind in the realm of cybersecurity, as limited public-private cooperation and constitutional constraints have prevented the government from taking decisive actions. Only quite recently, following a spike in cyberattacks – which, according to government data, originate from foreign sources in 99% of cases – the government decided to intervene more effectively to protect critical infrastructure.

In early February 2025, the government submitted to the Diet a bill allowing the police and, in specific and more limited cases, even the Self-Defence Forces to neutralise hostile servers in the event of a cyberattack targeting critical infrastructure.¹² The bill, currently discussed by Parliament, obliges operators of core infrastructure, such as the electricity network, financial services and railways, to report to the government if they come under cyberattack.

A few commentators have expressed critical opinions about the bill, as the power granted to the police to access private communications might violate rights guaranteed by the constitution. To mitigate these fears, however, the bill makes it mandatory for the police to obtain prior authorisation from an independent authority. Reservations notwithstanding, the bill is very likely to be approved, maybe with some minor amendments, since both the ruling and the opposition camp support the legislation.

At the same time, there is also a growing awareness of the risk of excessive dependence on foreign providers of services and products. Politicians and experts have voiced these concerns, and recent decisions seem to go in the direction of building a more autonomous system. Certainly, there are also contradictory signals, such as the decision of the Japanese Coast Guard to use Starlink for high-speed communications on its

¹¹ <https://www.nisc.go.jp/en>

¹² See <https://english.kyodonews.net/news/2025/02/2872bbccc100-update1/japan/cabinet-approves-cybersecurity-bill-to-bolster-cyber-defense.html>

vessels. However, the prevailing trend is toward strengthening domestic capabilities.

For example, in February of this year, Japan's space agency launched a navigation satellite, as the country seeks to have a more precise location positioning system of its own. The new satellite, the fifth, will be used to supplement American GPS, improving positioning data for smartphones, car and maritime navigation and drones. The plan is to have a seven-satellite system by March 2026. Once installed, the network will offer a more precise global positioning capability without relying on foreign services, including the US, according to the Japan Science and Technology Agency.

The Japanese government is also determined to reduce the nation's dependence on imports of cyber security products. At present, Japan-made products occupy less than half of the domestic market. Expanding the domestic industry is considered strategically important, but there are high barriers preventing domestic startups with limited track records from entering the market. In the latest document, released on 5 March, defining industrial strategy on cyber security, it is stated that the government will prioritise domestic products in its procurement. The government will also provide financial support for research and the development of new technologies, and, following a very Japanese approach, will dispatch specialist personnel to support commercialisation.

The Rebirth of the Semiconductor Industry: Prioritising Strategic Autonomy

To conclude this brief survey, let us focus on the semiconductor industry, a key element of Japan's economic security.

In the last couple of years Japan has embarked on an ambitious programme to relaunch domestic production. The country, that in the 1980s used to play a leading role in the semiconductor industry, has seen its competitiveness deteriorate to the point that its market share has fallen from half of the global market

to around 10%. Japan still maintains a strong position in the production of manufacturing equipment and materials, but is no longer a key player in finished chips.

There are multiple reasons behind this *défaillance*. Some in Japan argue that the main fault lies in the 1986 US-Japan Semiconductor Agreement, which restricted Japan's access to the American market. However, as pointed out by Professor Suzuki Kazuto of Tokyo University this is only one factor.¹³ The business model adopted by Japanese companies was also a culprit. Japan's insistence on the integrated device manufacturer model was in fact counterproductive. Semiconductor companies, many of them part of large, extremely differentiated conglomerates, handled all activities in-house, from chip design to manufacturing and packaging. This caused a loss of focus and a dispersion of human and financial resources in an industry requiring huge capital investments. The Japanese approach was the opposite of the one chosen by Taiwanese TSMC, today's global leader, which adopted the foundry business model, specialising in high-volume production for multiple clients. Japanese companies, unable to compete successfully with the likes of TSMC, were gradually driven out of the market.

However, when the pandemic caused a disruption of the supply chain and a worldwide chip shortage affecting a wide range of sectors, Japan realised how essential the industry is for economic security. Since then, the government has adopted a multipronged strategy to promote the recovery of the sector. It has strongly supported the establishment of Rapidus, the all-Japan company currently building a large plant in the northernmost island of Hokkaido that is expected to produce 2-nanometer semiconductors by 2027. But the government has not privileged domestic producers. It is also welcoming and supporting foreign companies investing in Japan: first and foremost, TSMC, the key competitor, following the golden

¹³ See K. Suzuki, "A chip renaissance: Japan is learning from past mistakes", *Japan Times*, 4 March 2025, p. 9.

rule that if you can't beat them, join them. With the generous support of the Japanese government, covering around half of the factories' construction costs, the Taiwanese company has invested in a joint venture with Sony, Denso and Toyota, world-class Japanese companies. A first plant, located in the southern Kumamoto prefecture, is already operating at full scale and a second will soon be built in the same region, which is likely to become a major hub of Japan's semiconductor industry. TSMC has also joined hands with the National Institute of Advanced Industrial Science and Technology in establishing a research centre in Japan. Even the all-Japan Rapidus is collaborating with IBM on the training of personnel and with Belgium's IMEC on research in advanced technologies.

