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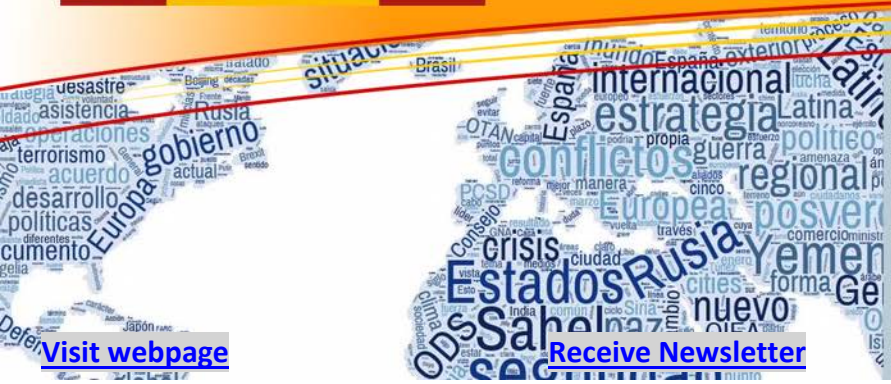
Miguel Golmayo

Energy port infrastructures: pillars of global energy security. A strategic analysis of risks and outlook



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Energy port infrastructures: pillars of global energy security. A strategic analysis of risks and outlook

This analysis is part of the Strategy Notebook:
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Abstract:

Port energy infrastructures have been consolidated as essential elements for global energy security. In a context where hydrocarbons, oil, gas and coal continue to account for more than 80% of global energy consumption, The discharge and redistribution of hydrocarbons become critical nodes for the functioning of the international economy.
Although traditional geopolitics has generally focused its attention on the major maritime bottlenecks (choke points) such as Panama, Malacca, Bab el-Mandeb or Gibraltar, this analysis underlines that energy ports are equally or even more strategic. Unlike maritime routes, these infrastructures often lack operational alternatives and the interruption of their operation would have an immediate impact on overall supply.
The risks they face are growing and multidimensional: terrorism, cyber attacks, regional conflicts, extreme weather events and geopolitical tensions. In a scenario of slow energy transition and persistent dependence on fossil fuels, the resilience, modernization and protection of these facilities becomes a priority.

Keywords: Port, oil, natural gas and security.

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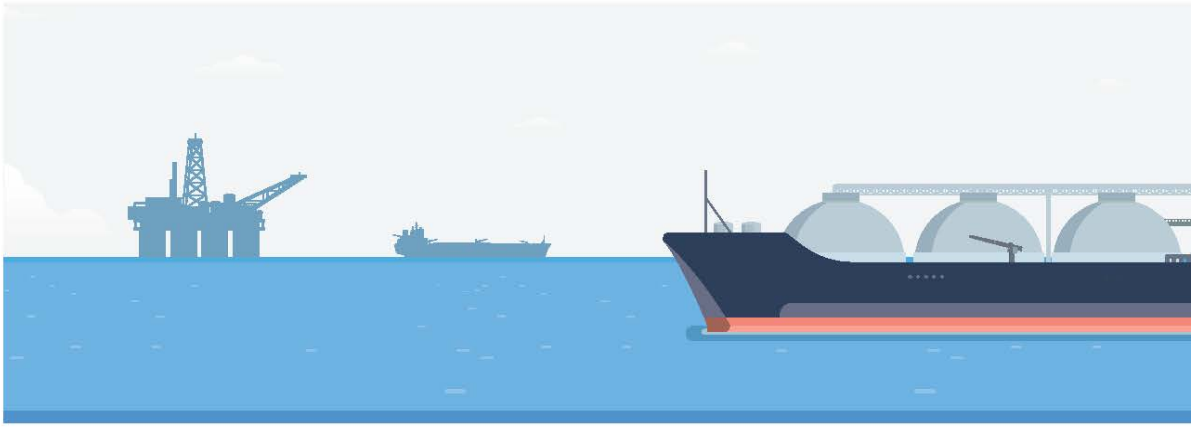
IMPORTANCE OF FOSSIL FUEL PORTS FOR GLOBAL ENERGY SECURITY



WHAT ARE THESE PORTS?

- **MARITIME INFRASTRUCTURES** SPECIALIZED IN LOADING AND UNLOADING OIL, NATURAL GAS, AND COAL.
- CONNECT **PRODUCERS, REFINERIES, STORAGE FACILITIES, AND INTERNATIONAL MARKETS.**
- SERVE AS **CRITICAL NODES** IN THE GLOBAL ENERGY CHAIN.

WHY THEY ARE ESSENTIAL FOR ENERGY SECURITY

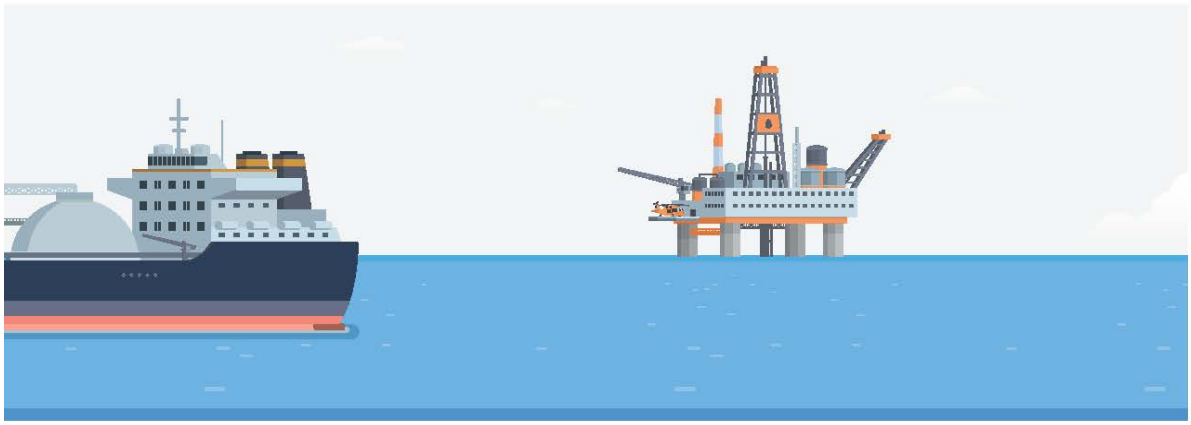
- ALLOW COUNTRIES **TO IMPORT OR EXPORT FUELS** ACCORDING TO THEIR DEMAND.
- **AVOID INTERRUPTIONS** THAT WOULD AFFECT ELECTRICITY, TRANSPORTATION, AND INDUSTRY.
- GUARANTEE THE **CONTINUOUS FLOW OF ENERGY.**

DIVERSIFY ROUTES AND SUPPLIERS

- **REDUCE DEPENDENCY** ON A SINGLE COUNTRY OR REGION.
- INCREASE **RESILIENCE** IN THE FACE OF GEOPOLITICAL CRISES.

SUPPORT ECONOMIC STABILITY

- **70%** OF THE WORLD'S OIL TRADE IS **TRANSPORTED BY SEA.**
- PORTS PROVIDE MORE **STABLE PRICES** AND CONSTANT **ACCESS TO ENERGY.**



RISKS THEY FACE

GEOPOLITICAL TENSIONS

BLOCKADES, SANCTIONS, OR CONFLICTS CAN SHUT DOWN KEY PORTS.

PHYSICAL VULNERABILITY

TERRORISM, CYBERATTACKS OR ACCIDENTS MAY DISRUPT OPERATIONS.

REQUIRE **HIGH STANDARDS OF SAFETY AND MAINTENANCE.**

HOW THEY STRENGTHEN ENERGY SECURITY

MODERN INFRASTRUCTURE

LNG TERMINALS, **STORAGE TANKS AND SPECIALISED DOCKING FACILITIES.**

CAPACITY TO RECEIVE **LARGE SHIPS** (VLCC, LNG CARRIERS).

