WIPO Technology Trends
Technical Annex

Future of Transportation on the Sea

WIPO

World Intellectual Property Organization
34, chemin des Colombettes, P.O. Box 18
CH-1211 Geneva 20, Switzerland

wipo.int

DOI: 10.34667/tind.57969

Cover: Getty Images / KrisCole,
pariwat pannium

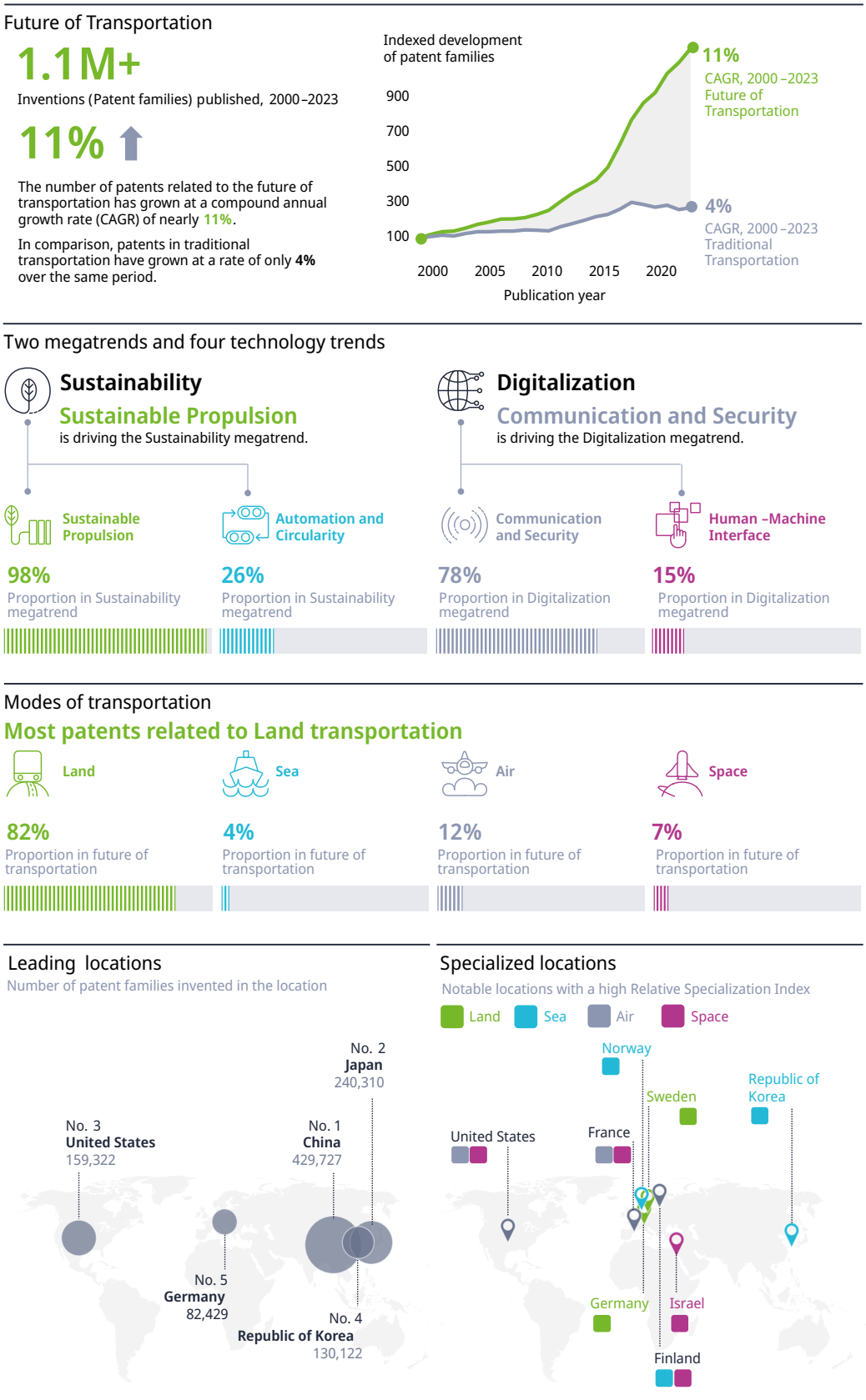
Table of content

Introduction to sea transportation

This technical annex to the WIPO Technology Trends Report 2025 on the Future of Transportation delves into the dynamic and evolving field of sea transportation, offering a detailed analysis of global patenting trends within the maritime industry. Through an examination of patent data, this annex provides insights into innovations across a range of maritime technologies, from vessel design and propulsion systems to autonomous navigation, cargo management and environmental sustainability. It captures trends in cutting-edge developments, such as fuel-efficient engines, advanced hull design and renewable energy integration, as well as digital advancements like smart ports and real-time logistics solutions. Full details on the research methodology and different patent indicators used can be found in the Appendix to the report.

By identifying key players, geographical patterns and areas of emerging technological focus, this annex offers a comprehensive perspective on how innovation is reshaping maritime transport to meet growing demands for efficiency, safety and reduced environmental impact. Aimed at industry leaders, policymakers, researchers and innovators, this annex is designed to be a strategic resource for understanding the future of sea transportation and its critical role in global trade and sustainability initiatives.

Figure B1 Exploring the main findings of the WIPO Technology Trends 2024 report on the Future of Transportation



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Overview of sea transportation

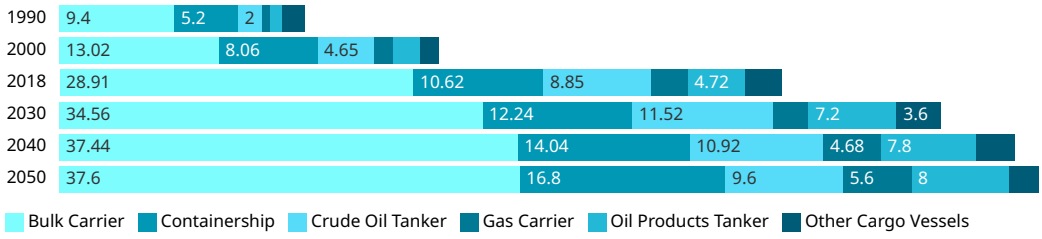
Sea transport (or maritime transport) refers to the movement of goods and passengers across bodies of water in vessels such as cargo ships, tankers, ferries and cruise liners, using sea routes and ports for international trade and travel.

Although the rise of air travel has reduced the importance of sea travel for passengers, it remains a favored mode of transport for shorter distances and leisurely cruises. As a result, coastal and marine tourism is vital to the economic prosperity of many island and coastal communities. Even more important is the role of sea transport for the global economy, as it accounts for over 80% of the world's trade in goods.[1]

Today's seaborne trade is largely driven by the transport of fossil fuels by tankers and dry bulk carriers (Figure B2). Other important segments are container shipping and other cargo ships. According to the shipping classification society DNV, total seaborne trade is projected to grow by 39% up until 2050.[2] A growing and more affluent global population is a key growth driver. However, sea trade will be affected by the move toward a more circular economy, reflecting a more climate-conscious society. This will lead to a decline in the transport of coal and oil, whereas DNV expects container ships and gas carriers to continue to show strong growth. However, the highest growth rates are forecast for specialized vessels serving the offshore wind industry.

Total seaborne trade is projected to grow by approximately 35% by 2050, driven largely by a growing and more affluent global population (DNV, 2021)

Figure B2 Global seaborne trade: historical development and forecast, 1990–2050



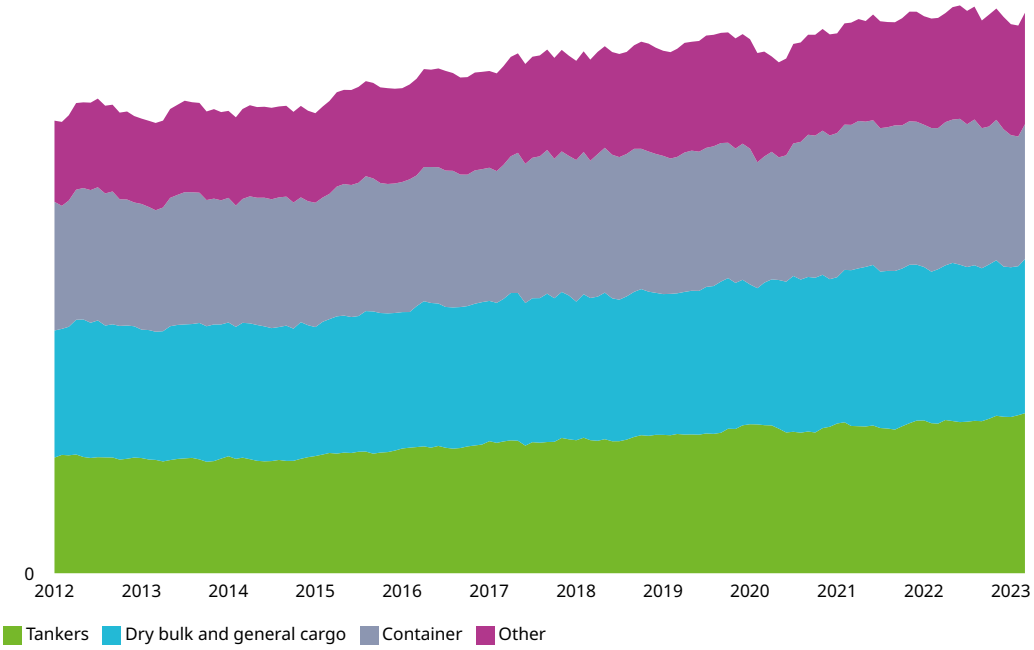
Note: Units: billion ton-miles.
Source: DNV, Clarksons research.

Sustainability and digitalization are megatrends playing a vital role in transforming the future of the maritime sector. The megatrend of sustainability will play a major role in the future of shipping. While ships are the most energy-efficient way to move large volumes of cargo over long distances, the sheer size of the industry means it has a significant impact on the environment. According to the World Bank, international shipping will have contributed around 3% of global greenhouse gas emissions in 2022, about the same as aviation.[3] Shipping's share of global sulfur (15% of the global total) and particulate matter (11% of the global total) emissions is much higher. Other negative environmental impacts of shipping include water pollution, noise and oil spills. Worse still, emissions from the shipping sector are heading in the wrong direction, with greenhouse gas emissions having increased by 5% in 2022 (Figure B3).[4]

1 UNCTAD (2024). Review of Maritime Transport 2024: Navigating Maritime Chokepoints. New York: United Nations Conference on Trade and Development. Available at: https://unctad.org/publication/review-maritime-transport-2024.
2 DNV (2021). Ocean's future to 2050: A sectoral and regional forecast of the Blue Economy. Available at: www.dnv.com/oceansfuture/shipping.
3 Dominioni, G., I. Rojon, R. Salgmann, D. Englert, C. Gleeson and S. Lagouvardou (2023). Distributing Carbon Revenues from Shipping. Washington, DC: World Bank. Available at: http://hdl.handle.net/10986/39876.
4 IEA (2023). International Shipping. International Energy Agency. Available at: www.iea.org/energy-system/transport/international-shipping.

Shipping emissions continue to increase

Figure B3 Carbon dioxide emissions by main vessel types, tons, 2012–2023



Source: UNCTAD (2023).

To achieve the goal of a more sustainable shipping industry, the International Maritime Organization (IMO)'s revised its emissions reduction targets in 2023 to ensure that they are in line with the ambitions of the Paris Agreement to limit global temperature rise.[5] As a result, the IMO is now aiming for a 15% reduction in emissions by 2030 and net-zero shipping by 2050.

Digitalization also holds great promise for shipping. By harnessing the power of digital technologies, ship movements can be optimized, fuel consumption can be reduced and better connectivity between land-based and maritime logistics networks can be achieved. This has the potential not only to streamline global supply chains, but also to significantly reduce the environmental footprint.

Sustainable Propulsion/Efficient Ship Design is a must if climate goals are to be met.

The shipping sector faces a difficult challenge: to reconcile continued growth with decarbonization targets, including net-zero shipping by 2050. Transitioning to more sustainable forms of propulsion is therefore key. Technological breakthroughs play an important role in advancing low and zero emission solutions. Key research areas are:

- More **sustainable carbon-based** fuels play an important role in shipping's transition to lower emissions. Liquefied natural gas (LNG) is the most important alternative fuel and dominates alternative fuel-powered newbuild orders. The use of LNG reduces emissions compared to traditional oil-based fuels and offers high energy density, allowing ships to travel long distances. On the downside, LNG-powered ships still emit greenhouse gases, concerns about methane leaks throughout the LNG supply chain exist, and LNG is more expensive than traditional fuels. However, greener solutions, such as biofuels and biogas, are even more expensive, and the availability of biofuels and biogas will need to increase significantly to meet shipping industry demand.
- An alternative is the use of **hydrogen, methanol or ammonia** in engines or **fuel cells**. Some hydrogen-powered ships are already in operation, but hydrogen has drawbacks. It is energy-intensive to produce and green hydrogen – produced from water by electrolysis – is not yet widely available. In addition, storing it is a challenge, because it takes up a lot of space.

5 IMO (2023). 2023 IMO Strategy on Reduction of GHG Emissions from Ships. International Maritime Organization. Available at: www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx.

Methanol could help, as this is liquid at ambient temperatures, so it can be transported, stored and bunkered in a similar way to diesel. A.P. Moller-Maersk, one of the biggest shipping companies in the world, announced 19 methanol dual-fuel containerships on order as of October 2022 for delivery between 2023 and 2025.[6] However, methanol is currently many times more expensive than conventional fuels. In the long term, the International Energy Agency (IEA) expects ammonia (made from hydrogen and nitrogen) to become a key fuel for shipping, accounting for 45% of marine fuel demand by 2050.[7] But although several demonstration projects for ammonia-fueled ships are underway, no ammonia-fueled ships are yet available.

- **Electric propulsion** holds promise for short-range shipping, especially for small and medium-sized vessels. Electric engines already operate on some short ferry journeys.[8] Electric propulsion systems can be more efficient than conventional engines, resulting in lower operating costs. They are also less complex and have fewer moving parts than traditional engines, which can lead to improved reliability and lower maintenance costs. In addition, wind and solar power can be installed on ships to provide additional propulsion. However, the sheer weight and space taken up by **batteries** on ocean-going vessels makes electric propulsion unviable until there are further technological breakthroughs.
- In addition to the use of cleaner fuels, optimizing energy consumption through **efficient ship design**, such as optimizing hull shape to minimize drag, designing efficient propellers or introducing air bubbles under the hull, is another key element in achieving more sustainable shipping.

In general, scaling up production and ensuring the cost-effectiveness of carbon-neutral fuels remains a challenge. Most alternative fuels produced today are grey or brown, meaning they're made from fossil fuels, such as coal or natural gas, and emit carbon dioxide in the production process. Fuel flexibility will be key to navigating the evolving landscape. It is likely that we will see a variety of alternative fuels gaining traction across the industry. Each has its advantages and disadvantages.

Regulation plays an important part in the development of greener ships

A lack of regulations is contributing to the slow uptake of alternative fuels.[9] While the IMO has issued safety regulations for methanol as fuel, similar guidelines for ammonia and hydrogen are still under development.[10] This uncertainty has discouraged shipowners from investing until now.

Clear regulations are needed that drive investment in sustainable fuels and the required infrastructure by creating a demand for these technologies. This can bring down costs and make them more viable for shipowners. For example, the new FuelEU Maritime initiative, that enters into force in 2025, is a step in the right direction. Among other things, it sets out measures to ensure that the greenhouse gas intensity of fuels used by the shipping sector will gradually decrease over time and includes a special incentive regime to support the uptake of renewable fuels.[11]

Communication and Security technologies make ships smarter and safer. They already play a crucial role in the maritime industry, and their importance will only increase in the future. We have identified the following key research areas within this technology trend:

- The most important area is **navigation**. Traditional satellites in geostationary orbit have been the backbone of maritime communications for decades ensuring reliable access to navigation signals for ships relying on systems such as the global positioning system (GPS).