There are, however, critical issues to be overcome for the industry to bloom. Firstly, there is the problem of how to hire enough skilled personnel. In rapidly ageing Japan, this is becoming a major problem in many industries, but it is particularly serious in the field of semiconductors. The old guard of skilled and experienced technicians is retiring, or has already done so and it will be quite a challenge to attract young, talented engineers to the relatively remote regions where Rapidus and TSMC are located.

Then there is a need to guarantee financial support in the years ahead. This is particularly true for Rapidus, that so far has been relying mainly on injections of public money. During the Kishida administration a bill was drafted to provide financial guarantees to private investors, but with the new administration the process has been halted, at least for now.

To conclude, it can be said that, spurred by security concerns, the Japanese government has taken a very proactive approach in supporting economic activities in critical sectors. It is a new version, with different objectives, of Japan's penchant for a proactive industrial policy: a return to a familiar past adjusted to the needs of current circumstances.

About the Authors

Lian Allub, Principal Economist, Socioeconomic Research Department at CAF - Development Bank of Latin America and Caribbean.

Katja Bego, Senior Research Fellow, Chatham House.

Michael Bennon, Research Scholar for the Global Infrastructure Policy Research Initiative at the Center for Democracy, Development and the Rule of Law (CDDRL), Freeman Spogli Institute, Stanford University.

Walter Cont, Acting Director of Socioeconomic Research at CAF - Development Bank of Latin America and Caribbean.

Michele Danesi, Research Trainee at ISPI Asia Centre.

Elisabetta De Bernardi, Chief Asset Management Officer di Mundys.

Nicola De Blasio, Senior Associate Research Fellow at ISPI and Senior Fellow leading Harvard Belfer Center.

Massimo Deandreis, General Manager, SRM Intesa Sanpaolo Group.

Gian Enzo Duci, Managing Director of ESA Group and Professor of Maritime and Transport Economics at the University of Genova.

Riccardo Dutto Global Head of Infrastructure & Real Estate in the Intesa Sanpaolo Group.

Ludovica Favarotto, Research Assistant at ISPI Centre on Geoeconomics.

Alessandro Gili, Research Fellow at the ISPI Centre on Geoeconomics and at the Centre on Infrastructure.

Andrea Gilli, Lecturer, University of St Andrews; Associate Fellow, Institute for European-Policy Making, Bocconi University; Non-Resident Senior Associate Fellow, NATO Defense College.

Hercules Haralambides, Professor of Maritime Economics and Logistics (MEL), and “Distinguished Chair Professor” at Dalian Maritime University (China).

Clelia Iacomino, Senior Associate Fellow at ESPI (European Space Policy Institute), specialising in Space Economy, Industrial Policy, and Innovation.

Gabriella Improta, Corporate Diplomacy Manager, Sparkle.

Roberto Italia, Junior Research Fellow at the ISPI Centre on Geoeconomics.

Cristina Lobillo Borrero, Director – Head of Energy Platform Task Force in DG ENER, European Commission.

Domenico Maggi, Director for International Relations and European Affairs, Snam.

Danilo Mattera Trimonti, Independent Analyst.

Alberto Mazzola, Executive Director at the Community of European Railway and Infrastructure Companies (CER).

Luca Milani, Partner McKinsey & Company.

Corrado Molteni, ISPI Senior Advisor, Professor of Japanese Studies at the University of Milano.

Paola Morselli, Junior Research Fellow at ISPI Asia Centre.

Stefano Napoletano, Senior Partner McKinsey & Company.

Theo Notteboom, Professor at the Department of Transport and Regional Economics, Faculty of Business and Economics, University of Antwerp, Belgium; Chair Professor 'North Sea Port' at the Maritime Institute, Faculty of Law and Criminology, Ghent University; Faculty of Sciences, Antwerp Maritime Academy, Belgium.

Alessandro Panaro, Head of Maritime & Energy Dept. SRM Intesa Sanpaolo Group.

Fabio Panunzi Capuano, VP – Head of Business Development & Corporate Diplomacy, Sparkle.

Laura Piovesan, Director General of the Projects Directorate, European Investment Bank (EIB).

Andrea Ricotti, Expert McKinsey & Company.

Alberto Rizzi, Policy Fellow, European Council on Foreign Relations (ECFR).

Eric Rudenshiold, Senior Fellow at the Caspian Policy Center and at the Johns Hopkins School of Advanced International Studies. He served as the U.S. National Security Council Director for Central Asia under Presidents Trump and Biden.

Matthias Ruete, European Coordinator for ERTMS, DG MOVE, European Commission.

Stefano Salomoni, Project Fellow, Clean Power, Grids and Electrification Program, World Economic Forum.

Nicola Sandri, Senior Partner McKinsey & Company.

Carlo Secchi, Carlo Secchi, Head of Centre on Infrastructure and Former Vice-President at ISPI; European Coordinator for the Atlantic Corridor at European Commission, and Professor Emeritus of European Economic Policy at Bocconi University in Milan.

Kabir Taneja, Deputy Director and Fellow, Middle East, with the Strategic Studies programme at ORF.

Roxana Vatanparast, Assistant Professor of Law, Capital University Law School.

Gelsomina Vigliotti, Vice-President, European Investment Bank (EIB).

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