INTERNATIONAL COOPERATION

AGREEMENTS BETWEEN COUNTRIES TO KEEP ROUTES OPEN.

COORDINATED EXERCISES ON **MARITIME SECURITY AND PHYSICAL SECURITY** IN PORTS.

CONCLUSIONS

WITHOUT FOSSIL FUEL PORTS, THE GLOBAL ENERGY SYSTEM WOULD COLLAPSE DUE TO A LACK OF SUPPLIES.

FOSSIL FUEL PORTS ARE STRATEGIC PIECES THAT SUPPORT THE GLOBAL ECONOMY.

Introduction

Consumption of crude oil barrels in 2025 was slightly over 103 million barrels per day worldwide, which approximately 60%–70% were transported by sea. As for natural gas, figures for 2025 are expected to reach 78 billion cubic metres, of which approximately 20–30% is transported by sea, and this percentage is on the rise: in 2025 alone, 96 new gas tankers were expected to join the global fleet.

According to official data gathered by CORES[1] and the CNMC[2], in 2024 Spain imported 64.6 tonnes of crude oil, equivalent to about 473 million barrels, amounting to practically 100% of Spanish oil consumption as the country has no significant oil production of its own nor do any international oil pipelines enter its territory. In terms of natural gas, approximately 16.8 billion cubic metres (bcm) of LNG were unloaded whilst another 9.9 bcm arrived from Algeria through the Medgaz pipeline, covering total consumption of 29 bcm, of which about 4.4 bcm were reexported. All of this makes Spain a European energy hub dependent on its port infrastructures for the entry and redistribution of fossil fuels.

Given global levels of oil and gas consumption in 2025 and forecasts for the coming years, it would seem unrealistic to think that the world's use of oil and gas will end in the short or medium term, thereby making it necessary to secure, among other things, points of loading and unloading.

Current estimates with regard to transport of oil and natural gas worldwide, in Europe, and in Spain are as follows[3]:

OIL	MARITIME TRANSPORT	PIPELINE	TRAIN/ROAD
Worldwide	60%–70%	20%–30%	5%–10%
Europe	70%	25%	5%
Spain	99%–100%		

[1] CORES, Corporación de Reservas Estratégicas de Productos Petrolíferos. Spain's official oil stockholding agency, which collects and publishes oil and gas statistics.
[2] CNMC, Comisión Nacional de los Mercados y la Competencia. Spain's official market regulator, which supervises the national gas and electricity systems.
[3] https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=615492&utm.
EU's petroleum imports fall as LNG shipments rise in 2025

NATURAL GAS	MARITIME TRANSPORT (LNG)	PIPELINE	TRAIN/ROAD
Worldwide	30%–35%	65%–70%	Marginal
Europe	30%–35%	65%–70%	
Spain	65%–70%	30%–35%	

A classic theme in hydrocarbon geopolitics has always been the importance of certain strategic locations in maritime routes known as chokepoints. These include the Panama Canal, the entrances to the Red Sea, the Strait of Gibraltar, the Strait of Malacca, and the Strait of Bab-el-Mandeb, which often becomes the centre of attention whenever tensions erupt involving Iran and its standing threat to block the pass with the help of Houthi rebels. A number of secondary chokepoints also exist. These are just some of the examples that regularly appear whenever a crisis or possible armed conflict threatens to plunge the world into a new energy crisis.

Other points, however, also exist that hold vital importance to ensuring worldwide hydrocarbon supply and which, though they rarely make headlines, are just as important as maritime chokepoints. These are the ports for loading and unloading of oil, natural gas, and their derivatives. These ports have an additional handicap in that they have no alternative, as opposed to what happens at times with maritime routes.

In an interconnected world where energy demand grows steadily and fossil fuel sources still account for 80% of global consumption, the ports where hydrocarbons are loaded and unloaded play a key role. These points of transit allow the movement of crude oil, liquefied natural gas (LNG), liquefied petroleum gas (LPG), and refined derivatives between producing and consuming countries.

Despite their importance, energy ports seem condemned to a secondary role. This oversight constitutes a strategic vulnerability, especially in a context of growing threats of all kinds, physical and cyber terrorism, geopolitical tensions, extreme natural events, armed conflicts, etc.

Energy security has emerged as an essential part of world geopolitical and economic stability. Some of the world's busiest oil ports play a crucial role in global energy logistics, handling massive volumes of crude oil, natural gas and refined petroleum products.

These include ports such as the Port of Rotterdam in the Netherlands, Europe's largest and an important oil refining and distribution hub for the entire continent. Another is the Port of Houston in the United States, a key actor in the energy corridor along the US Gulf Coast and a centre for both imports and exports of crude oil and petroleum products. Elsewhere, Ras Tanura in Saudi Arabia is one of the world's largest oil export terminals whilst the Port of Singapore is a strategic transshipment hub in Asia and vital for oil trading and storage.

Something similar can be said for liquefied natural gas (LNG) infrastructures, as the world's main LNG ports are likewise crucial for global energy commerce. These ports are equipped with specialised terminals for LNG import and exports, which often require large-scale infrastructure for the liquefaction and regasification of natural gas.

Ras Laffan Industrial City in Qatar, with the world's largest LNG export terminal, handles a significant share of global LNG supply. In the United States, the Port of Sabine Pass, located in Louisiana, is one of North America's largest LNG export facilities. In Europe, the Port of Sines in Portugal is a key hub for LNG imports being a deepwater port and a strategic position on the Atlantic Ocean. The Yamal LNG plant in Russia, north of the Arctic Circle, is a vital Russian LNG extraction facility despite the harsh working conditions in this part of the world. Hosting one of India's busiest LNG terminals, the Port of Dahej is crucial to meeting the country's growing energy demand. South Korea's Port of Incheon is an important LNG import terminal and serves one of the world's largest LNG consumers. Lastly, the Port of Yokohama in Japan plays a key role in the country's supply chain, with Japan being the world's top importer of LNG. All of these are just a few examples to be kept in mind.

Ignorance of the risks

When we talk about key infrastructures, many experts and even media outlets seem stuck in conversations about oil pipelines, gas pipelines, and straits. They are usually the infrastructures that grab the most headlines and dominate debates, as if they were the only guardians of our energy security. But it's an obsession and, in reality, a

dangerous distraction. By focusing all our attention on these three types of infrastructure, we neglect the other strategic nodes whose vulnerabilities can have disastrous consequences.

There is no doubt that pipelines and maritime shipping routes are of vital importance. However, making them our sole point of concern is a mistake. National and global energy security does not boil down to these three things alone. It is a bias that leads to a false sense of security and control, and which prevents us from seeing the whole picture in terms of risk.

But it's not just oil and gas ports that are vital: ports in general are the backbone of global commerce. Ports are the gateway for everything that makes our daily lives possible: food, fuel, medicines, technology. And still, they are absent from public discourse, as if invisible. What would happen if a key port was paralised due to a physical or cyberattack, or simply an accident? The answer is simple: broken supply chains, market instability, and an immediate economic impact. The invisibility of ports is not harmless but rather a vulnerability that we are choosing to ignore.

The lack of investment in physical and digital protection is another consequence of this ignorance of the risks. Whilst cyberattacks become increasingly sophisticated and physical threats become unpredictable, we continue to rely at time on obsolete systems. It's like leaving the door open and not expecting anyone to enter. There is a widening gap between our perception of security and to what extent that protection actually exists. And as for physical security, one need look no further than the drones of unknown origin overflying many European airports in 2025 to understand that we are wholly defenceless to drone attacks on port infrastructures.

Perhaps the gravest error is to assume that each country can deal with these risks on its own. The absence of international cooperation is a luxury we cannot afford. Critical infrastructures are global by their very nature, meaning that whatever happens in a European port can have repercussions in Asia and the Americas. Without alliances, shared protocols, and an earnest exchange of information, our reactions are condemned to being too little and too late.