6 Maersk (2022). A.P. Moller – Maersk continues green transformation with six additional large container vessels. Available at: www.maersk.com/news/articles/2022/10/05/maersk-continues-green-transformation.
7 IEA (2023). Transport. International Energy Agency. Available at: www.iea.org/energy-system/transport.
8 The Guardian (2018). Future sailors: What will ships look like in 30 years? Available at: www.theguardian.com/environment/2018/may/03/future-sailors-what-will-ships-look-like-in-30-years.
9 The Conversation (2023). Green fuels in shipping face major challenges for 2050 net zero target. Available at: https://theconversation.com/green-fuels-in-shipping-face-major-challenges-for-2050-net-zero-target-211797.
10 IMO (2023). Progress on safety guidelines for hydrogen- and ammonia-fuelled ships. International Maritime Organization. Available at: www.imo.org/en/MediaCentre/Pages/WhatsNew-1968.aspx.
11 European Council (2023). FuelEU maritime initiative: Council adopts new law to decarbonise the maritime sector. Available at: www.consilium.europa.eu/en/press/press-releases/2023/07/25/fueleu-maritime-initiative-council-adopts-new-law-to-decarbonise-the-maritime-sector.

Modern navigation systems, such as radar and collision avoidance systems (CAS) using lidar, radar and sonar technologies, can detect and warn ships of a potential collision, reducing the risk of accidents and ensuring safer navigation. In addition, better data sources (sensors, satellites etc.) are enabling advanced data management systems that can collect and analyze vast amounts of data. These data can be used to optimize routes and improve operational efficiency, resulting in reduced emissions and improved environmental performance.

- **Device-to-device communication** is also becoming increasingly important. This includes technologies such as internet of things (IoT) in shipping, connected ships or smart ports. For example, advanced sensor networks and surveillance systems can provide real-time monitoring of ship operations and cargo, detecting and alerting crew members to potential hazards. D2D communication also has some overlap with navigation technologies facilitating the exchange of information between ships, enabling cooperative navigation and collision avoidance. In modern smart ports, D2D communication enables efficient coordination between ships, port authorities and logistics providers, shortening waiting times and optimizing port operations.
- Modern **low-latency communication** includes technologies, such as 5G, HAPS (high-altitude platform station)/HALE (high-altitude long endurance), or advanced satellite technologies. These new technologies complement and enhance existing navigation and D2D communication technologies. While traditional satellite communications have limitations in terms of latency, newer low Earth orbit (LEO) satellite constellations and terrestrial networks, such as 5G, significantly reduce latency and enable real-time data exchange. HAPS/HALE drones can complement this, by providing continuous coverage over large geographical areas and filling gaps in satellite coverage. Together, these technologies provide enhanced global connectivity, allowing vessels to better stay in touch with shore operations and other vessels.
- **Cloud** platforms provide secure storage and efficient real-time analytics of vast amounts of data collected from ships, ports and logistics networks. Insights from these data can help optimize route planning, fuel consumption, maintenance schedules and overall resource allocation.
- As ships become more connected and dependent on digital technologies, creating more entry points for cyberattacks, **cybersecurity** is increasingly important. Maritime cybersecurity measures protect against cyberattacks that could disrupt operations, steal information or compromise control of the ship.

Taken together, these technologies form the backbone of the gradual evolution toward smarter and more autonomous ships. Smaller autonomous vessels are already operational for tasks such as surveying, inspection and cargo transport in controlled environments on short-distance inland waterways. Large commercial vessels have mostly not moved beyond a basic level of autonomy, such as semi-autonomous docking systems, because high costs are still high and there are concerns about cyber and operational risks.[12]

In the future, however, we can expect to see remotely-operated unmanned ships and/or truly autonomous ships. The main benefit of unmanned or autonomous vessels is their potential to significantly improve maritime safety. Around from 70% to 80% of maritime accidents are due to human error, something new intelligent ships could help minimize.[13] In addition, the use of unmanned or autonomous vessels also promises to improve efficiency, by increasing the capacity of waterways, reducing operating costs and allowing more efficient use of space in ship design.

Piracy and terror attacks remain a threat in international shipping

Piracy remains a significant threat to shipping in certain regions of the world. Global piracy and armed robbery incidents increased by 4% in 2023 compared to 2022, according to the International Maritime Bureau's Piracy Reporting Centre.[14] A major area of concern is the Singapore Strait, where the number of robbery incidents reached an eight-year high in 2023.

12 Bureau Veritas (2024). Are we ready for autonomous ships? Available at: https://marine-offshore.bureauveritas.com/insight/business-insights/are-we-ready-autonomous-ships.
13 The Nautical Institute (1994). Human error – a fragile chain of contributing elements. Available at: www.nautinst.org/resources-page/human-error---a-fragile-chain-of-contributing-elements.html.
14 IMB (2024). New IMB report reveals concerning rise in maritime piracy incidents in 2023. International Chamber of Commerce International Maritime Bureau (IMB). Available at: https://iccwbo.org/news-publications/news/new-imb-report-reveals-concerning-rise-in-maritime-piracy-incidents-in-2023.

In addition, piracy has resurfaced in the Red Sea, where missile and armed drone strikes by Houthi militias and hijackings by Somali pirates have destabilized maritime shipping.[15]

Communication and Security technologies play an important role in the fight against piracy. For example, an automatic identification systems (AIS) transmits a ship's identification, position, course and speed. This allows authorities and other ships to track vessel movement and identify suspicious activity near shipping lanes. New technologies like drones for surveillance or AI-powered CCTV technology are also being explored to further enhance security. Another approach are security systems onboard such as a protected citadel within the ship where the crew can retreat and defend themselves in case of a pirate attack.[16] Apart from new technologies, international cooperation including information sharing, coordinated responses from maritime authorities and extradition processes remain essential in the protection against piracy.

Automation and Circularity technologies will boost productivity and enable more energy-efficient ships, shaping the way we transport goods around the world. Key research themes are:

- **Efficient material use** is one way to increase the energy efficiency of new ships. Additive manufacturing (also known as 3D printing) holds great promise in this regard. It enables the creation of complex, lightweight structures using less material than traditional methods. This translates into lighter ships, reduced fuel consumption and lower emissions. In addition, the ability to produce spare parts on board ships using additive manufacturing can reduce downtime and improve operational efficiency.[17] Another way to increase energy efficiency in shipbuilding is to use advanced materials, such as carbon fibre reinforced polymers, instead of steel to build lighter ships.[18]
- **Smart production/robotics** technology plays a vital role in shipbuilding, maintenance and logistics. Automated cranes and container handling systems streamline loading and unloading, maximizing efficiency. In addition, industrial robots are taking on increasingly specialized roles within the shipping industry. One example is their use in hull cleaning and maintenance. Robots that attach to the hull and navigate its surface can efficiently clean and remove barnacles and other marine growth, contributing to both environmental and economic benefits. Another example is ship inspection: inspection robots equipped with advanced sensors and cameras can navigate tight spaces and access hard-to-reach areas, identifying cracks, corrosion and other potential problems with greater accuracy and efficiency than a manual inspection.
- **Recycling:** The practice of "beaching" ships poses significant environmental and safety risks. New technologies are being developed to recycle ship components and materials in a more environmentally-friendly way. New hydrometallurgical recycling processes extract valuable metals without harmful emissions, while shipbuilders are increasingly incorporating recycled materials into new buildings. Such efforts exemplify the shift toward a circular economy, where ships are designed to be easily dismantled and their components reused or repurposed. Enforcement of the Hong Kong Convention (IMO) and the EU Ship Recycling Regulation (European Commission) will further push the industry toward cleaner and safer dismantling practices.

Human–Machine Interface (HMI) technologies are still at an early stage within the shipping industry, but emerging as useful tools that will improve the way we interact with ships. However, it is important to note that all HMI technologies remain at the early stages of development and adoption in shipping. Research areas include:

- **Extended reality** technologies (including augmented reality, virtual reality, mixed reality and the metaverse), offer immersive training experiences. For example, a trainee engineer

15 Very, F. and M. Blaine (2024). Red Sea and Western Indian Ocean attacks expose Africa's maritime vulnerability. Africa Center for Strategic Studies. Available at: https://africacenter.org/spotlight/red-sea-indian-ocean-attacks-africa-maritime-vulnerability.
16 Virtual Maritime Academy (2024). Understanding the citadel: A key anti-piracy defense strategy. Available at: www.virtualmaritime.academy/understanding-the-citadel-a-key-anti-piracy-defense-strategy/?v=d88fc6edf21e.
17 Kostidi, E. and N. Nikitakos (2024). Revolutionizing the marine spare parts supply chain through additive manufacturing: A system dynamics simulation case study. Journal of Marine Science and Engineering, 12(9), 1515. Available at: www.mdpi.com/2077-1312/12/9/1515.
18 European Commission (2023). Key technologies for the digitalisation of transport. Available at: https://digital-strategy.ec.europa.eu/en/policies/technologies-digitalisation-transport.

could virtually experience challenging maintenance tasks onboard a vessel at sea, by wearing a headset that overlays digital information onto the real world. Such simulations eliminate risk to life and equipment, while providing training in a controlled environment. In addition, remote experts can guide trainees through complex procedures using interactive augmented reality overlays, bridging geographical distances and providing real-time support.

- **Speech recognition** technology has the potential to improve communication, efficiency and safety in shipping. For example, this technology could enable hands-free voice commands to control navigation systems, access information and report data, thereby reducing the workload and fatigue of bridge personnel.
- **Facial recognition** has potential applications in shipping, including improved access control and secure boarding for crew and authorized personnel at ports and onboard vessels. It could also improve security and reduce theft by identifying authorized personnel when handling cargo. It could also speed up the boarding and embarkation process for passenger ships. However, there are serious privacy concerns in respect to the collection and storage of biometric data that will require strong privacy regulations and informed consent from individuals, as well as robust security measures to prevent data breaches.
- **Touch displays** could replace physical buttons and knobs for navigation and system control, offering intuitive interfaces and faster access to information. **Data gloves** could be useful for remote inspection and repairs with augmented reality overlays, enhancing efficiency and safety.

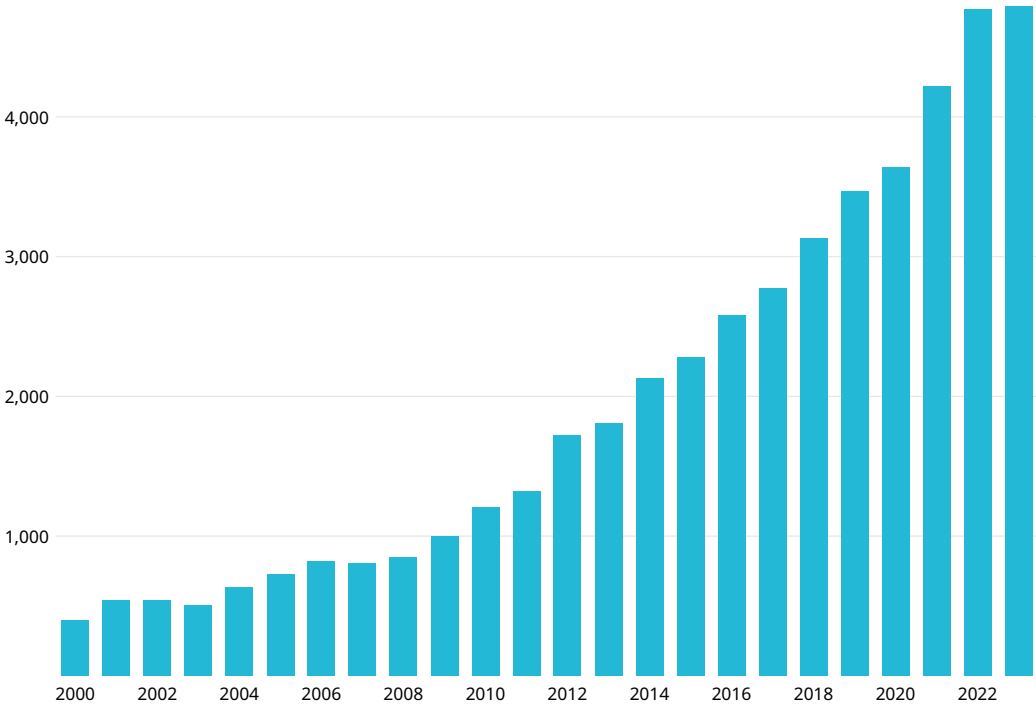
Global patent trends

Global patent development

Significant advances in sea transport technologies are reflected in the sharp increase in patent activity. Since the start of the millennium, the number of patent family publications per year has increased from around 400 in 2000 to almost 4,800 in 2023 (Figure B4). The growth rate of patent publications has been relatively stable over that period, with a compound annual growth rate (CAGR) of around 11%. In total, the patent search identified almost 47,000 patent families in the field of sea transportation since 2000.

The patent publication growth rate has remained relatively stable over the period, with an compound annual growth rate (CAGR) of approximately 11%

Figure B4 Development of global patent family publications, 2000–2023



Note: Patent family publications per earliest publication year.
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

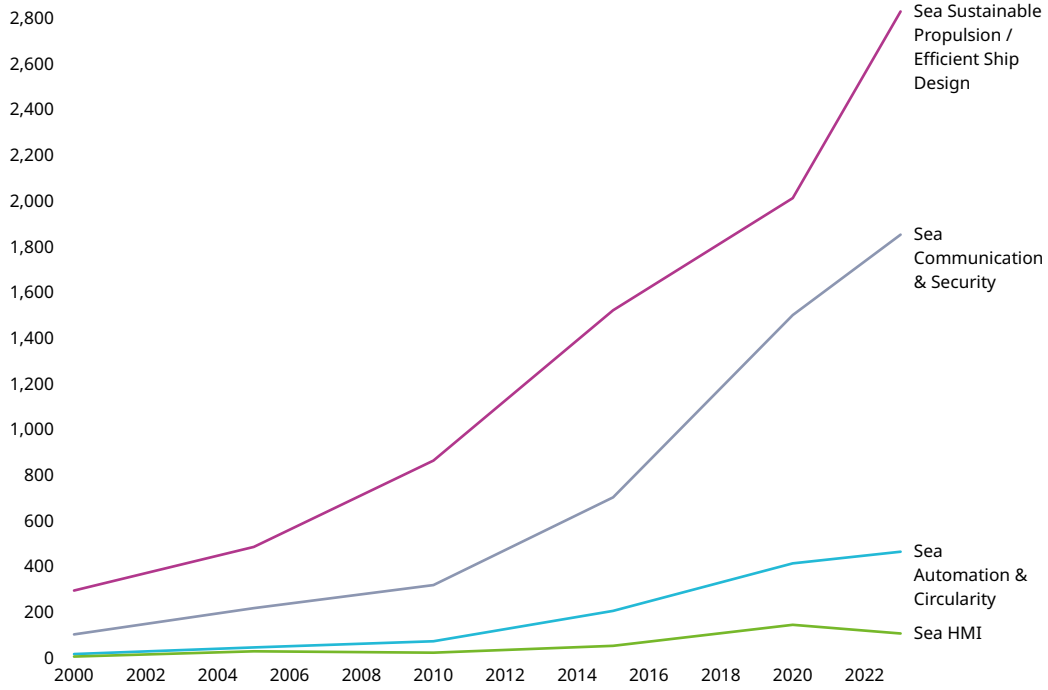
Overview of the four technology trends

At the level of the four technology trends, most research activity in maritime transport is focused on Sustainable Propulsion/Efficient Ship Design technologies. Between 2000 and 2023, the number of published patent families increased from 291 to more than 2800 (Figure B5). Communication and Security is another key research area. In this field, the annual number of

patent families published has increased from 99 to 1849 since 2000. Automation and Circularity technologies have also become an important area of research in the maritime industry, as evidenced by an increase in patent family publications from just 13 in 2000 to 461 in 2023. In contrast, Human–Machine Interface technologies still play a relatively minor role in maritime transport, with only about 100 patent family publications in 2023.

Most research activity in maritime transport is concentrated on Sustainable Propulsion and Efficient Ship Design technologies

Figure B5 Development of patent family publications in the four technology trends, 2000–2023



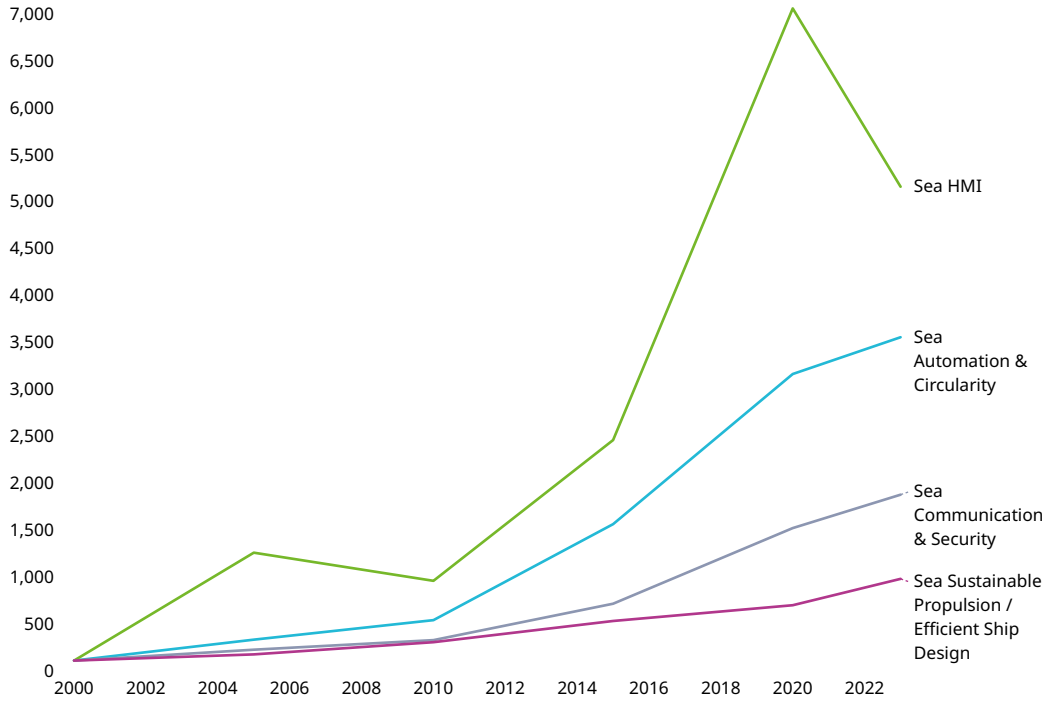
Note: Patent family publications per earliest publication year. Some patents are classified in more than one technology trend, therefore the sum of the four technology trends is larger than the total amount of patent publications.

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

In fact, patent growth is highest in HMI technologies, as shown in Figure B6. Between 2000 and 2023, patent families increased from only 2 to more than 100, a compound annual growth rate (CAGR) of 18.7%. Patent growth was also high in the other three technology trends.

Between 2000 and 2023, HMI patent families increased from just 2 to over 100, reflecting a CAGR of 18.7%

Figure B6 Indexed development of patent family publications in the four technology trends, 2000–2023



Note: Indexed development of patent family publications with patent family publications in 2000 = 100.
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patent coverage

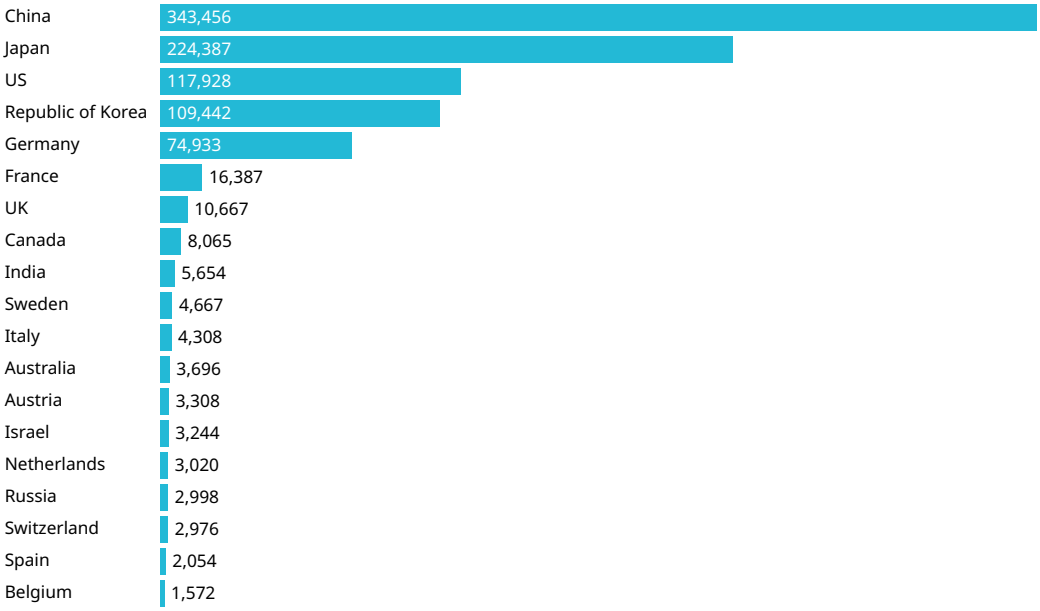
Analysis based on filing authorities of patent families in sea transport technologies provides an overview of global filing strategies. Members of patent families can be filed directly in one or more countries, via national patent offices, via the Patent Cooperation Treaty (PCT) route administered by WIPO or via the European Patent Convention (EP) route administered by the European Patent Office.

Figure B7 shows that China is the top filing country. Between 2000 and 2023, more than 21,000 patent families in sea transport technologies were filed in China seeking patent protection. The Republic of Korea and the United States of America (US) have also attracted many patent filings since 2000.

It is also worth noting that the PCT and EP routes are relevant for inventors seeking patent protection. Over the last decade, there have been almost 8,400 patent filings under the PCT and more than 5,800 patent filings under the EP.

China and Japan collectively account for more than 60% of the total global patent families

Figure B7 Total patent publications by filing authority, 2000–2023



Source: WIPO, based on patent data from EconSight/PatentSight, October 2024.

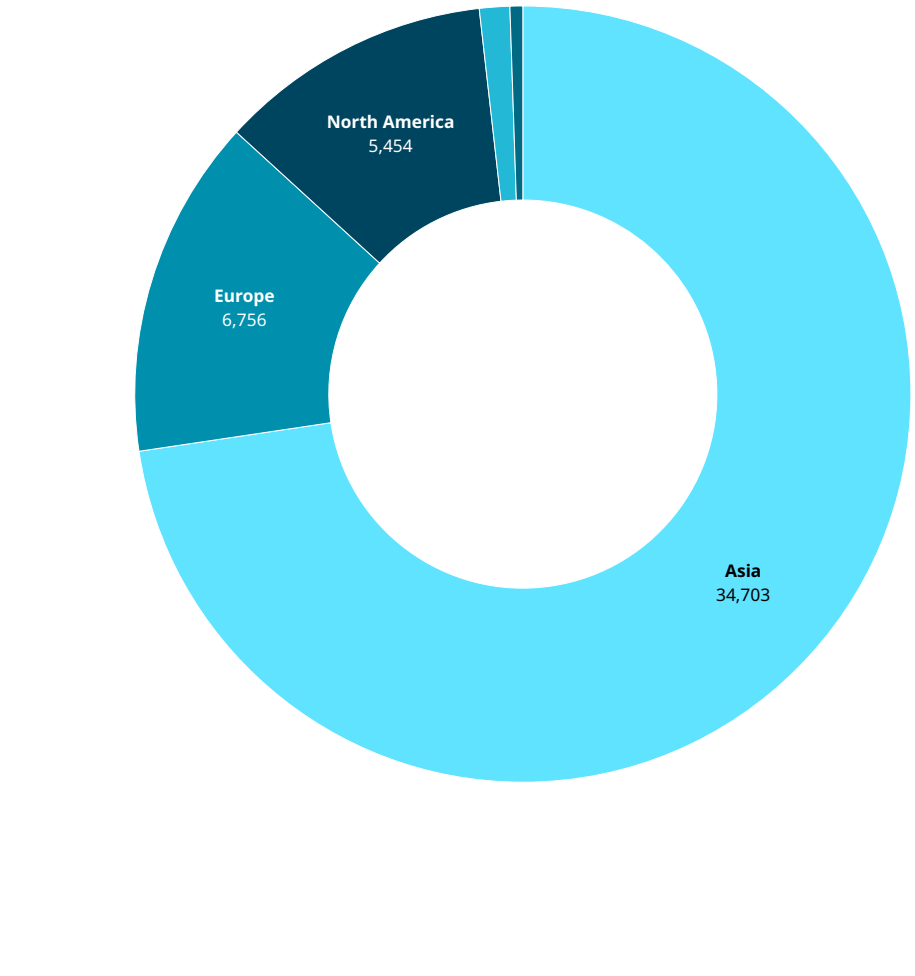
Top inventor locations

Regional breakdown

Asia accounts for most of the research activity related to the four technology trends. Between 2000 and 2023, there were 34,703 patent family publications from inventors based in Asia (Figure B8). Europe (6,756 patent family publications) and North America (5,454) are other key research regions. The number of patent family publications from the other regions (Africa, Latin America and the Caribbean (LAC), and Oceania) remains rather low.

Asia dominates research activity across the four technology trends

Figure B8 Regional breakdown: total patent family publications, 2000–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Top inventor locations

At a country level, China and the Republic of Korea lead global research activity in sea transportation technologies. Between 2000 and 2023, inventors from China published more than 17,000 patent families in these technologies, while inventors from the Republic of Korea were responsible for almost 11,720 patent family publications (Figure B9). As a result, these two countries have published more than half of all global patent families.

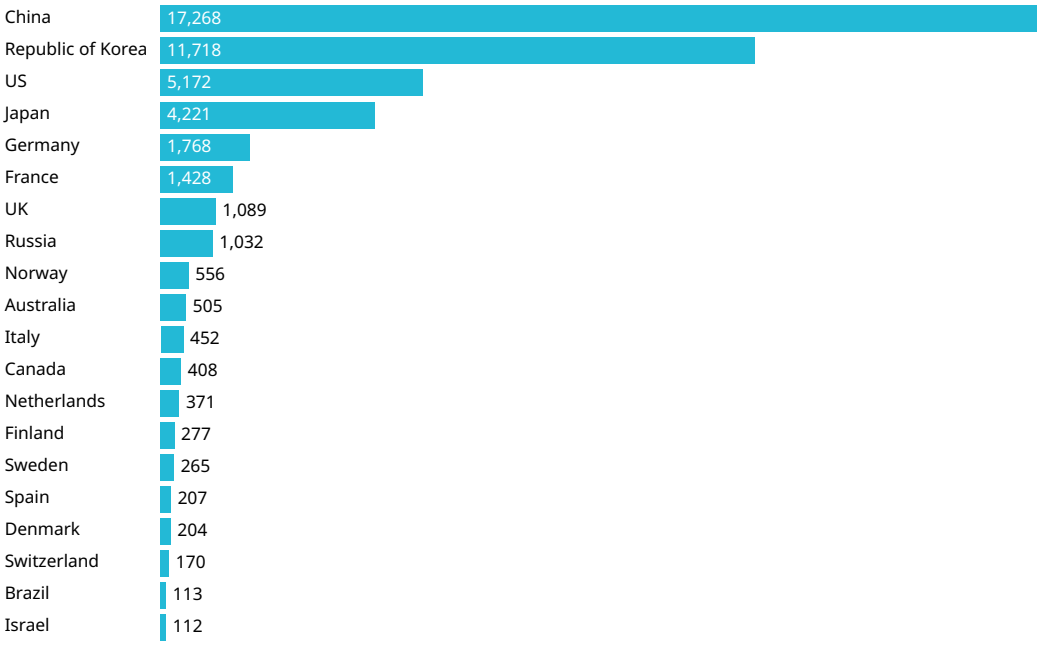
With a total of around 5,170 patent family publications between 2000 and 2023, the United States is the third most important research location, followed by Japan in fourth place, with 4,220 patent family publications. Germany is the leading European research location (5th globally), with more than 1,760 patent families published in the same period.

France, the United Kingdom UK) and the Russian Federation have all published more than 1,000 patent families since 2000. Norway and Australia follow in ninth and 10th place in the global ranking, respectively, with around 500 patent family publications each.

Among the rest of the top 20 inventor locations, there are several European countries (Italy, the Kingdom of the Netherlands, Finland, Sweden, Spain, Denmark and Switzerland), as well as Canada, Brazil and Israel. These top 20 inventor locations account for the majority of patenting activity related to sea transportation technologies.

China and the Republic of Korea together account for more than half of all global patent families

Figure B9 Top inventor locations: total patent family publications, 2000–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Development and patent growth since 2000

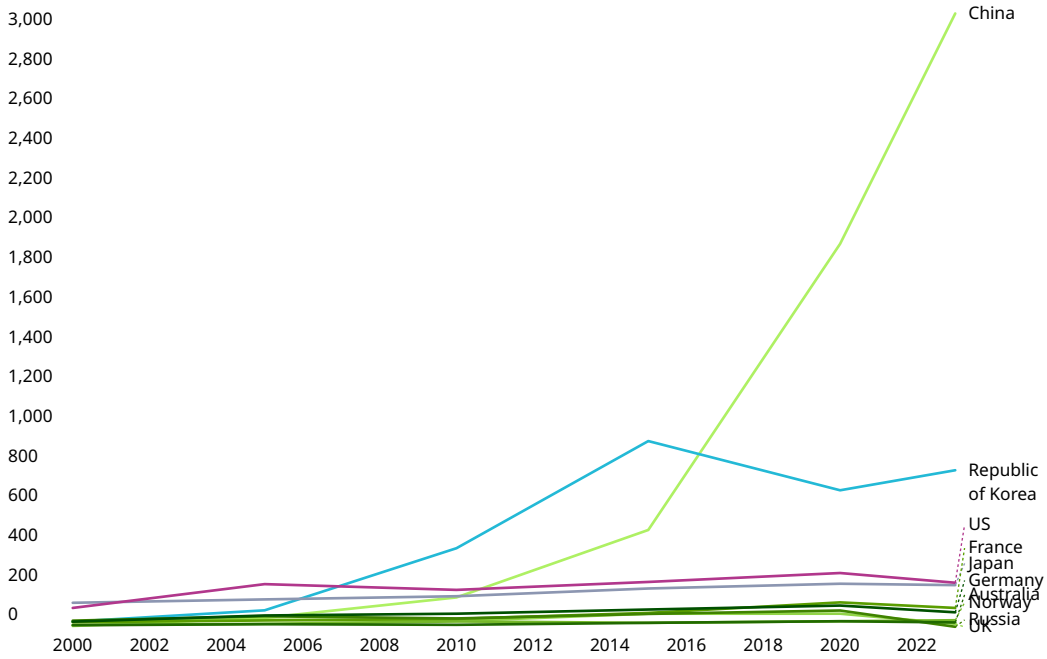
Figure B10 illustrates the impressive rise of China as a research location in shipping. In 2000, China published only five patents in shipping technologies and was, therefore, not among the top 10 research countries. By 2010, this number had risen to 149, placing it fourth in the global ranking. In 2017, China overtook the Republic of Korea and climbed to the top of the global ranking. Overall, annual patent publications rose from 5 to 3,092 between 2000 and 2023 (17,268 in total).

Research activities from the Republic of Korea have also developed very dynamically, with patent publications rising from 27 in 2000 to 790 in 2023. Patent family publications from the

United States, Japan and Germany have also increased between 2000 and 2023, albeit at a much slower pace and with many fluctuations along the way. Among the remaining top 10 research countries, France shows a dynamic development, with patent family publications increasing from 24 in 2000 to 96 in 2023. In contrast, the Russian Federation is the only top research country whose number of patent family publications has decreased since 2000.