Ignorance of the risks is not simply a lack of information. It is also a lack of interest in information and analysis that leads to a dangerously complacent attitude. Whilst we remain fixated on pipelines and straits, we are neglecting a vital component of

the we points in our system. Recognising the importance of ports, investing in security, and relying on international cooperation are not options: they are obligations. The question is not whether we should do this but how long we are going to take to react. Whilst it is true that many steps have already been taken, taking a deeper look at many ports leads one to believe that there is still much to do.

Bolstering port security

Securing the world's ports is a matter of global urgency. As we have said, ports are much more than mere entry and exit points for goods: they are truly the logistical heart of global commerce. Nevertheless, their security continues taking a backseat to other issues in public discourse. Amid a scenario of growing threats—from cyberattacks to physical sabotage—it has become imperative that we take tangible measures to fortify their resilience.

The first line of defence must be both digital and physical.

From the digital perspective, ports depend on IT systems to manage operations, coordinate cargo, and ensure the traceability of goods. Without regular cybersecurity audits, ports run the risk of their vulnerabilities going undetected until an attack paralises all activity. Transparency and continuous assessment are key to anticipating threats.

No port can rely on a single IT system. System redundancy—alternative systems that can spring into action if the main systems fail—is vital in preventing collapse. In an environment in which every minute of inactivity means, among other things, millions in losses, delays, and the loss of confidence, being able to react immediately marks the difference between resilience and chaos.

In addition to digital security, physical security is just as necessary. Ports must be secured against intrusions, sabotage, and outside threats through strict access controls, advanced surveillance, and contingency plans. Physical infrastructures are just as vulnerable as their digital counterparts are require comprehensive protection.

The risks to ports transcend borders. An attack on one strategic port can have repercussions in markets across different continents. This is why international cooperation and the creation of shared protocols is so essential. Port security cannot be

an isolated undertaking: it requires global coordiantion, exchange of information, and a joint response.

However, security does not depend solely on systems and protocols: ultimately, people are at its core. Investing in specialised training for port workers and in public awareness-raising campaigns goes a long way towards forging a culture of prevention. Well-prepared personnel know how to detect anomalies, respond quickly, and mitigate the impact of incidents.

As we've said, securing ports is not a luxury but a necessity. The proposals offered here—digital audits, system redundancy, physical security, international cooperation and training—are not simple recommendations. They are vital elements that guarantee the secure flow of global commerce. Any neglect of this urgency would only ensure fragility in a world that demands resilience.

The risks of port concentration and expansion without diversification

Returning to the matter at hand, the concentration of ports around oil, oil derivatives, and natural gas has become a decidedly risky strategy. What may seem like logistical efficiency is really a strategic burden and a multiplier of risks. When too many strategic flows depend on a handful of nodes, any interruption—whether by accident, due to attack, or because of geopolitical crisis—can lead to collapse on a global scale.

Ports specialised in hydrocarbons concentrate massive volumes of crude oil and liquefied natural gas. This concentration turns these facilities into high-value targets. The effects of an incident in one key port go beyond the regional scope, paralising entire supply chains and causing prices to skyrocket. Efficiency, thus, simply results in fragility.

Such dependence on a reduced number of ports created systemic vulnerability. We're not just talking about physical risks, such as sabotage or natural events, but also hybrid threats that can include cyberattacks capable of crashing management systems, disinformation campaigns that can destabilise markets, or geopolitical pressures t

hat weaponise infrastructures. Port concentration effectively amplifies the risk inherent to any threat.

The emergence of green hydrogen and other new fuels should be treated as an opportunity to diversify logistics nodes. However, the trends seem to indicate a

repetition of the same pattern: the concentration of operations in a few specialised ports. This not only serves to lock in these vulnerabilities but also adds additional layers of risk to the most sensitive and strategic of products.

Port concentration of oil and oil derivatives, natural gas, and now green hydrogen is a strategy that, despite its apparent efficiency, is deeply dangerous. Without the diversification of logistics, every port becomes a bottleneck and a perfect target. Securing these infrastructures and expanding the network of energy nodes is not simply an option: it is the only way to keep the heart of global commerce from becoming its Achilles's heel.

The following table illustrates this point:

Dimension of risk	Concentrated ports	Diversified ports
Impact due to interruption	High	Low
Attractiveness to threats	High	Low
Operational redundancy	Limited	High
Production cost	Elevated, concentrated	Elevated, distributed
Systemic resilience	Fragile	Robust

Energy ports and the pitfalls of expansion

The construction of new port infrastructures for hydrocarbon commerce stands out as a strategic necessity in a world that still depends—and will continue to depend for many years—on oil and natural gas. However, the road that leads to such expansion is full of obstacles that cast doubt on the viability and, especially, the sustainability of such an enterprise.

Building a port specialised for hydrocarbons is not a minor undertaking. Budgets can well exceed $10 billion, making each project a high financial risk. Moreover, with an energy transition underway, committing these kinds of resources to fossil fuel infrastructures seems like an investment in an uncertain future.

Port construction projects, especially those related to energy, often face opposition from local communities and environmental organisations. Their construction entails an impact on coastal ecosystems, added emissions, and pollution risks. Social opposition

leads to delays and can erode a project's legitimacy, thus influencing political calculations focused more on electoral criteria than energy security.

A port, no less, is not an island and requires land, railway, and energy connections in order to function. As such, the difficulty of integrating these infrastructures in saturated areas or with geographical limitations adds extra complexity and cost. Without an efficient logistical network, a port becomes a giant with leaden feet.

Construction of an energy port can take more than a decade to complete. In a global market where demand and technology changes quickly, these far-off deadlines only add more uncertainty to projects. Something that seems indispensable today could be obsolete tomorrow. Hydrocarbon ports are also subject to geopolitical tensions and energy market volatility. Changes in government, international crises, and a sharp drop oil prices can turn a multimillion-dollar project into a financial black hole. Any lack of political or economic stability is as big an obstacle as the cement that supports a port's infrastructures.

Thus, the expansion of ports specifically designed for hydrocarbons faces a dilemma: is it worth the billions invested in infrastructures that soon could be made obsolete by the transition to clean energy? All the financial, social, logistical, political, and other obstacles are not simple technical barriers to overcome: they are warnings that the model of concentration around fossil fuels, which some believe is past its time, in truth still has many years ahead. Port expansion may indeed be a good option. Nevertheless, some believe it is better to batten down the hatches now than to risk the future on colossal investments. We trust that it will never happen, but if one day one of these ports is blown sky-high—and heaven forbid it should occur—we will have to decide how to divide the blame.