China's significant rise as a leading research location in the shipping industry is evident

Figure B10 Top 10 inventor locations: development of patent family publications, 2000–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

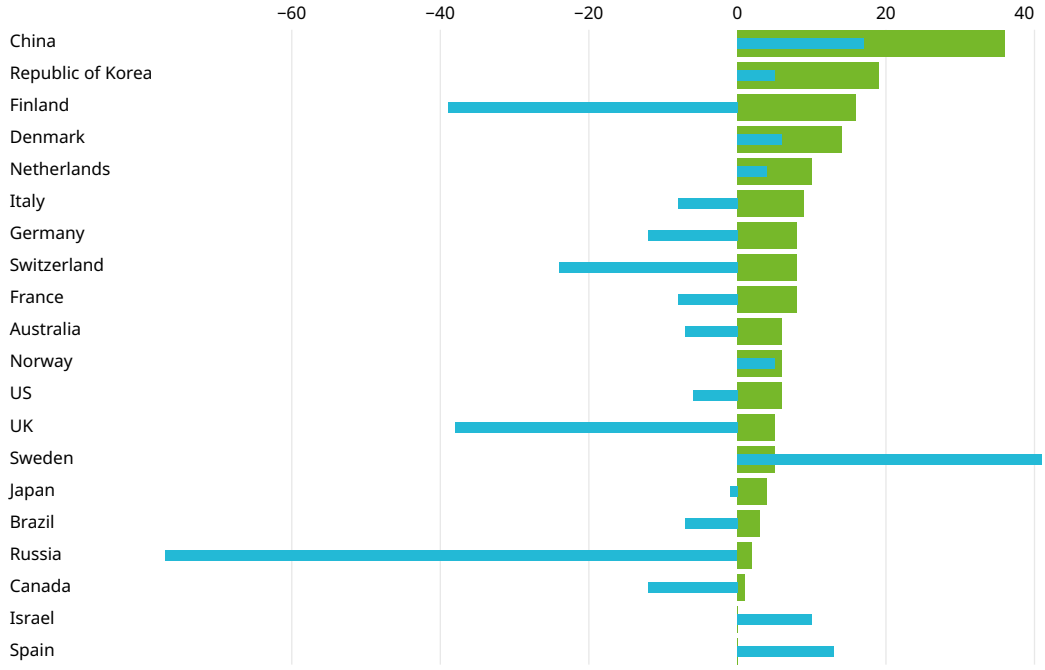
In terms of growth rate of patent family publications, the Asian countries China and the Republic of Korea are clearly ahead, with very dynamic growth rates between 2000 and 2019 and also positive growth rates after 2020 (Figure B11).

The most dynamic European country is Denmark, with a high compound annual growth rate both between 2000 and 2019 and between 2020 and 2023.

Some countries – Finland, Switzerland, the United Kingdom and the Russian Federation – had a positive patent growth rate between 2000 and 2019, but declining patent family publications from 2020 onward. Conversely, Sweden's patenting activity has accelerated significantly in recent years.

Denmark is the most dynamic European country, showing a high growth rate from 2000 to 2019 and from 2020 to 2023

Figure B11 Top inventor locations: growth of patent family publications, compound annual growth rate 2000–2019 and 2020–2023



Note: Only countries with at least 50 patent family publications between 2000 and 2023 were considered. There were no patent family publications in 2000 in Israel or Spain. Therefore, no patent growth rates could be calculated for these two countries.

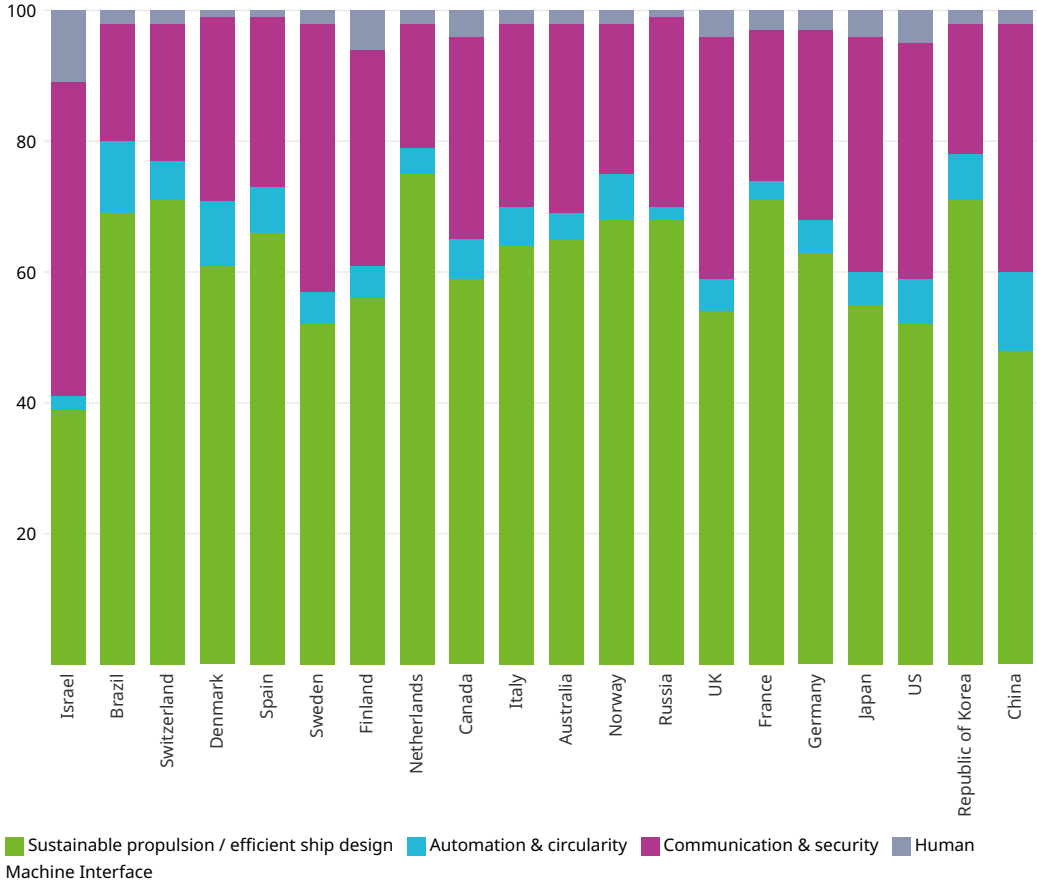
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Research priorities: countries

For almost all top research locations, Sustainable Propulsion/Efficient Ship Design is the main research area, followed by Communication and Security technologies (Figure B12 and Table B1). The sole exception is Israel, where patenting activity in Communication and Security technologies outweighs activity in the field of Sustainable Propulsion/Efficient Ship Design.

Israel is the sole exception where patenting activity in Communication and Security technologies surpasses activity in Sustainable Propulsion/Efficient Ship Design

Figure B12 Top 20 countries: research priorities, by share



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

For almost every top research location, Sustainable Propulsion/Efficient Ship Design is the main research area, followed by Communication and Security technologies

Table B1 Top countries: research priorities, by volume

		▼ Sea transport total	Sustainable propulsion	Automation & circularity	Communication & security	Human Machine Interface
1	China	17,268	9,169	2,313	7,377	316
2	Republic of Korea	11,718	8,867	876	2,448	263
3	US	5,172	3,035	402	2,077	316
4	Japan	4,221	2,518	221	1,643	176
5	Germany	1,768	1,185	95	538	64
6	France	1,428	1,082	50	356	37
7	UK	1,089	651	58	441	52
8	Russia	1,032	720	22	312	5
9	Norway	556	405	43	138	6
10	Australia	505	363	23	164	6
11	Italy	452	308	27	138	12
12	Canada	408	270	28	139	17
13	Netherlands	371	288	17	75	6
14	Finland	277	177	15	105	18
15	Sweden	265	149	14	119	7
16	Spain	207	143	16	56	1
17	Denmark	204	134	22	62	3
18	Switzerland	170	129	11	38	4
19	Brazil	113	85	13	22	3
20	Israel	112	51	3	64	14

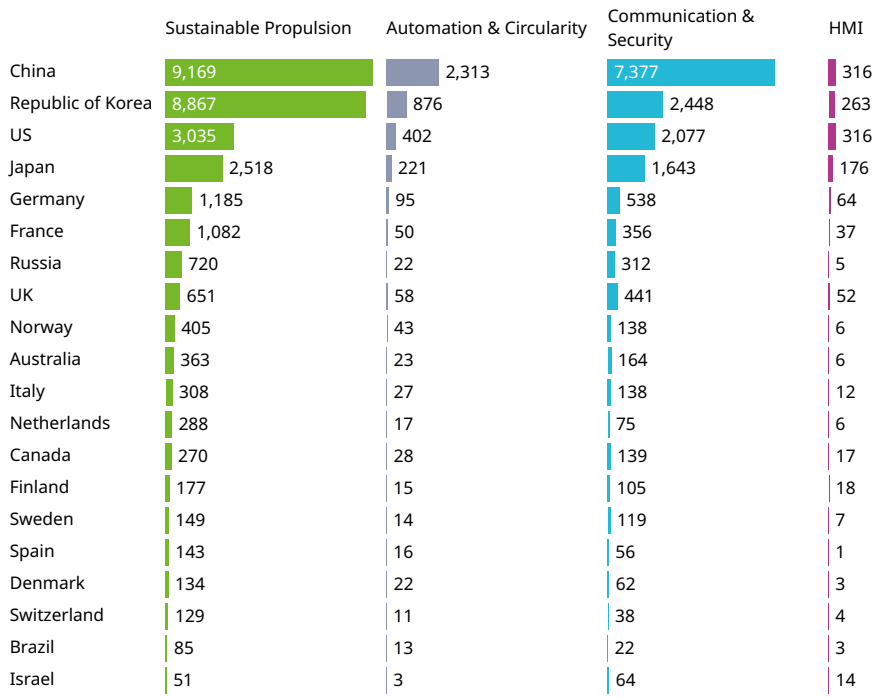
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Top inventor locations per technology trend

The country rankings for the four transport technology trends show China and the Republic of Korea are at a similar level of patenting activity in Sustainable Propulsion/Efficient Ship Design, but China is the clear leader in both Communication and Security and Automation and Circularity technologies (Figure B13). In HMI technologies, there is a three-way race between China, the United States and the Republic of Korea.

In HMI technologies, China, the United States and the Republic of Korea are in a three-way race for dominance

Figure B13 Total patent family publications, 2000–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Relative Specialization Index (RSI)

The Relative Specialization Index (RSI) for sea transport technologies illustrates the extraordinarily important role played by the maritime industry in Norway (Figure B14). The country reaches a very high RSI index of 0.9 over all observed time periods. Shipping technology research is also very important in Denmark, France, the Republic of Korea and Finland.

At the opposite end of the country ranking of the top 20 nations in sea transport research are Japan and Brazil, where a negative RSI score indicates a low level of specialization.

Exceptionally important role of the maritime industry in Norway for sea transport technologies is observed

Figure B14 Top 20 countries: relative specialization, 2000–2023

Note: RSI is the Relative Specialization Index.
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Top patent owners

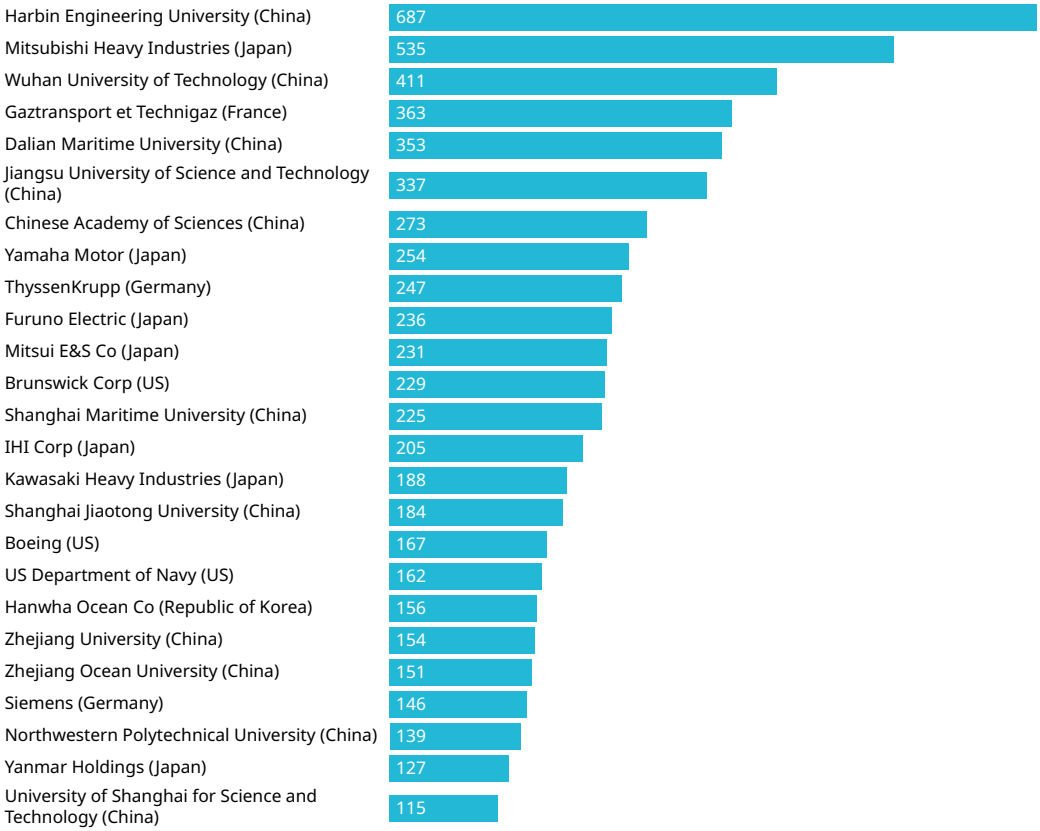
Top patent owners: patent activity

A look at the top applicants reveals that Chinese universities and Japanese companies dominate the research landscape in marine technologies. Harbin Engineering University tops the list, with 687 patent families published between 2000 and 2023 (Figure B15). Wuhan University of Technology, Dalian Maritime University, Jiangsu University of Science and Technology and the Chinese Academy of Sciences are also in the top 10.

Japan's Mitsubishi Heavy Industries has published 535 patent families since 2000 and ranks second overall. Mitsubishi Heavy Industries is active in the development of low-emission fuels and autonomous ships. Yamaha Motor and Furuno Electric are other Japanese companies among the top 10 global research players. French naval engineering company Gaztransport et Technigaz and German conglomerate ThyssenKrupp are also in the top 10.

Chinese universities and Japanese companies dominate the research landscape in marine technologies

Figure B15 Top patent owners, 2000–2023



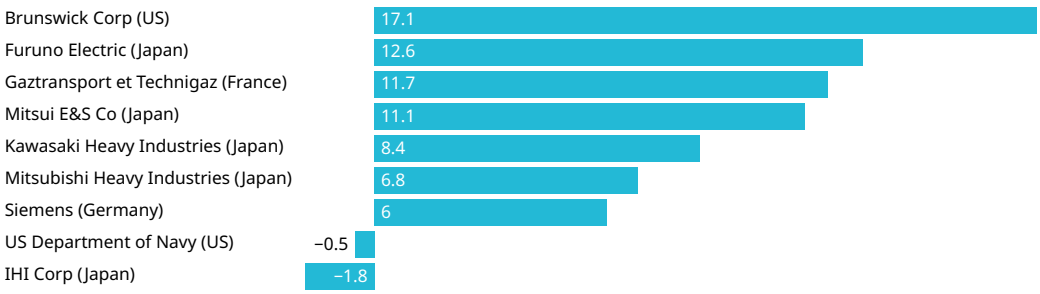
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Top patent owners: patent growth

Patenting activity in sea transport technologies has grown dynamically over the last decades (Figures B16–B19). Most top applicants have increased their patent portfolios since 2000 (Figure B18). However, since 2020, annual patent family publications by some of the top applicants have been on a downward trend (Figure B19).

Most top applicants have expanded their patent portfolios since 2000

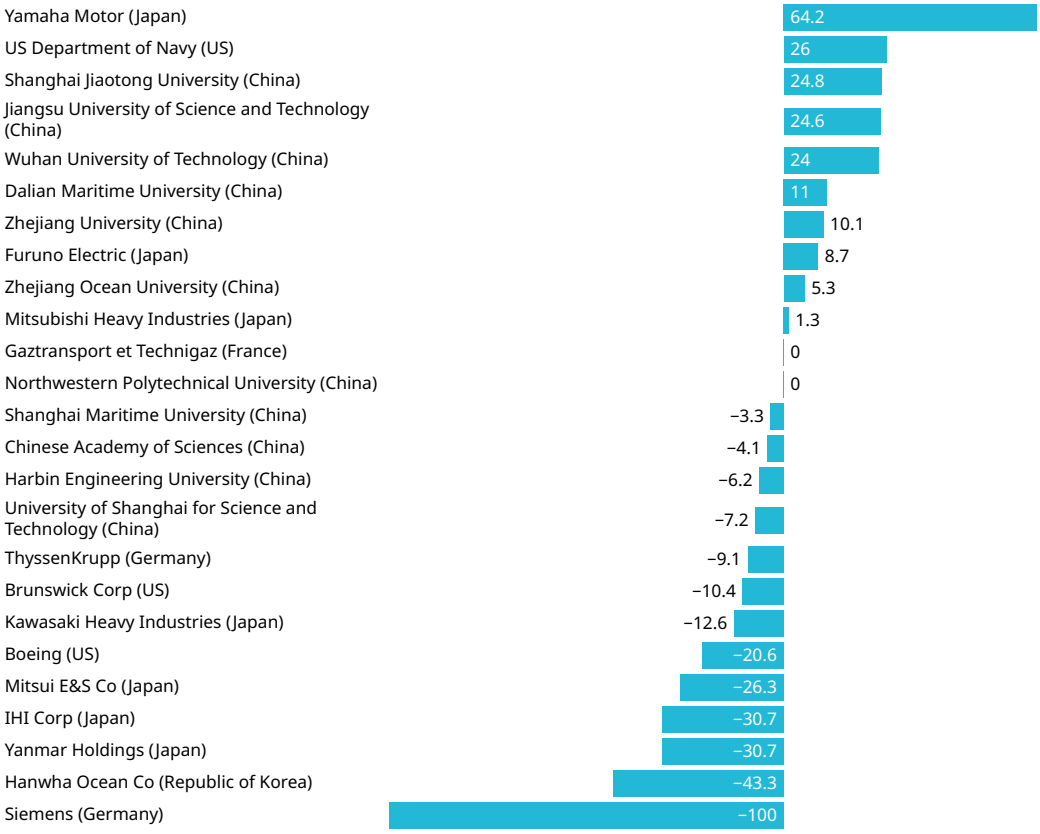
Figure B16 Top patent owners, growth 2000–2019 (p.a.)



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Since 2020, several top applicants have experienced a decline in annual patent family publications

Figure B17 Top patent owner, growth 2020–2023 (p.a.)



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

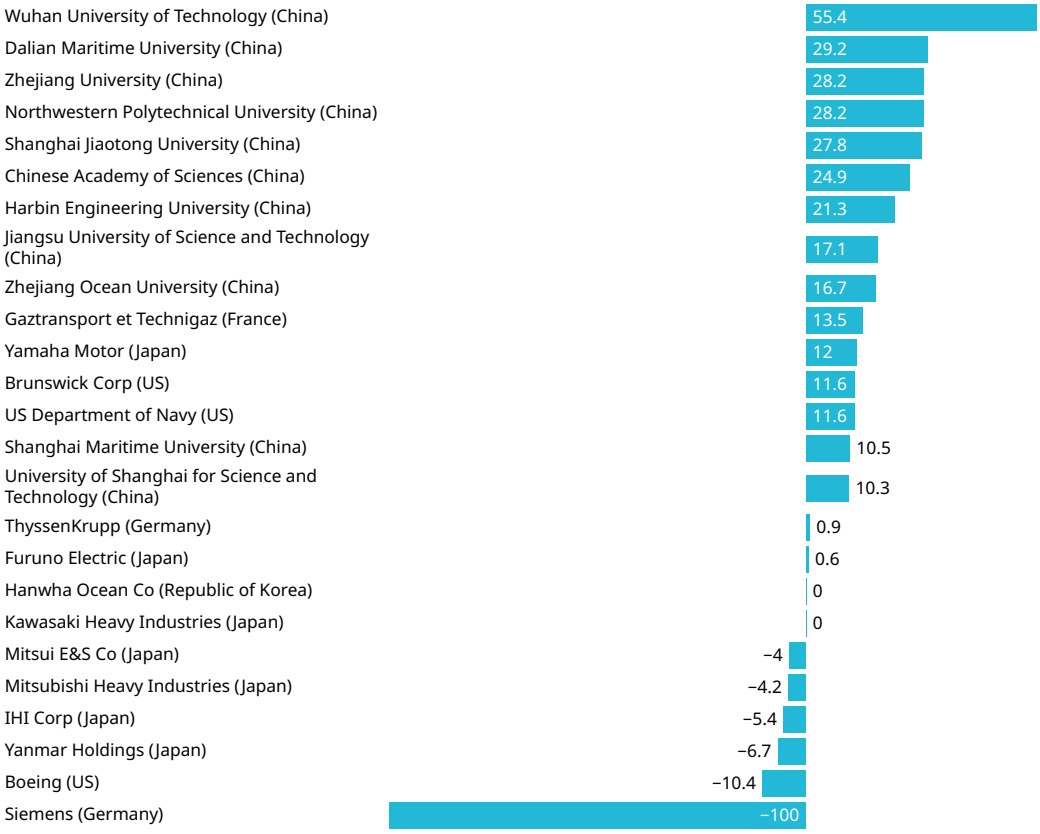
Patenting activity in sea transport technologies has seen significant growth over the past decades

Figure B18 Top patent owners, growth 2000–2023 (p.a.)

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Wuhan University in China has shown exceptionally high growth in maritime patenting activity in the last 5 years

Figure B19 Top patent owners, growth 2018–2023 (p.a.)



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

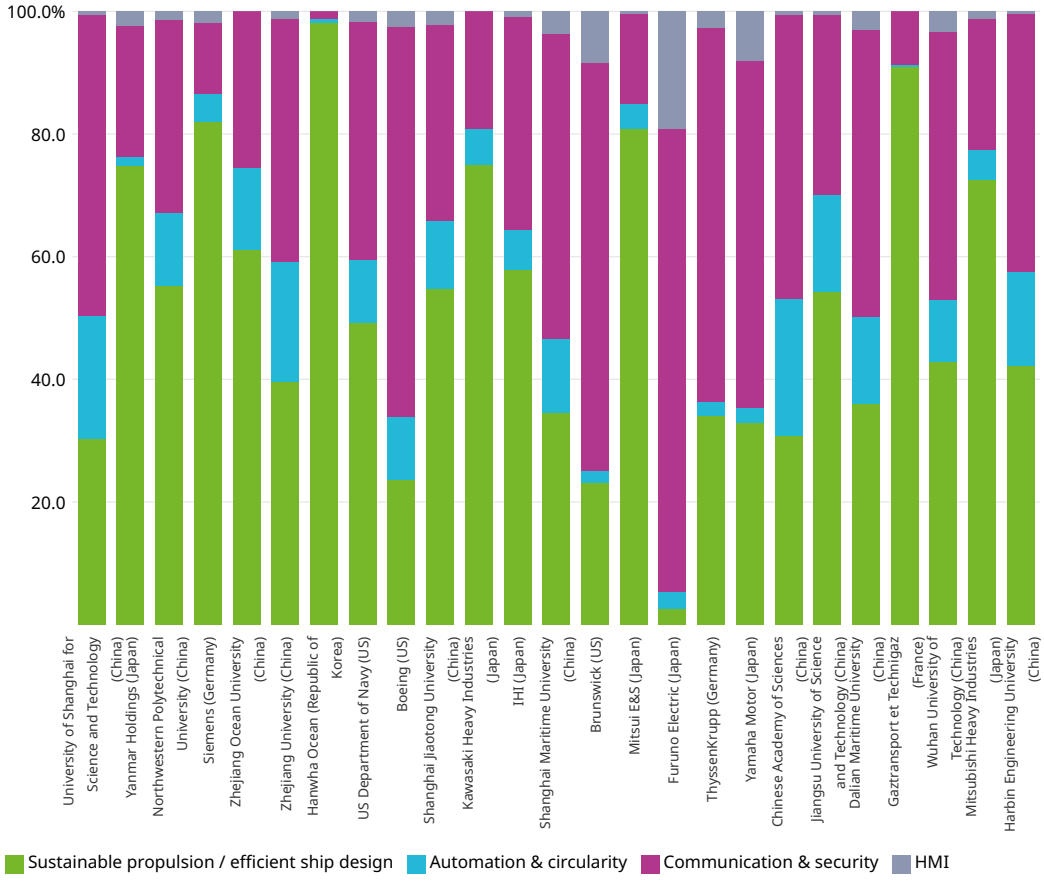
Top patent owners: research priorities

The research priorities of the top patent owners show some differences. Some companies, such as Hanwha Ocean, Gaztransport et Technigaz, Siemens and Mitsui E&S, published almost all their patent families in the field of Sustainable Propulsion/Efficient Ship Design (Figure B20). In absolute terms, Gaztransport et Technigaz, Mitsubishi Heavy Industries and Harbin Engineering University are the top patent holders in this technology trend (Figure B21).

Others, such as Furuno Electric, have a clear research focus on communication and safety technologies. However, Harbin Engineering University has the highest patenting activity in absolute terms.

Research priorities of the top patent owners reveal some differences

Figure B20 Top 25 patent owners: research priorities



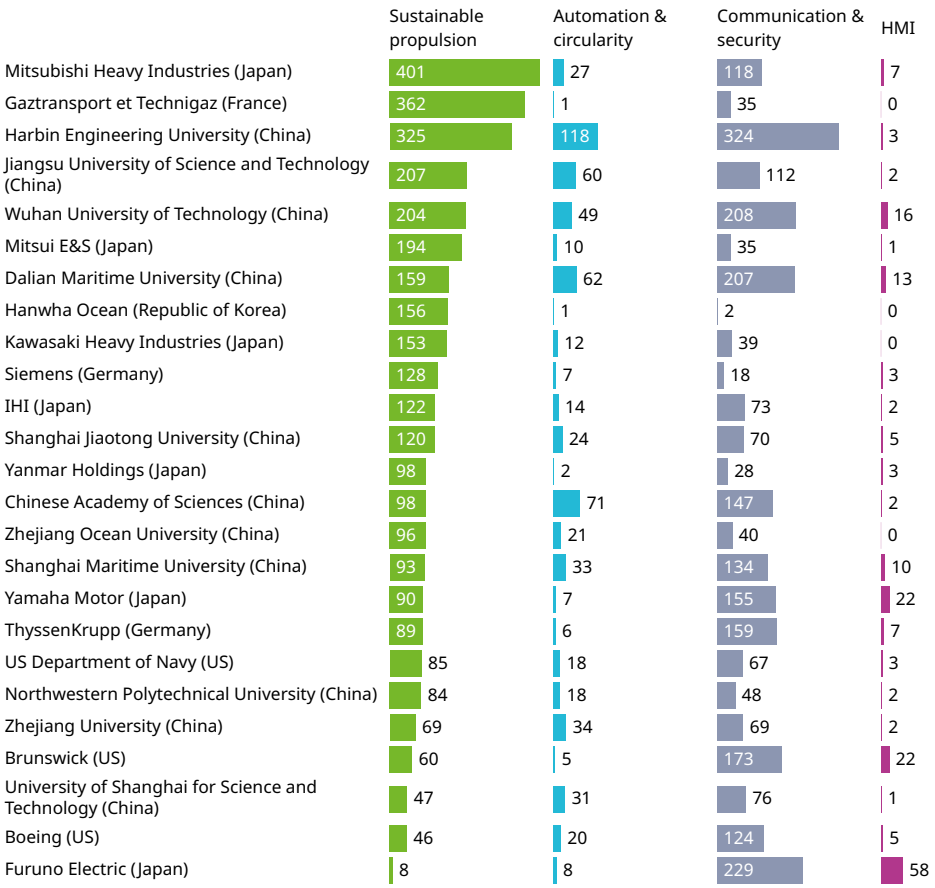
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Harbin Engineering University is also the top ranked patent holder in terms of published patent families in Automation and Circularity technologies ahead of the Chinese Academy of Sciences.

None of the 25 marine research companies and institutions shown have a significant share of HMI patent family publications, only Wuhan University of Technology and ThyssenKrupp have published more than one patent family since 2000.

Harbin Engineering University is the top-ranked patent holder in Automation and Circularity technologies, surpassing the Chinese Academy of Sciences

Figure B21 Top 25 patent owners: patent family publications, 2000–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patenting activity in the four technology trends

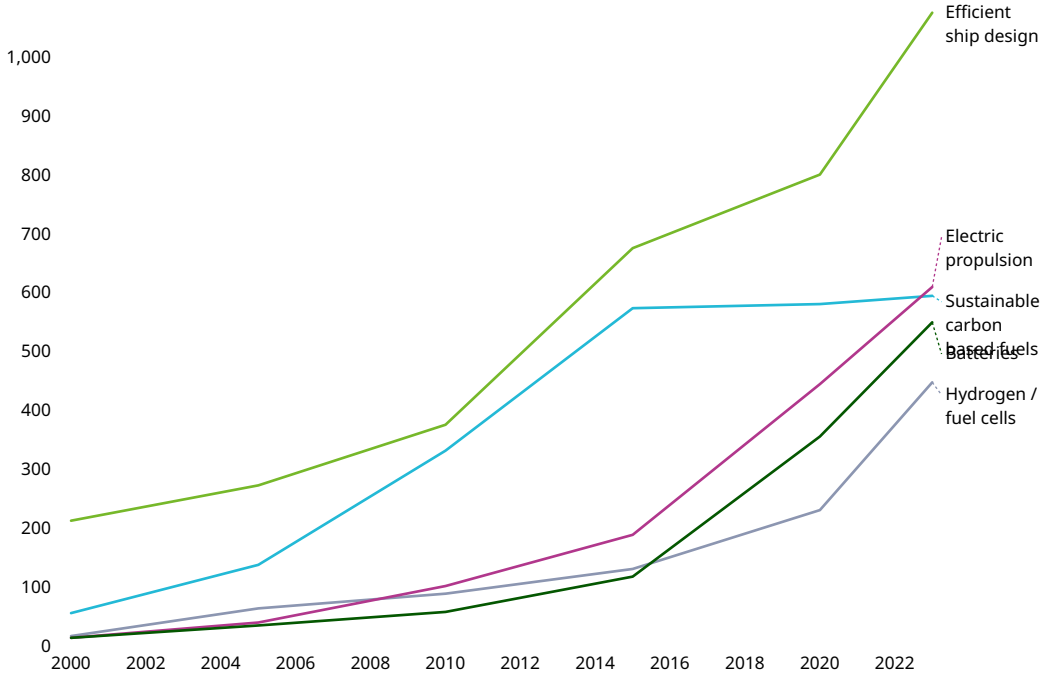
Sustainable Propulsion/Efficient Ship Design

Within this technology trend, the most important area in terms of patent family publications is efficient ship design. This includes research activities that focus on optimizing hull shape to minimize drag, designing efficient propellers or introducing air bubbles under the hull. The number of patent family publications has increased from only 211 in 2000 to 1,074 in 2023 (Figure B22).

Another important research area is sustainable carbon-based fuels, where patent family numbers have grown from 54 to 593 between 2000 and 2023. The vast majority of patents in this area relate to LNG fuels for ships. However, patenting activity in sustainable carbon-based fuels has declined in 2023, after peaking at 834 patent family publications in 2022.

Within Sustainable Propulsion, efficient ship design is the most important area in terms of patent family publications

Figure B22 Sustainable Propulsion/Efficient Ship Design: development of global patent family publications, 2000–2023



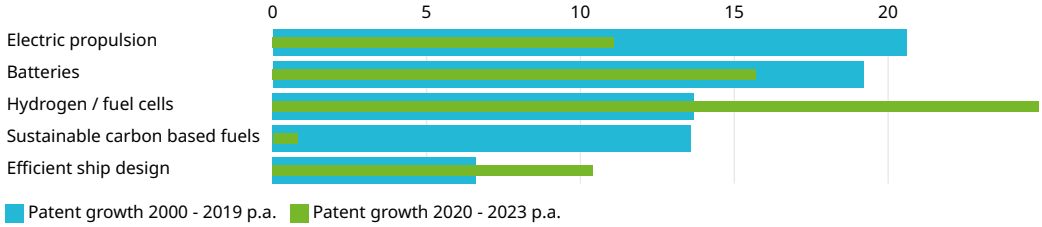
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

In terms of growth rates of patent publications, electric propulsion, hydrogen/fuel cells and batteries have shown the most dynamic development over various different time periods since 2000 (Figures B23–B25). Patent growth in sustainable carbon-based fuels was high between

2000 and 2019 (13.6% p.a. on average), but the dynamic has slowed down significantly in recent years (Figure B23). In contrast, patent growth in the important area of efficient ship design has accelerated noticeably in recent years, despite the large volume of patents that already exist in the field. This shows that new developments within efficient ship design remain a key research area for creating greener ships.