A little-known reality

The strategic function of energy ports

Energy ports are more than simple energy nodes where multiple systems converge: maritime transport, storage, processing, distribution, and digital monitoring. Their function is not limited to the loading and unloading of energy products, as they also include:

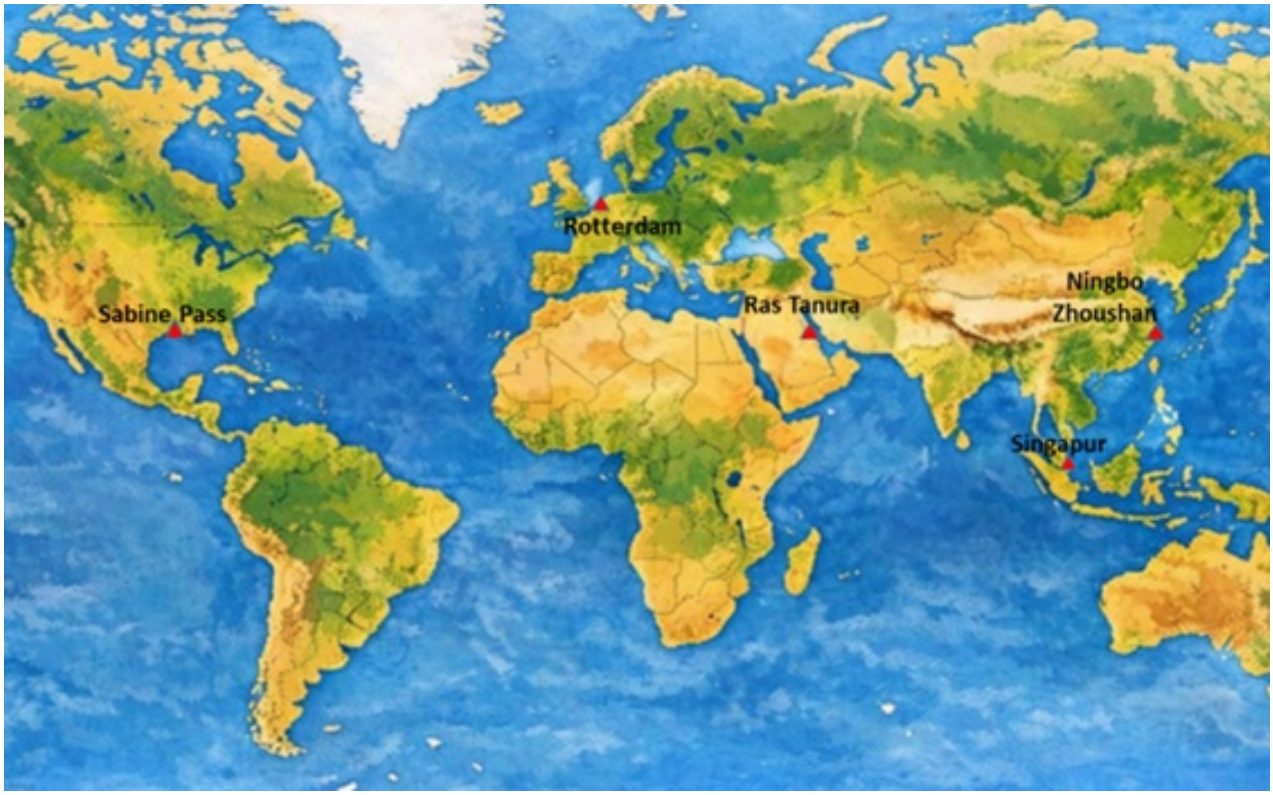
- Temporary storage in high-capacity tanks.
- Interconnections with refineries and regasification plants
- Land distribution via pipeline and tanker trucks.
- Digital monitoring via SCADA[4] systems and OT[5] networks.

The operational efficiency of these ports determines the continuity of energy supply in entire regions. Any paralysis, for any reason, could cause an unprecedented disaster that would surely create a domino effect with consequences beyond energy supply, affecting industries, homes, and essential services. Ultimately, the ensuing erosion of public confidence in the political system could lead to great instability. Then, radicals groups on one end of the spectrum or the other would likely attempt to take advantage of such instability to generate chaos.

The world's premier energy ports

Whilst not forgetting to keep the value of brevity in mind, we will now focus our study on the energy ports we consider to be the world's most important due to their capacity, location, and strategic importance:

[4] SCADA (Supervisory Control and Data Acquisition) is a system that enables: real-time industrial process monitoring; monitoring of devices such as valves, engines, sensors, and PLCs (programmable logic controllers); data collection from multiple locations for dispatch to a central station; visualisation and analysis of process performance for making informed decisions.
[5] OT (Operational Technology) is hardware and software for managing physical industrial processes such as energy, manufacturing, transport, etc.



Ras Tanura (Saudi Arabia)

Located on the eastern coast of Saudi Arabia, Ras Tanura is not just a port city but also a key component in the clockwork of global energy. Since its founding in the 1940s as a strategic enclave for oil exportation, Ras Tanura has grown into one of the world's largets and most sophisticated oil ports. Operated primarily by Saudi Aramco, it represents the logistical heart of a nation whose economy revolves are oil.

The Port of Ras Tanura was born as part of an ambitious oil infrastructure project led by Saudi Aramco. It was initially designed to be populated by foreign workers, especially from the United States, in a separate community full of Western-style services. With the passing of time, it has transformed into a crude oil export operations centre with facilities that rival those of any industrial port on the planet.

Ras Tanura handles a significant portion of the oil that Saudi Arabia exports around the world, totalling over 250 million tonnes of crude per year. Being a deepwater port and with the construction of artificial islands, it is capable of receiving the massive VLCC oil

tankers[6]. In addition to crude oil, it also handles refined products from the nearby refinery, one of the world's largest.

The port's infrastructure includes:

- Offshore platforms operated by Saudi Aramco and international partners such as Schlumberger and Halliburton.
- A private airport for logistical operations.
- Land connections with industrial centres such as Jubail and Dhahran.
- Industrial automation systems based on SCADA and OT networks.

The oil leaving Ras Tanura goes to supply major economies such as those of China, Japan, South Korea, various countries in Europe, and the United States. Multinational corporations such as Shell, ExxonMobil, and Total have trade agreements with Saudi Aramco, which consolidates the port as a vital node in the global energy system.

Security at Ras Tanura is top priority. In terms of physical security, the port has perimeter fencing, armed guards, biometric access controls, and regular patrols. However, it is in the digital realm where the deployment of an advanced protection architecture is evident.

SCADA systems supervise industrial processes in real time whilst OT networks connect sensors, PLCs, and actuators with control centres. This infrastructure is segmented to prevent any attack on the IT network from affecting the OT network[7]. Other security systems include industrial firewalls, intruder detection systems, artificial intelligence to analyse traffic, and server redundancy to ensure operational continuity.

Despite all the measures taken for maximum security, Ras Tanura is not immune to risks. In March 2021, an attempted drone attack on nearby Saudi Aramco facilities was

[6] Terminals for VLCC (Very Large Crude Carrier) ships—capable of transporting up to 320,000 toinnes of dead weight—require specialised infrastructures due to their size and draught.
[7] Generally, over 20 metres of depth are necessary to accommodate the draught of these ships.
Mooring systems: SBM (Single Buoy Mooring) or CALM (Catenary Anchor Leg Mooring) for safe operations at sea.
Pumping capacity: High speed loading/discharge for large volumes of crude.
Land infrastructure: Pipelines connected to oil fields or refineries.

reported. The attack was intercepted but revealed vulnerabilities by air. Furthermore, the malware programme Shamoon,[8] which affected Saudi Aramco 2012, illustrated how industrial systems can be the target of sophisticated cyberattacks.

Its main weaknesses include:

- The growing interconnection between IT and OT networks.[9]
- The exposure and concentration of critical infrastructure such as offshore platforms.
- Economic dependence on oil, which turns any interruption into a national threat.

Maintaining operational continuity is vital. Likewise, protecting industrial data, environmental management, and resilience in the face of geopolitical or health crises are essential elements. Ras Tanura must be prepared to respond to contingencies of all kinda, from sabotage to pandemics.

Ras Tanura isn't simply a port: it is a symbol of global energy infrastructure. Its strategic importance requires constant vigilance, investments in security, and technological adaptation in an increasingly interconnected and vulnerable world. It represents the balance between industrial tradition and digital modernisation; between power in logistics and strength in cybersecurity. All this without neglecting classic physical security against any kind of attack, from crude or low-tech assaults to long-range rocket or missile strikes.

Over the last 10 years, Saudi Arabia has suffered several significant attacks on its oil facilities, mostly attributed to the Iranian-backed Houthi rebels in Yemen. These attacks have revealed the vulnerabilities in Saudi energy infrastructures and had global repercussions for oil markets.

The main attacks on Saudi oil facilities:

- May 2019: a drone attack by Houthi rebels on a Saudi Aramco pipeline, forcing a temporary halt in oil pumping.