Electric propulsion, hydrogen/fuel cells, and batteries have demonstrated the most dynamic development across various periods since 2000

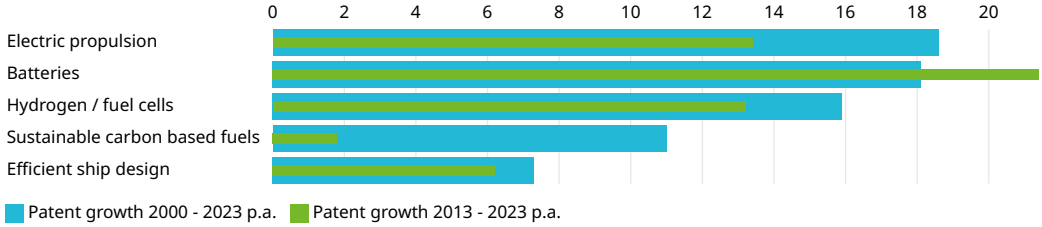
Figure B23 Sustainable Propulsion/Efficient Ship Design: growth of patent family publications, 2000–2019 and 2020–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patent growth in efficient ship design has accelerated significantly in recent years, despite the field having an already substantial patent base

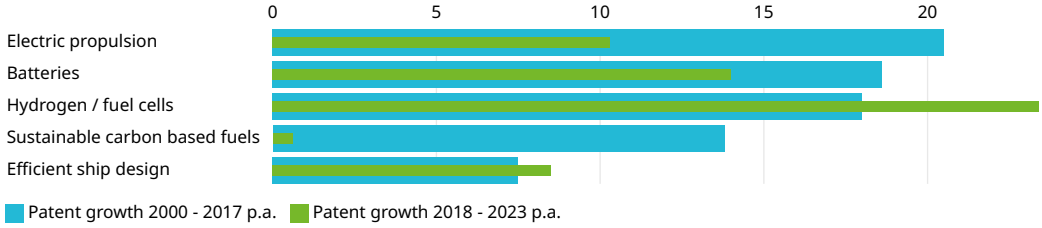
Figure B24 Sustainable Propulsion/Efficient Ship Design: growth of patent family publications, 2000–2023 and 2013–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Hydrogen and fuel cell technologies have undergone remarkable growth over the past five years

Figure B25 Sustainable Propulsion/Efficient Ship Design: growth of patent family publications, 2000–2017 and 2018–2023

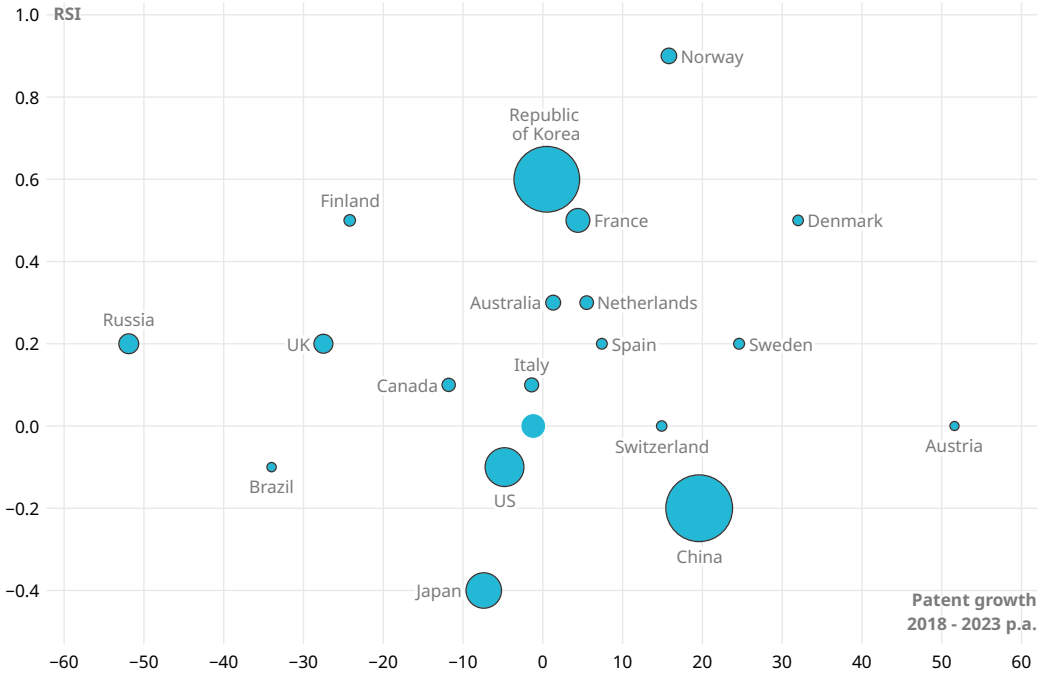


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Figure B26 shows that inventors from China and the Republic of Korea are responsible for the majority of patent family publications. While patent family publications from China have increased dynamically in recent years, patenting activity from the Republic of Korea has stagnated. However, unlike China, the Republic of Korea has a high RSI value, indicating a clearly above average degree of specialization. Only Norway has a higher RSI than the Republic of Korea over the period from 2000 to 2023.

Norway is the only country that had a higher RSI than the Republic of Korea between 2000 and 2023

Figure B26 Sustainable Propulsion/Efficient Ship Design: country comparison, RSI (2000–2023) and growth rates (2018–2023)



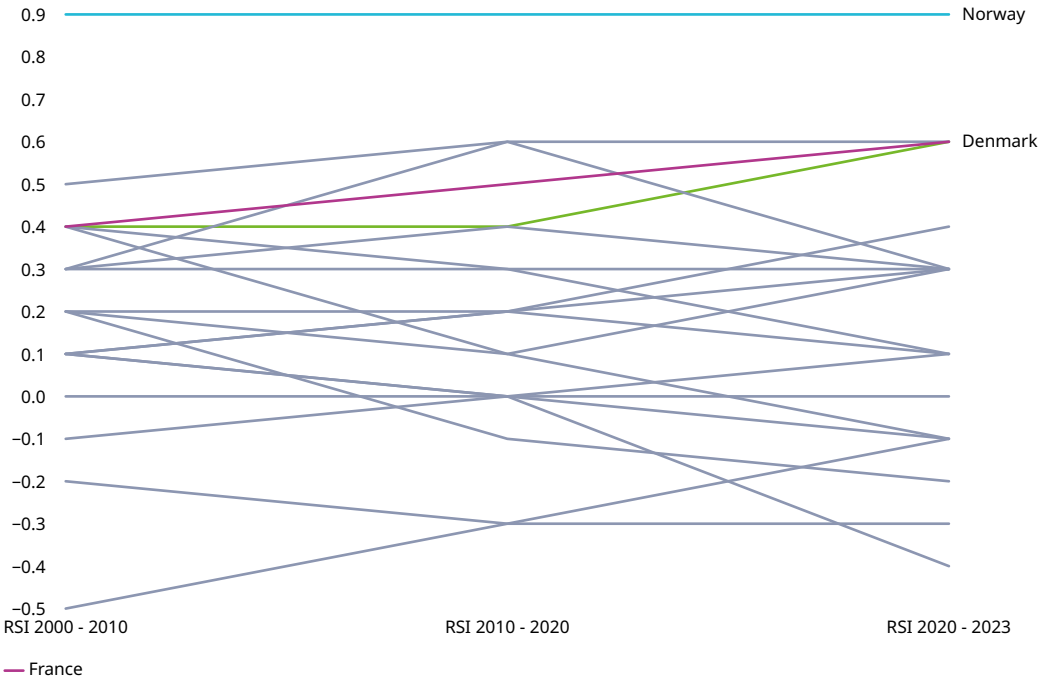
Notes: The size of the bubbles reflects the number of patent family publications at the country level in the field of Sustainable Propulsion/Efficient Ship Design. The compound annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Looking more closely at RSI values over the different time periods, the outstanding degree of specialization in Norway is again highlighted. Other highly specialized countries are France, Denmark and the Republic of Korea (Figure B27). In contrast, Japan, Brazil, China and the United States have a negative RSI value, which is an indication of below average research specialization in Sustainable Propulsion technologies within the marine sector.

Norway's exceptional level of specialization is again evident

Figure B27 Sustainable Propulsion/efficient aircraft turbines: top 20 countries' Relative Specialization Index (RSI), 2000–2023



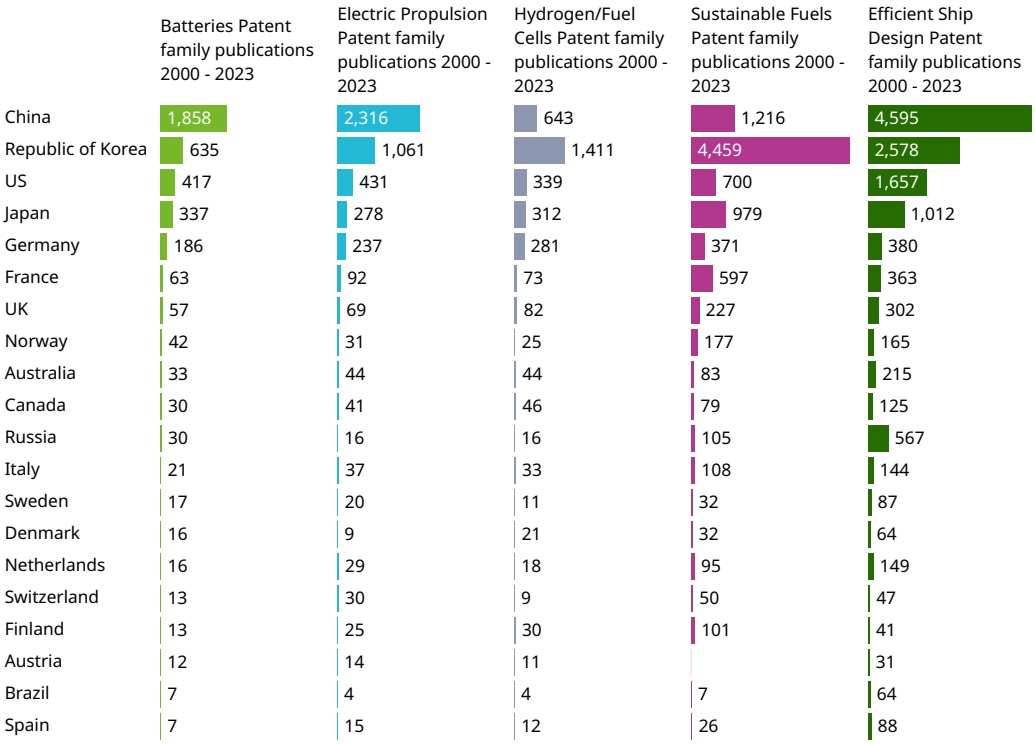
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Analysis of the top research countries in the different subgroups of Sustainable Propulsion/ Efficient Ship Design provides the following key results (Figure B28):

- China is the technology leader in efficient ship design, batteries and electric propulsion.
- The Republic of Korea has published most patent families in hydrogen/fuel cell research and sustainable fuels.

China leads in efficient ship design, batteries and electric propulsion, whereas the Republic of Korea dominates in hydrogen/fuel cell research and sustainable fuels

Figure B28 Top 20 inventor locations for Sustainable Propulsion/Efficient Ship Design subgroups, 2000–2023



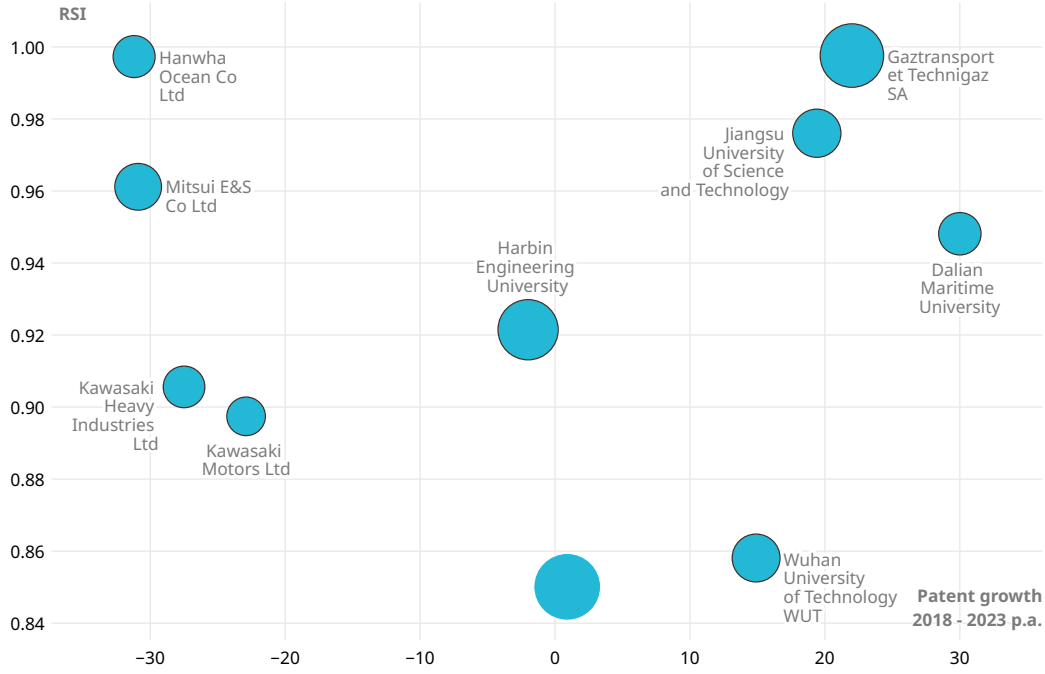
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Mitsubishi Heavy Industries, Gaztransport et Technigaz, Harbin Engineering University, Jiangsu University of Science and Technology and Wuhan University of Technology are the top five research companies/institutions in Sustainable Propulsion/Efficient Ship Design in terms of patent family publications (Figure B29). They all have a very high RSI score.

However, four of the top 10 patent owners have seen a decline in patent family publications since 2018. They include the Japanese companies Mitsui E&S Co, Kawasaki Heavy Industries, Kawasaki Motors and the Korean company Hanwha Ocean. Patenting activity from Harbin Engineering University and Mitsubishi Heavy Industries has stagnated in recent years. In contrast, the other Chinese research universities in this field and the French company Gaztransport et Technigaz have continued to increase their patenting activity.

Since 2018, four of the top 10 patent owners have experienced a decline in patent family publications

Figure B29 Sustainable Propulsion/Efficient Ship Design: comparison of top owners, Relative Specialization Index (RSI) (2000–2023) and growth rates (2018–2023)



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

The top patent owners in the five subgroups are as follows (Figure B30):

- Harbin Engineering University is the top patent holder in both batteries and efficient ship design.
- China Huaneng Group has published the most patent families for electric ship propulsion.
- The two German industrial conglomerates Siemens and ThyssenKrupp are research leaders in the use of hydrogen/fuel cells for ships.
- Gaztransport et Technigaz is at the forefront of research into sustainable fuels.