[8] Shamoon is one of the most destructive malware programmes, known for its ability to completely erase the hard drives of infected systems. Also known as DistTrack, the virus appeared for the first time in 2012 with comebacks in 2016 and 2018

[9] IT (Information Technology) manage business-related data and digital systems whilst OT networks (Operational Technology) monitors machines, physical processes, and industrial production.

- September 2019: the Abqaiq–Khurais attack, the most serious in recent history, in which drones and missiles struck the Abqaiq refinery and the Khurais oil fields, causing production in Saudi Arabia to drop to 5.7 millions of barrels per day, nearly half its capacity.
- January 2020: a 10-drone Houthi operation attack the Shaybah oil field in the Eastern Province, affecting one of the country's most important oil reserves.
- March 2021: Houthi rebels attacked Saudi Aramco's facilities en Ras Tanura.
- March 2022: drones and missiles caused a fire at a Saudi Aramco storage plant in Jeddah, close to the Formula 1 track and shortly before the Saudi Arabian Grand Prix.

Sabine Pass (United States)

Sabine Pass is the port that has spearheaded the natural gas revolution in the United States. On the US Gulf Coast on the border between Texas and Louisiana, this port terminal has redefined the role of the United States in the global energy market. As opposed to traditional ports focused on crude oil, Sabine Pass is specialised in exporting liquefied natural gas (LNG), giving it a key position in the global energy transition. Operated by Cheniere Energy, today it is the United States' number one LNG export terminal. Boasting capacity in excess of 30 million tonnes per year, it has become a key port for supply to, among other destinations, Europe following the Russian gas crisis.

Sabine Pass's modern history begins in 2016, when Cheniere Energy opened the first LNG export terminal in the US. This marked the start of Sabine Pass's radical transformation from a Gulf Coast backwater to the leading LNG production site in the country and one of the most important worldwide.

The terminal was designed to scale rapidly, with multiple phases of expansion that have allowed it to increase production capacity and adapt to growing international demand.

Sabine Pass is home to highly specialised infrastructure:

- Six operational liquefaction trains, capable of producing more than 30 million tonnes of LNG per year.
- Sea docks designed for large has tankers.

- Thousands of industrial valves, including cryogenic and rapid isolation systems such as HIPPS.
- Connected by land to gas distribution networks in the US, facilitating transport from gas fields to the terminal

These infrastructures ensure the efficiency of LNG exports whilst guaranteeing high standards of safety and sustainability in operations.

Sabine Pass exports LNG to over 30 countries consolidating the position of the United States as a "theoretically" reliable supplier in uncertain times for energy. The US has reached this role due in part to the Russian gas crisis stemming from the invasion of Ukraine and the subsequent energy sanctions imposed on Russia, in addition to the sabotage of the pipelines Nord Stream 1 and 2.

The main destinations of exports include:

- Europe, especially following the energy crisis of 2022, where LNG from the US has proved essential in reducing dependence on Russian gas despite its much higher price.
- Asia, with Japan, South Korea, and China leading demand.
- South America and the Middle East, emerging markets transitioning to cleaner energy sources.

Security at Sabine Pass is divided into two complementary levels, physical security and digital security:

- Biometric access controls for personnel.
- Perimeter surveillance with sensors, thermal cameras, and armed patrols.
- Emergency protocols in the event of leaks, fires, or sabotage.
- SCADA systems for real-time monitoring of industrial processes.
- Segmented OT networks, which prevent the spread of cyberattacks from IT networks.

- Industrial firewalls, intrusion detection systems (IDS) and artificial intelligence algorithms for traffic analysis.
- Collaboration with technology companies such as Bechtel and AMPO to ensure operational integrity.

Despite its sophistication, Sabine Pass is not exempt from threats and so must face risks and vulnerabilities:

- Cyberattacks targeting SCADA systems, especially in moments of geopolitical tension.
- Dependence on cryogenic infrastructure, which requires constant and specialised maintenance.
- Exposure to extreme weather events, such as hurricanes affecting the Gulf Coast.

To date, no serious attacks have been reported, but the terminal has undergone intensive audits by the Federal Energy Regulatory Commission (FERC), resulting in continuous improvements to its security protocols.

Sabine Pass operates under the logic of resilience and efficiency. Its priorities include:

- Operational continuity, even in crisis scenarios.
- Industrial data protection, key in preventing digital sabotage.
- Environmental management, with strict controls to prevent emissions and spills.
- Technological adaptability, to integrate new solutions without compromising safety.

Sabine Pass is much more than a port terminal: it is the symbol of the new era of US energy. Its global LNG export capacity, the cutting-edge infrastructure, and focus on security make it a benchmark for 21st century energy ports. In a world in search

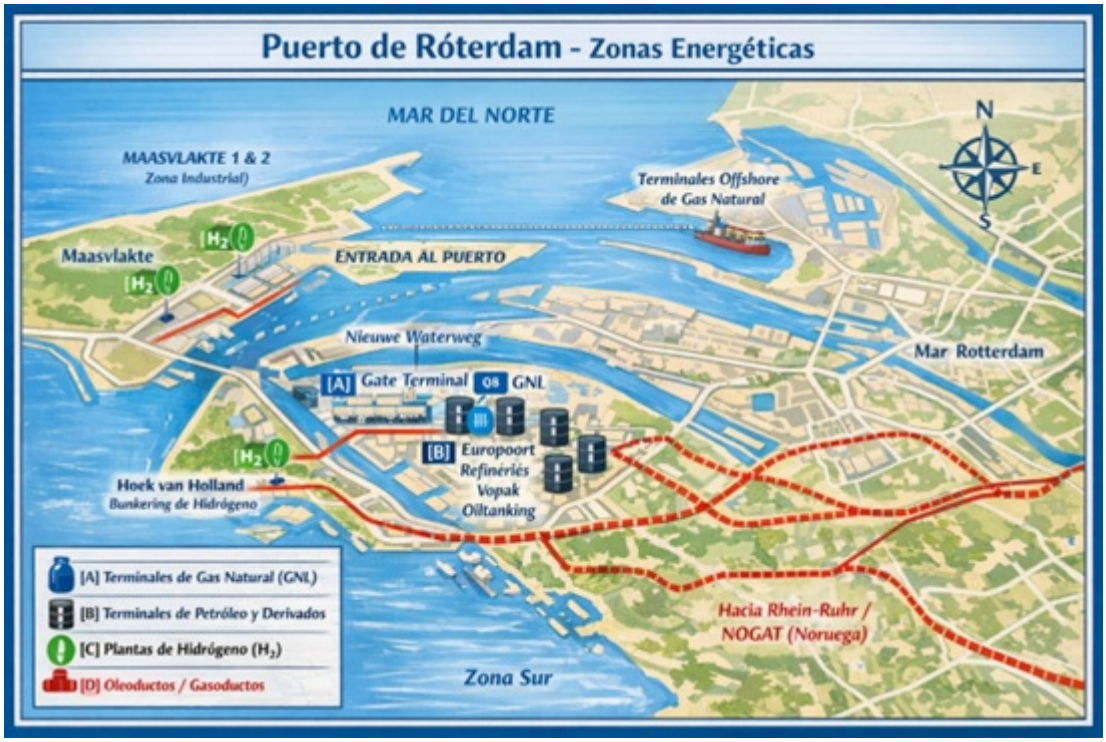
of alternatives to oil, Sabine Pass stands out as the port of the future where innovation, sustainability, and strategy converge.

Rotterdam (Netherlands)

The Port of Rotterdam, in the Netherlands, holds not only the title of largest port in Europe in terms of total cargo volume, but also positions itself as one of the most advanced logistics nodes in the world in the handling of crude oil, natural gas, and hydrocarbon products. In fact, it is the largest energy port in Europe, with more than 300 million tonnes of energy cargo passing through terminals for crude oil, LNG, derivatives, and petrochemical terminals. Its specialised infrastructure, intermodal connectivity, and its strategic role in European energy security make it a key component of the continent's economy.

The Port of Rotterdam, one of the largest and most advanced in the world, has witnessed a radical transformation thanks to the Maasvlakte I and II expansion. These extensions have not only increased the port's operational capacity but have also marked a turning point in port automation, positioning Rotterdam as a global benchmark in smart and sustainable logistics.

Opened in 1973, Maasvlakte I was the port's first major expansion into the North Sea. This engineering work made it possible to receive ships of greater draught and improve the port infrastructure. Although it did not incorporate advanced automation, it laid the groundwork for the technological development that would come decades later.



Operational since 2015, Maasvlakte II represents the pinnacle of port innovation. This expansion was designed from the ground up to integrate automation, energy efficiency, and environmental sustainability technologies.

Rotterdam manages about 100 million tonnes of crude oil per year, although in 2024 there was a slight drop of 4.5% due to scheduled maintenance at several refineries. The port has unloading and storage terminals directly connected to refineries such as Shell Pernis, one of the largest in Europe. In addition, it has cross-border pipelines linking Germany and Belgium, facilitating distribution of crude oil imports by land. The port extends over 42 kilometres, where we can find five refineries, more than 30 crude oil storage tanks, dozens of terminals for petrol, diesel, fuel oil, kerosene, etc., LNG terminals with a capacity of 12 million cubic metres. Furthermore, expansion has begun with green and blue hydrogen terminal projects, which would turn Amsterdam into a hydrogen hub.

The Port of Rotterdam is connected to a vast energy transport network that makes it a strategic hub for Europe through:

- The Rotterdam–Rhineland pipeline: transporting crude oil from the port to refineries in Germany, especially in the Ruhr region.
- The Transalpine Pipeline (TAL): although it does not start directly from Rotterdam, it is connected to the European network that distributes refined products to Austria and Italy.
- Refined product terminals: from Botlek and Europoort, petrol, diesel, and kerosene are distributed by road, rail, and ship.
- Gas pipeline network: connected to the Netherlands' Gasunie network, which distributes gas throughout Western Europe.
- H2Import project: slated to receive green hydrogen from countries such as Spain, Morocco, and Chile.
- The HyTransPort project: a hydrogen pipeline that will connect the port with industrial parts of the country.
- LOHC and ammonia: terminals are being developed to import hydrogen in liquid organic form or ammonia, facilitating its safe transport.
- Rail: the port has direct links with Germany, Switzerland, and Eastern Europe, allowing the transport of energy products by train.
- River transport: more than 91,000 river vessels a year transport energy products along the Rhine and other rivers.

In short, the Port of Rotterdam stores, processes, and distributes energy across the continent through an integrated network of pipelines, railways, and river routes.

Thanks to its deepwater docks, the port can receive VLCC supertankers, making it a key entry point for oil from the Middle East, Africa, and the Americas.

The Port of Rotterdam is also noted for its ability to manage a wide range of derived products, such as fuel oil, kerosene, petrol, diesel, lubricants, and petrochemicals. In 2024, the volume of these products increased by 0.8%, driven by the fuel oil trade and the growing demand for kerosene in the aeronautical sector.

The port is home to petrochemical clusters that transform raw materials into industrial products such as plastics, fertilisers, and solvents. The terminals are equipped with specialised pumping, cooling and chemical safety systems, adapted to the characteristics of each type of load.

Although the volume of liquefied natural gas (LNG) decreased by 5.3% in 2024, we will have to wait for official 2025 figures to see a rebound in volume proportional to the increase in US LNG purchases which followed the arrival of President Trump and his tariff policy.

Rotterdam remains a key player in the reception and distribution of LNG. Its terminals are connected to European distribution networks, facilitating supply to northern and central European countries.

Following the 2022 energy crisis and the reduction in Russian gas imports, the port has played an essential role in Europe's energy diversification. Its facilities include cryogenic tanks, regasification systems, and cargo platforms for methane tankers.

Hydrocarbon management in Rotterdam is supported by an advanced safety architecture. The port employs SCADA systems and OT networks to monitor industrial processes in real time, and has implemented specific cybersecurity protocols for hazardous product terminals.

At the environmental level, Rotterdam promotes the reduction of emissions through the use of biofuels, the electrification of docks, and carbon capture projects. These initiatives are part of its strategy to become a climate-neutral port in the coming decades.

Despite its sophistication, the Port of Rotterdam faces significant challenges:

- Geopolitical volatility can affect the stability of energy supply.
- Critical infrastructures are exposed to cyber and physical risks.
- The energy transition will require adapting traditional terminals to new fuels such as green hydrogen.
- An alarming concentration of capabilities.

The Port of Rotterdam is not just a maritime transit point: it is a strategic hub for fossil energy in Europe, with advanced capabilities to handle oil, gas, and hydrocarbon derivatives. Its role in energy security, specialised infrastructure, and commitment to sustainability make it a global benchmark in energy logistics.

But there is another reality: we could call the Port of Rotterdam the largest time bomb in Europe, alarmingly exposed to attempted physical attack by drones, dirty bombs, or other means. The port is notorious for its high degree of permeability to illicit traffic all kinds. In fact, it is considered the main gateway for illicit drugs into Europe—especially cocaine—which should be cause enough for great alarm. Both Europol and the Dutch police have warned that criminal networks use the same channels to smuggle other illicit goods into Europe. Perhaps it is necessary to remember how, throughout 2025, the appearance of unidentified drones at different European airports demonstrated the serious security deficiencies of these facilities. Far from being excluded, the Port of Rotterdam must be placed at the top of this list.

At the end of 2025, the Dutch government's National Coordinator for Counterterrorism and Security (NCTV) had established the country's official terrorist threat level as 4 out of 5, meaning that the authorities believed there to be a realistic threat of a terror attack occurring anywhere in the Netherlands.

Singapore

In the heart of Southeast Asia, where the busiest shipping routes on the planet converge, we have the Port of Singapore: the world's largest marine fuel supply port. It's also a world leader in terms of efficiency and cargo volume and, as a global hub for transshipment and bunkering,[10] plays a strategic role in the global trade of oil, natural gas, and hydrocarbon products. Its privileged location, cutting-edge technology, and sustainable approach to operations make it a world leader in energy logistics, with a floating LNG terminal and future hydrogen infrastructure.

Singapore is one of the world's leading bunkering hubs, supplying fuel to thousands of vessels every month. The port manages more than four million tons of conventional fuels

[10] Bunkering is the process of supplying fuel to ships. Bunkering is an essential part of maritime transport operations, making it possible for ships to refuel as needed during their routes.

per month and its terminals are designed to receive, store, and distribute crude oil efficiently and safely. Its capabilities allow it to function as a regional redistribution hub, supplying neighbouring countries and facilitating intercontinental trade.

It manages a wide range of refined products such as fuel oil, diesel, kerosene, lubricants, and petrochemicals, essential for the maritime and manufacturing industry in Southeast Asia.

It houses refining and processing facilities that for transforming raw materials into high value-added industrial products.

Although Singapore is not a large producer of natural gas, its port acts as a regional LNG distribution hub. Its terminals are designed to:

- Receive methane tankers with cryogenic loads.
- Store the gas in refrigerated tanks.
- Regasify and redistribute the product to Southeast Asian markets.
- It actively participates in LNG futures trading, consolidating its role as a financial and logistics hub for gas in Asia.

Hydrocarbon management in Singapore is supported by world-class technological architecture:

- SCADA systems and OT networks for real-time monitoring of industrial processes.
- Automated cranes and autonomous vehicles to minimise risk to humans.
- Cybersecurity protocols including blockchain, artificial intelligence, and network segmentation.