Harbin Engineering University leads in ship batteries and design, China Huaneng in propulsion, Siemens and ThyssenKrupp in hydrogen, and Gaztransport in sustainable fuels

Figure B30 Top 5 owners in the subgroups of Sustainable Propulsion/Efficient Ship Design

Subgroup	Company	Patent family publications
Batteries	Brunswick Corp	31
Batteries	Yanmar Holdings	31
Batteries	Yamaha Motor	32
Batteries	Wuhan University of Technology	35
Batteries	Harbin Engineering University	41
Electric propulsion	Shanghai Jiaotong University	34
Electric propulsion	Wuhan University of Technology	35
Electric propulsion	Power Construction Corp of China	38
Electric propulsion	Siemens	49
Electric propulsion	China Huaneng Group	63
Hydrogen/fuel cells	Siemens Energy	31
Hydrogen/fuel cells	Mitsubishi Heavy Industries	39
Hydrogen/fuel cells	Harbin Engineering University	49
Hydrogen/fuel cells	ThyssenKrupp	49
Hydrogen/fuel cells	Siemens	50
Sustainable fuels	Mitsui E&S	108
Sustainable fuels	Kawasaki Heavy Industries	120
Sustainable fuels	Hanwha Ocean	142
Sustainable fuels	Mitsubishi Heavy Industries	151
Sustainable fuels	Gaztransport et Technigaz	354
Efficient ship design	Dalian Maritime University	111
Efficient ship design	Wuhan University of Technology	127
Efficient ship design	Jiangsu University of Science and Technology	142
Efficient ship design	Mitsubishi Heavy Industries	158
Efficient ship design	Harbin Engineering University	202

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

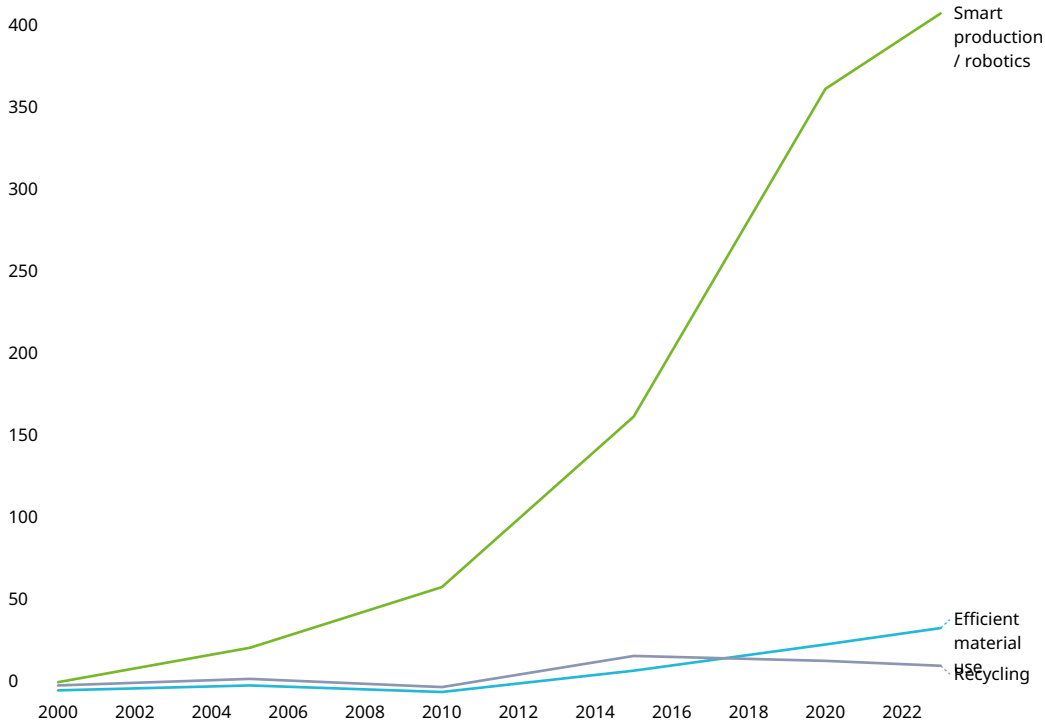
Automation and Circularity

Automation and Circularity technologies in the sea transport field include the areas of smart production, efficient material use and recycling.

Smart production (including robotics) is the key research field within Automation and Circularity technologies, with more than 400 patent publications in 2023 (Figure B31). Patenting activity in efficient material use technologies and recycling is still quite limited by comparison.

Smart production, including robotics, is the key research area in Automation and Circularity technologies, with over 400 patent publications in 2023

Figure B31 Automation and Circularity: development of global patent family publications, 2000–2023

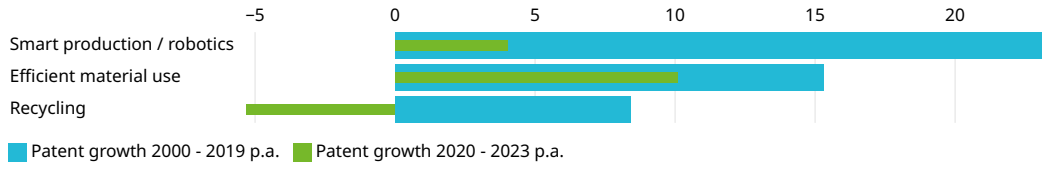


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patent growth in efficient material use has been exceptionally high in all analyzed time periods (Figures B32–B34). This is mainly due to the strong research momentum in additive manufacturing. Patent growth in smart production/robotics in shipping has also been very dynamic; however, growth has slowed down in recent years (Figure B32). In contrast, patent activity in recycling remains at a low level and patent growth has also been disappointing within the last several years. This is a source of concern as recycling is an important element of the shift toward a circular economy and new recycling technologies are necessary to achieve cleaner and safer dismantling practices of old ships.

Patent growth in efficient material use has been exceptionally high across all analyzed time periods

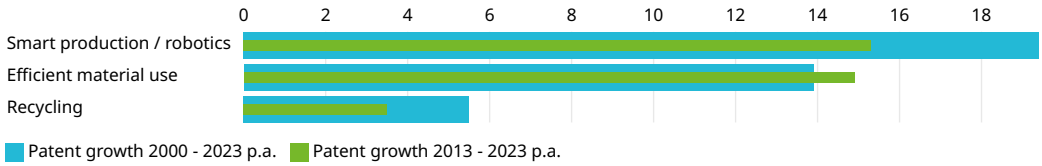
Figure B32 Automation and Circularity: growth of patent family publications, 2000–2019 and 2020–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patent growth in smart production/robotics in shipping has been dynamic, though it has slowed in recent years

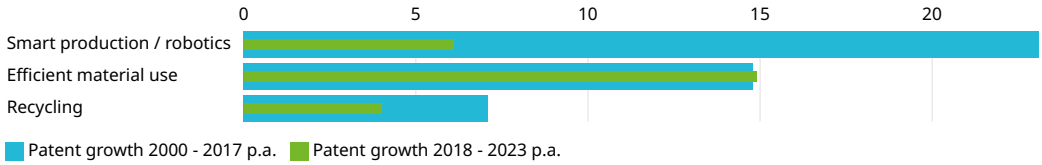
Figure B33 Automation and Circularity: growth of patent family publications, 2000–2023 and 2013–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patent activity in recycling remains low, with disappointing growth in recent years

Figure B34 Automation and Circularity: growth of patent family publications, 2000–2017 and 2018–2023

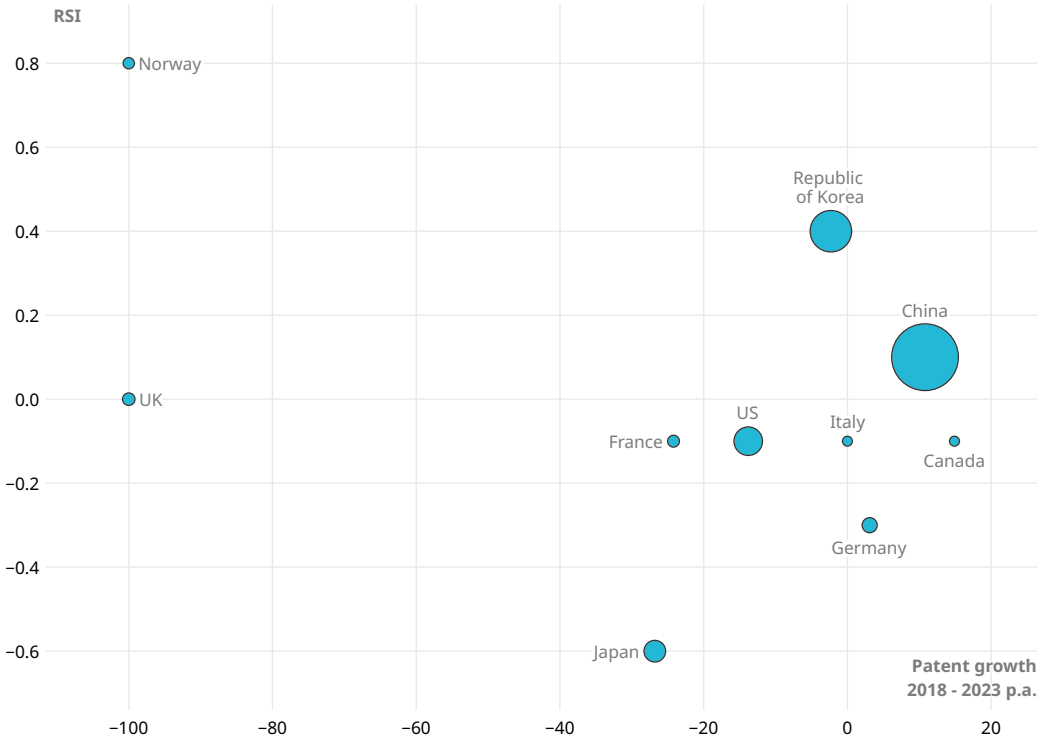


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Figure B35 shows that inventors from China and the Republic of Korea are publishing the most patent families. Moreover, patent growth was also high in China in recent years. Among the major research countries, Canada has achieved high growth rates since 2018, while patenting activity in France and Japan has declined.

China's RSI value is slightly above 0, showing neither an above-average nor below-average specialization in research activities in Automation and Circularity technologies. In contrast, the Republic of Korea has a very high and Japan a very low RSI value.

Figure B35 Automation and Circularity: country comparison, RSI (2000–2023) and growth rates (2018–2023)



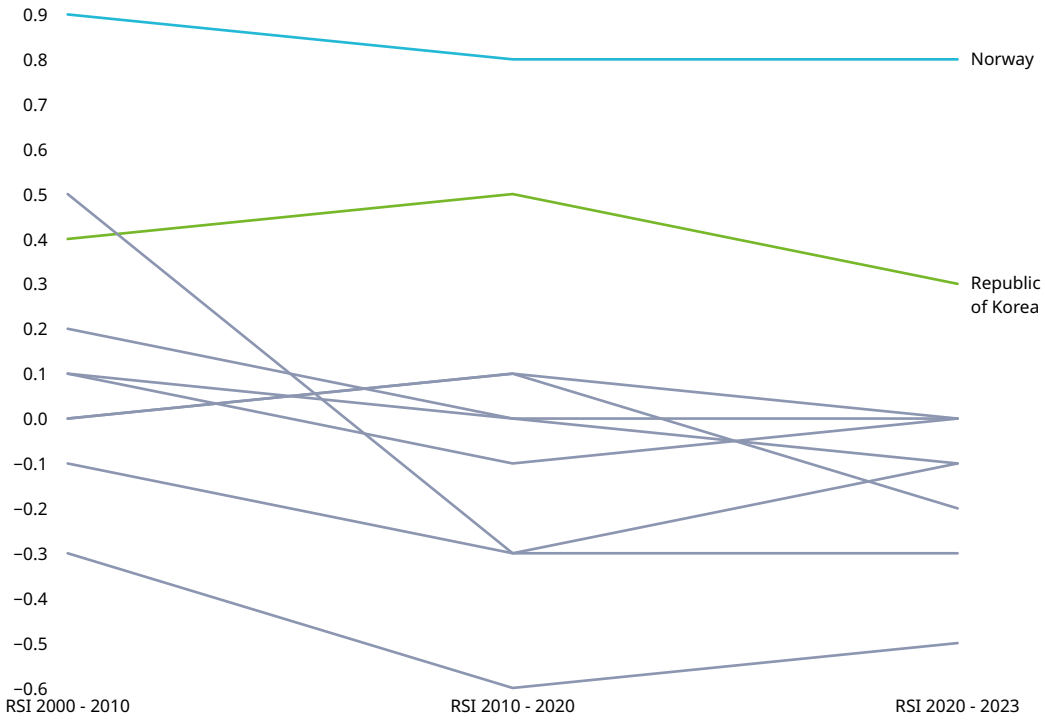
Notes: The size of the bubbles reflects the number of patent family publications at the country level in the field of Automation and Circularity. The compound annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Looking more closely at RSI values over the different time periods shows that both Norway and the Republic of Korea have a very high degree of research specialization in Automation and Circularity technologies within the shipping sector (Figure B36).

Norway and the Republic of Korea exhibit a high degree of research specialization in Automation and Circularity technologies within the shipping sector

Figure B36 Automation and Circularity: top 10 countries' Relative Specialization Index (RSI), 2000–2023



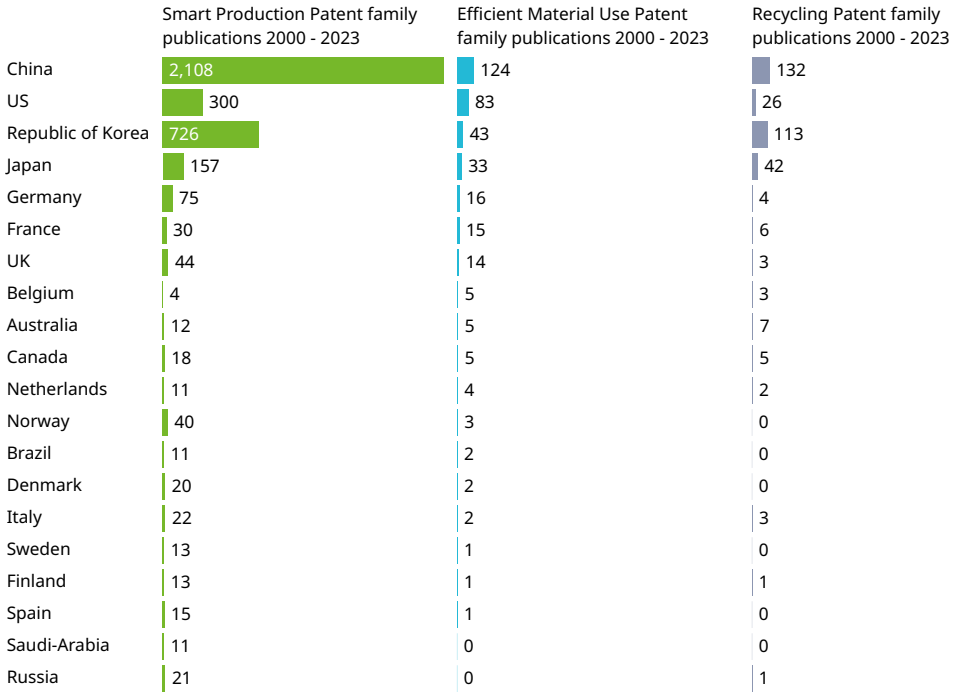
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Analysis of the top research countries in the different subgroups of the Automation and Circularity technology trend provides the following key results (Figure B37):

- China is far ahead in terms of the absolute number of patent family publications in smart production and also ranks first in efficient material use and recycling.
- The Republic of Korea ranks second in smart production and recycling. It is only slightly behind China in recycling.
- The United States is an innovation leader in efficient material use (ranked second behind China).