Singapore is much more than a point of loading and unloading: it is a global energy hub where technology, strategy and sustainability converge. Its capacity for handling oil, gas, and hydrocarbon derivatives accurately and safely makes it, according to many experts, a model of port efficiency in the 21st century.

There are three major threats facing the ports: logistical congestion, piracy in the Singapore Strait, and regional geopolitical tensions.

The issue of logistical congestion concerns the sheer number of ships that accumulate in the area due to its strategic location. External factors, such as the crisis in the Red Sea and the increase in global demand for goods, exacerbate the problem.

As regards piracy and maritime crime, the number of attacks in the Singapore Strait shot up from seven to 27 in one year, an increase of 285%. Although many are small-scale atracks, firearms were used in 14 incidents. All of these incidents put both crews and goods at risk.

In terms of geopolitical tensions, the Straits of Malacca and Singapore are critical chokepoints for global trade and energy transportation. Regional conflicts and rivalries between powers in Asia and the Middle East can affect the free movement of goods.

There is also the matter of organised crime and cyberattacks. Modern ports, including Singapore, are targets of smuggling, organised crime and cyberattacks seeking to exploit their critical role in global trade. The technological interconnection makes the port a target for attacks that could paralyse operations or manipulate logistical data.

Ningbo-Zhoushan (China)

On the east coast of China, in the province of Zhejiang, stands the Port of Ningbo-Zhoushan, a colossal maritime infrastructure that has risen to become one of the busiest ports on the planet. Beyond its leadership in total cargo volume in the world, the port plays a strategic role in the handling of crude oil, natural gas, and hydrocarbon products, consolidating its importance in national energy security and in global trade.

The Port of Ningbo-Zhoushan handles tens of millions of tons of crude oil each year, thanks to its specialised liquid bulk terminals. These facilities are designed to receive supertankers and facilitate the storage and distribution of crude oil to refineries and industries in China's interior.

Some of its assets include:

- Deepwater docks with capacity for VLCC vessels.

- Automated tanks with pressure, temperature, and safety control systems.

- Pipelines interconnected with regional refineries and key industrial zones.

Its strategic location in the Yangtze Delta allows for seamless connectivity with the country's main logistics corridors.

In addition to crude oil, Ningbo-Zhoushan manages a wide range of refined products such as fuel oil, petrol, diesel, lubricants, and petrochemicals. The terminals are equipped with pumping and automated mixing technology, as well as chemical safety systems for hazardous loads.

The port is also home to industrial clusters dedicated to the transformation of hydrocarbons into high value-added products, such as plastics, fertilisers, and solvents. Its intermodal infrastructure—which includes railways, motorways, and waterways—allows for efficient distribution both nationally and internationally.

Although China has other hubs more specialised in LNG, Ningbo-Zhoushan also deals with liquefied natural gas, strengthening its role as an energy logistics hub. Its LNG terminals include:

- Cryogenic tanks for safe storage.
- Regasification plants for redistribution to the interior of the country.
- Connections with energy distribution grids, which strengthen national energy security.

Hydrocarbons commerce at Ningbo-Zhoushan is backed by an advanced technological architecture:

- SCADA systems and OT networks for real-time monitoring of industrial processes.
- Cybersecurity protocols to protect critical infrastructures against digital threats.
- Environmental measures to reduce emissions, prevent spills and protect coastal ecosystems.

The port also participates in initiatives related to the New Silk Road, reinforcing its role as a strategic node in China's trade and energy expansion.

Despite its scale and sophistication, the Port of Ningbo-Zhoushan also faces significant challenges:

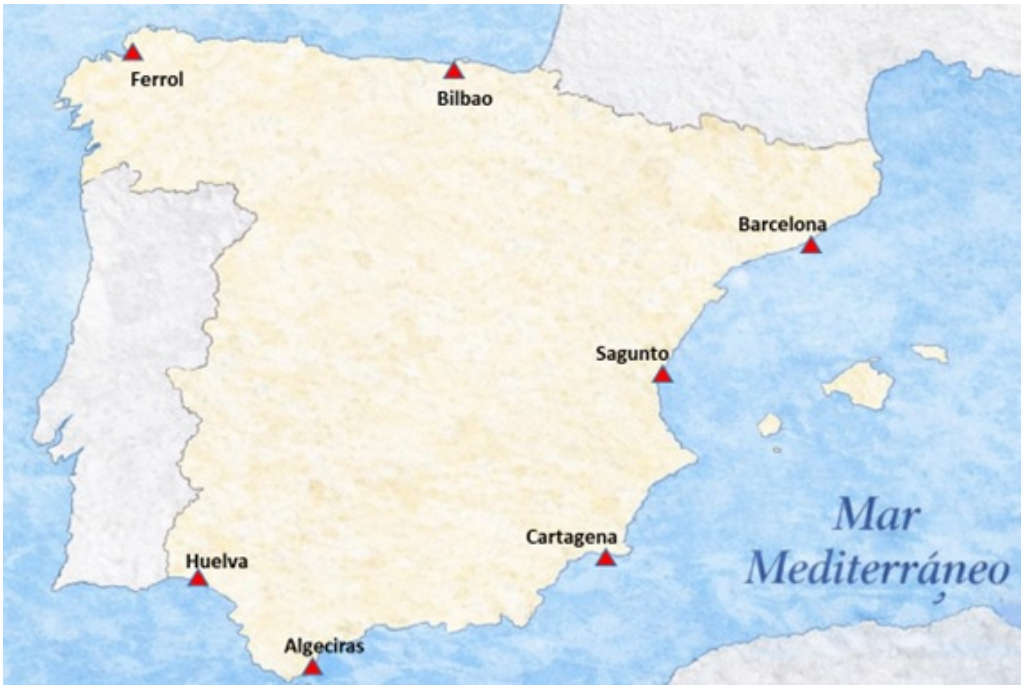
- Cybersecurity risks, derived from its high degree of automation.
- Logistical congestion, especially in high-demand seasons.
- Exposure to geopolitical tensions, which can affect energy trade and maritime routes.

The Port of Ningbo-Zhoushan is not just a maritime transit point—it is a global energy hub, where operational efficiency, advanced technology, and geopolitical strategy converge. Its capacity for handling oil, gas, and hydrocarbon derivatives makes it a linchpin of China's energy security.

But security risks in Ningbo-Zhoushan are high, due to the size of the port and the presence of hazardous materials in its daily operation. Recent incidents show that even a single accident can have global repercussions on logistics, the economy, and the environment. In August 2024, a powerful explosion on the vessel YM Mobility, a container ship docked in the port, generated a huge fireball and forced the evacuation of the crew and the temporary closure of several terminals that affected international supply chains. The ship was carrying hazardous materials, which magnified the risk of fire and contamination.

Spain as a maritime energy hub

Spain is, at times, one of Europe's primary energy logistics nodes due to its port network specialising in the loading, unloading, and storage of crude oil, refined products, and liquefied natural gas (LNG). With more than 200 million tonnes of energy goods per year moved through Spanish ports and a storage capacity of more than eight million cubic metres, Spain attempts to maintain a strategy role in the continent's energy supply.



Port of Algeciras (Cádiz)

The Port of Algeciras is an important logistics enclave for the Mediterranean and Europe. With an annual volume of more than 100 million tonnes, specialised in crude oil, refined products and bunkering operations, it has established itself as a first-rate energy and commercial node. Its infrastructure includes modern hydrocarbon terminals, pipeline connections, and rail network, as well as advanced security systems such as leak and fire detection, perimeter surveillance, and Seveso III protocols for hazardous substances.

Port of Cartagena, Murcia

The Port of Cartagena has established itself as an important energy enclave in Spain. With an annual volume of nearly 30 million tonnes, its activity focuses on the traffic of crude oil, refined products, and liquefied natural gas (LNG). LNG storage capacity reaches 600,000 m³, making it a key node for Spanish and European energy security.

Its infrastructure is directly connected to the nearby Repsol refinery and it has an active regasification plant, bolstering its strategic role in the hydrocarbon and gas supply chain. In terms of safety and security, the port is equipped with anti-pollution containment barriers, automatic extinguishing systems, and is subject to regular industrial cybersecurity audits.

However, its importance makes it an attractive target for terrorist threats and cyberattacks, which are currently the primary risks faced. The concentration of energy operations in Cartagena makes it a potential target for terrorist groups. The hydrocarbon terminals and its regasification plant are facilities whose interruption would have an immediate impact on the energy supply.

Port of Bilbao (Basque Country)

The Port of Bilbao, located in the Basque Country, handles an annual volume of over 25 million tonnes. Its activity focuses on the traffic of crude oil, derivatives, and liquefied natural gas (LNG). Additionally, its LNG storage capacity reaches 300,000 m³, making it a strategic node in national energy security.

The port's infrastructure includes a direct connection to the Petronor refinery as well as a regasification plant, consolidating its importance in the hydrocarbon and gas supply chain. In terms of safety and security, the Port of Bilbao has continuous environmental control systems, a network of thermal sensors, and regular emergency drills, demonstrating a commitment to prevention and resilience.

Port of Huelva (Andalusia)

The Port of Huelva is an energy enclave in southern Spain. With an annual volume of more than 30 million tonnes, its activity focuses on the traffic of crude oil, refined products, and liquefied natural gas (LNG). Its the LNG storage capacity is up to 600,000 m³, consolidating its role as a strategic node in Spanish and European energy security.

The port's infrastructure is extensive and complex, with nine docks, 13 mooring points and over 110 kilometres of pipes connected to pipelines, which guarantees an uninterrupted flow of hydrocarbons and gas into the interior of the peninsula.

Port of Barcelona (Catalonia)

The Port of Barcelona is an energy and logistics hub in Spain. Its activity is focused on the traffic of liquefied natural gas (LNG) and refined products, with an LNG storage capacity of 760,000 m³, the largest in the country. This infrastructure makes it a key point for national and European energy security.

Its high-capacity regasification plant and multipurpose terminals reinforce its strategic role in the supply chain. In terms of security, the port has redundant control systems, continuous environmental monitoring and integrated contingency plans, demonstrating a commitment to prevention and resilience.

Port of Sagunto (Valencia)

The Port of Sagunto is an important energy hub on the Spanish Mediterranean coast. Its activity focuses on the traffic of liquefied natural gas (LNG), with a storage capacity of 600,000 m³, making it a critical point for national energy security.

The port's infrastructure includes a modern regasification plant and direct connection to the national gas pipeline network, guaranteeing the continuous supply of gas to the interior of the peninsula.

Port of Ferrol (Galicia)

The Port of Ferrol is an energy enclave specialised in the traffic of liquefied natural gas (LNG). With a storage capacity of 150,000 m³,* its smaller-scale regasification plant and its specialised terminals make it an important point within Spain's energy network, although with less volume than other major ports. This is perhaps due to its difficult-to-access location in the Ferrol estuary, despite the infrastructure being designed for safe and efficient operations.

Puerto de Gijón (Asturia)

The Port of Gijón has reclaimed its role in the Spanish energy sector with the reactivation of its regasification plant. Its activity focuses on the traffic of liquefied natural gas (LNG), with a storage capacity of 300,000 m³ that makes it important node for gas distribution in northern Spain. The port's infrastructure includes direct connection to the northern distribution network, ensuring energy supply to the region and reinforcing its strategic importance.

Threats, strengths and weaknesses

This strategic relevance of Spanish ports in terms of hydrocarbons and their derivatives generally makes them highly attractive targets for terrorist threats and cyberattacks, which represent the most critical risks faced today. The concentration of energy traffic and the presence of critical facilities make all these ports a potential target for terrorist groups.

Any attack on a port's critical infrastructures, the explosions caused, sabotage on loading/unloading operations, coordinated attacks against ships in bunkering operations or hydrocarbon terminals, oil pipelines, gas pipelines, etc., with the resulting interruption of operations, would have an immediate impact on energy supply.

In many cases, a port's strategic location—whether close to the Strait of Gibraltar or very close to large populations—makes it a sensitive point in international conflicts and regional tensions. The impact of an attack would be disastrous, from the interruption of energy flows and economic losses in the millions to the weakening of international confidence in the port as a safe node—in addition to the risk involved for the local population, though perhaps not receiving sufficient consideration.

Strengths would include implementing Seveso III protocols[11] at times or SCADA systems, advanced detection systems and perimeter surveillance. These ports can also boast physical security systems and industrial cybersecurity audits.

Its weaknesses include critical dependence on digital systems for operational management. The digitisation of port operations, computerised logistics management, and remote control of a large part of operations opens the door to cybersecurity risks. Attacks on control systems that manage plants and terminals can manipulate them and alter critical processes. Leak sensors can be altered and automated cranes can be paralysed. There is the risk of the use of ransomware, which would lock authorities and operators out of port management systems and demand ransoms, thereby affecting operational continuity. Hybrid threats must also be considered, blending physical and

[11] The Seveso III Directive (officially Directive 2012/18/EU) is the European regulation that regulates the prevention and control of major-accident hazards involving dangerous substances, named after the 1976 chemical accident in Seveso, Italy. It aims to reduce the likelihood of explosions, fires, or toxic leaks and minimise their consequences on human health, the environment, and property. The directive classifies establishments into two tiers according to the amount of hazardous substances present, imposing obligations such as notification to the authorities, preparation of safety reports, internal and external emergency plans, and information to the population about risks and preventive measures. In Spain, it is implemented through Royal Decree 840/2015, which adapts these regulations to Spain's national legal framework and obliges chemical industries to maintain high standards of safety and transparency.

digital attacks to maximise impact. And let us not forget the high concentration of energy traffic in a single node. Sometimes, a direct connection to refineries and regasification plants poses a risk. There are also simple physical attacks, using any of the procedures that terrorists currently employ.

Conclusions

As we have already discussed, global energy dependence on hydrocarbons makes up a significant percentage. Ensuring the production, transport, and distribution of these hydrocarbons is of the utmost importance if we wish to avoid serious energy and economic crises. This chapter has attempted to shed light on what we could call the ugly duckling of the story: ports for loading and unloading of hydrocarbons, which are yet another link in a fragile chain that must be safeguarded in its entirety.

The global energy port network is truly a vital part of global trade and energy. It must not only guarantee national supply but also buttress energy security across the globe. Thus, port security is paramount.

The importance of energy ports makes them a priority target for physical terrorism threats and cyberattacks. Port resilience will depend on their ability to fortify physical and digital security, diversify critical infrastructure, and establish international partnerships that ensure rapid and coordinated incident response.

In some cases, their proximity to major centres of population makes them doubly interesting targets for terrorism. The consequences of physical attacks can be devastating, not just in terms of energy but also with regard to human casualties.

Greater awareness must be raised among the relevant authorities regarding this vulnerability. The logistical advantages of large concentrations of energy installations in ports is a double-edged sword, which begs consideration as this concentration increases.

Maintaining the current structure of mega-ports, done mainly for economic reasons, means assuming a very high risk that can take an incalculable toll on human lives and capital.

Generally speaking, the focal points of maritime routes, which are given so much importance, usually have alternatives. Whilst it is true that these alternatives are usually

longer and therefore make products more expensive, they nevertheless exist as alternative. The same, however, cannot be said for many loading and unloading ports.

The war in Ukraine has shown us how drones have become a lethal, low-cost threat that is very difficult to counter at present. Moreover, the problem also exists beyond Ukraine, if we consider the problems caused by the mere presence of rogue drones near European air traffic. The use of these same drones, but armed, against port energy facilities is a real threat for which we must be prepared.

*Miguel Golmayo**
Navy captain in reserve