China leads in smart production, efficient material use, and recycling, with the Republic of Korea second in smart production and recycling, and the United States second in efficient material use

Figure B37 Top 20 inventor locations for Automation and Circularity subgroups, 2000–2023

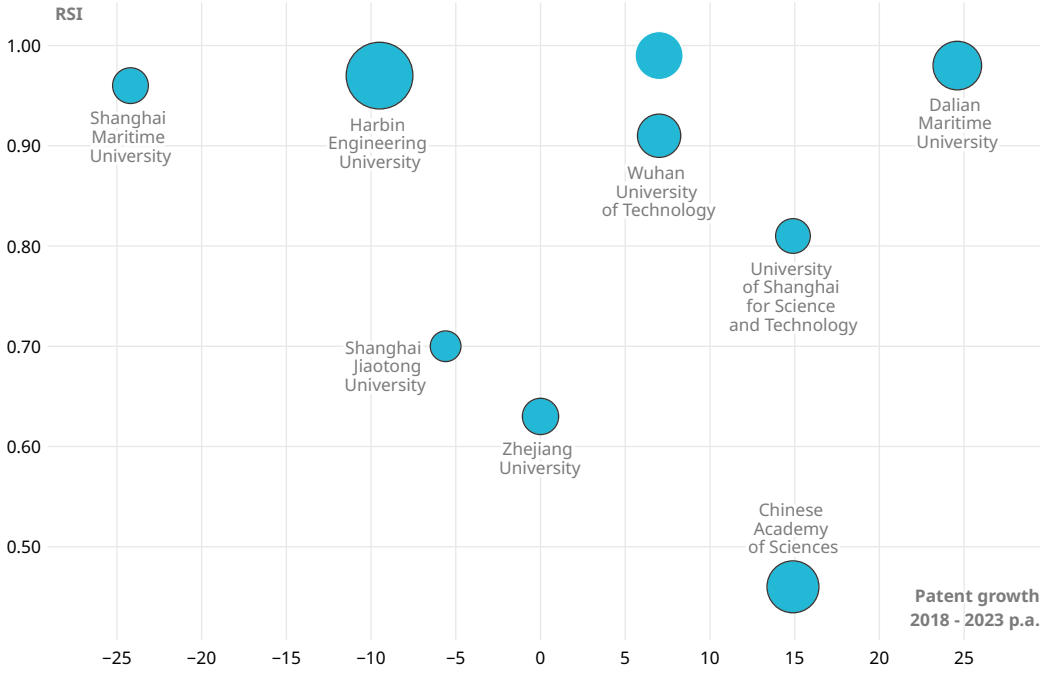


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Harbin Engineering University is the leading research institution in Automation and Circularity technologies within the maritime sector, with 118 patent families published to date, almost twice as many as the second ranked Chinese Academy of Sciences (Figure B38). In general, Chinese research institutions dominate the Automation and Circularity landscape, accounting for nine of the top 10 applicants. The one non-Chinese company in the top 10 is Mitsubishi Heavy Industries of Japan in ninth place.

Chinese research institutions dominate the Automation and Circularity landscape, with nine of the top 10 applicants

Figure B38 Automation and Circularity: comparison of top patent owners, Relative Specialization Index (RSI) (2000–2023) and growth rates (2018–2023)



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

The top patent owners in the three subgroups are as follows (Figure B39):

- Harbin Engineering University is a technology leader in all three Automation and Circularity subgroups.
- In the technology efficient material use, the U.S. Department of the Navy has published nine patent families since 2000, as many as the Harbin Engineering University.
- The Chinese Academy of Sciences is another important research institution in Automation and Circularity technologies in the shipping sector, with a particular focus on intelligent production technologies.

Harbin Engineering University leads all subgroups, while the US Department of Navy has published nine patent families in efficient material use

Figure B39 Top five applicants in the subgroups of Automation and Circularity

Subgroup	Company	Patent family publications
Efficient material use	Chinese Academy of Sciences	4
Efficient material use	Boeing	6
Efficient material use	Arkema	6
Efficient material use	US Departement of Navy	9
Efficient material use	Harbin Engineering University	9
Smart production	Wuhan University of Technology	47
Smart production	Jiangsu University of Science and Technology	56
Smart production	Dalian Maritime University	61
Smart production	Chinese Academy of Sciences	66
Smart production	Harbin Engineering University	106
Recycling	Zhejiang Ocean University	3
Recycling	Japan Atomic Energy Agency	3
Recycling	Mitsubishi Heavy Industries	3
Recycling	Jiangsu University of Science and Technology	3
Recycling	Harbin Engineering University	6

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Communication and Security

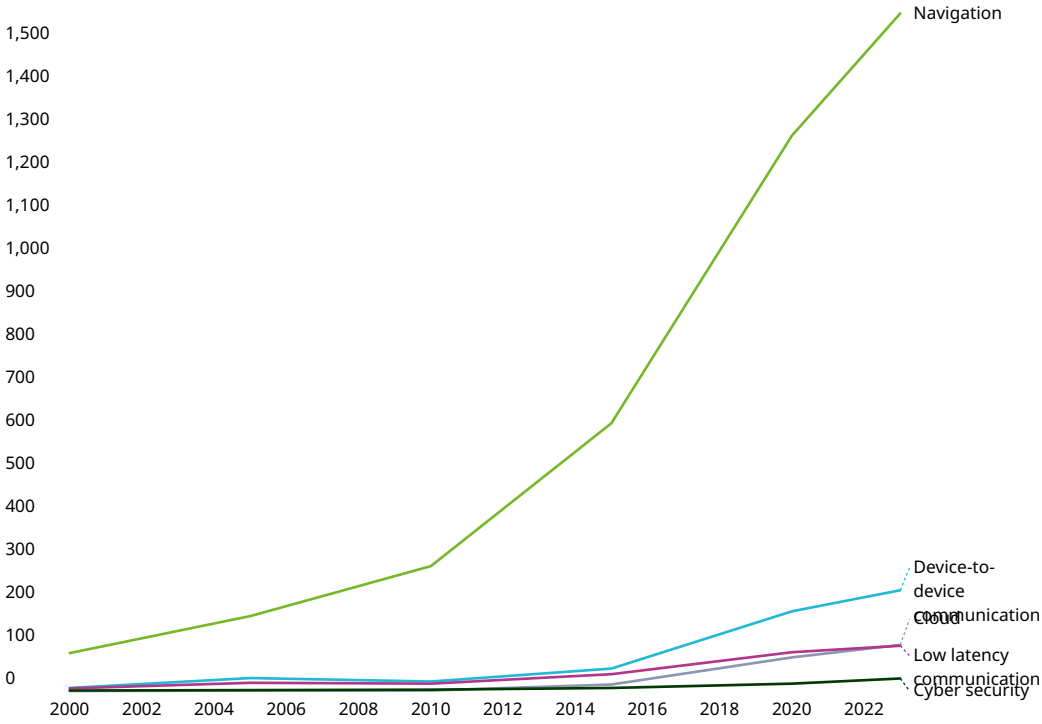
In Communication and Security technologies within the shipping sector most research activity takes place in navigation technologies such as lidar, radar, sonar or GPS. In this field, the average number of patent family publications per year has increased from 88 in 2000 to 1,574 in 2023 (Figure B40).

A second important research area is device-to-device communication, with around 230 patent family publications in 2023.

Patenting activity in low-latency communication, cloud and cybersecurity has also risen, but remains at a lower level.

Within the shipping sector, most research in Communication and Security technologies focuses on navigation technologies like lidar, radar, sonar, and GPS

Figure B40 Communication and Security: development of global patent family publications, 2000–2023

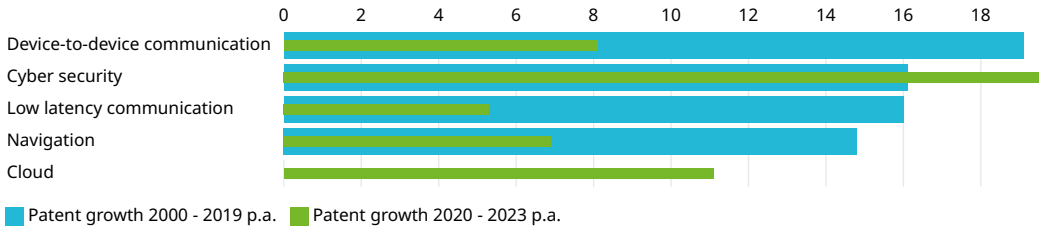


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patent growth has been high in all Communication and Security areas (Figures B41–B43). Since 2020, patent publications for cybersecurity in shipping have grown particularly strongly (Figure B41).

Patent growth has been strong across all areas of Communication and Security technologies

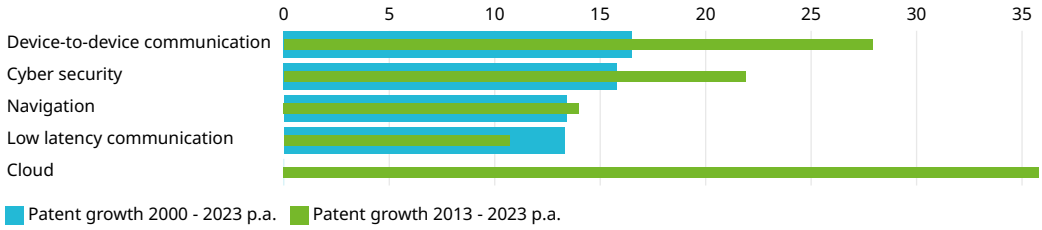
Figure B41 Communication and Security: growth of patent family publications, 2000–2019 and 2020–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Whereas patenting activity in hydrogen/fuel cells and batteries continues to grow, electric propulsion and sustainable carbon-based fuels have seen a slight decline over the last five years

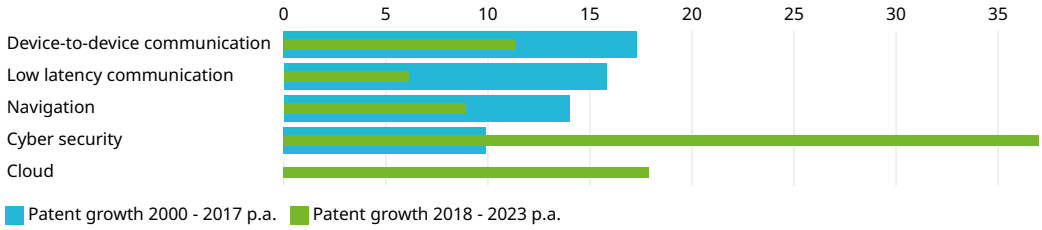
Figure B42 Communication and Security: growth of patent family publications, 2000–2023 and 2013–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Since 2020, patent publications for cybersecurity in shipping have experienced significant growth

Figure B43 Communication and Security: growth of patent family publications, 2000–2017 and 2018–2023

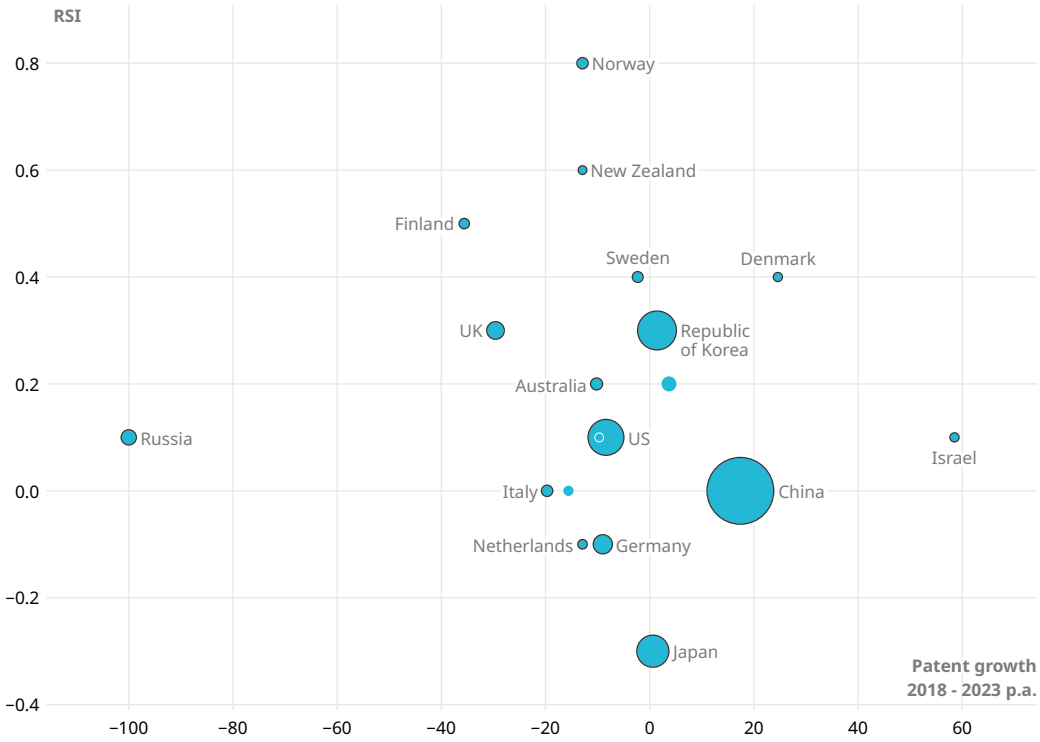


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Figure B44 shows that inventors from China to be publishing the most patent families. Moreover, patent growth has also high in China over recent years. Only Denmark and Israel have achieved even higher growth rates since 2018. However, China's RSI value is only around 0, showing neither an above average nor a below average specialization in research activities in Communication and Security technologies. Again, Norway has by far the highest RSI value.

Since 2018, only Denmark and Israel have experienced a higher growth rate than China

Figure B44 Communication and Security: country comparison, Relative Specialization Index (RSI) (2000–2023) and growth rates (2018–2023)



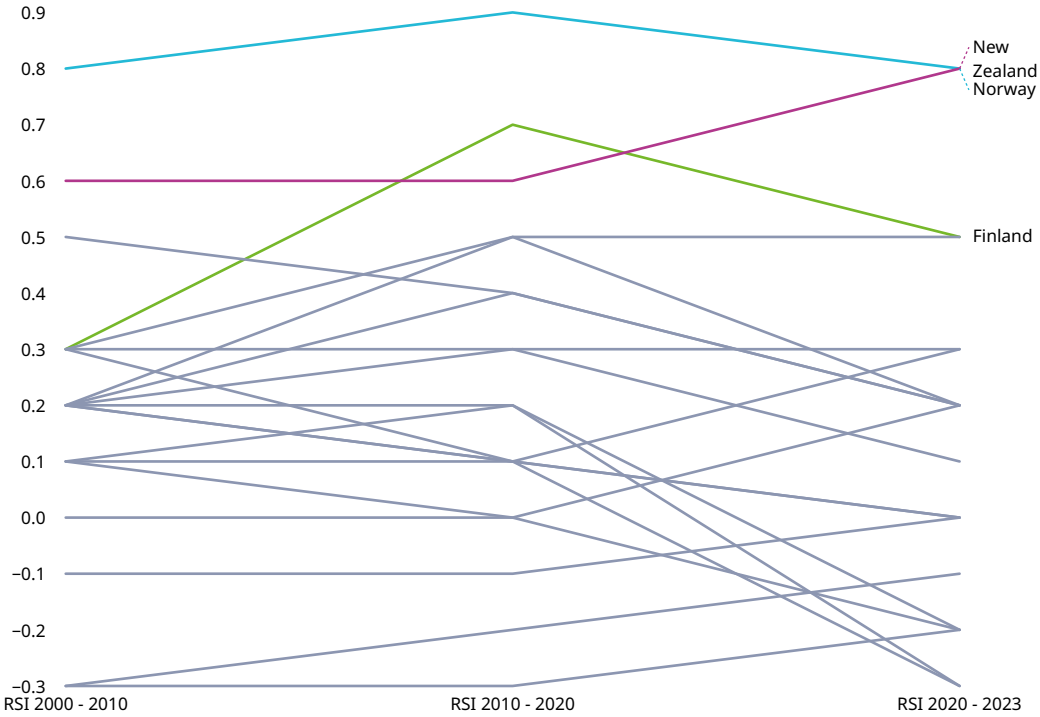
Notes: The size of the bubbles reflects the number of patent family publications at the country level in the field of Communication and Security. The compound patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Looking more closely at RSI values over the different time periods shows that both Norway and New Zealand have a very high degree of research specialization in Communication and Security technologies within the shipping sector (Figure B45). Other highly specialized countries are Finland and Denmark.

Both Norway and New Zealand exhibit a very high degree of research specialization in Communication and Security technologies within the shipping sector

Figure B45 Communication and Security: top 20 countries' Relative Specialization Index (RSI), 2000–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Analysis of the top research countries in the different subgroups of the Communication and Security technology trend provides the following key results (Figure B46):

- China is ahead in terms of the absolute number of patent family publications in all five Communication and Security subgroups. The country's lead is particularly high in device-to-device communication, navigation technologies and cloud technologies.
- The Republic of Korea is in second place in both device-to-device communication and navigation technologies.
- The United States has the second highest number of patent family publications in cloud technologies, cybersecurity and low-latency communication.

China leads in the absolute number of patent family publications across all five Communication and Security subgroups

Figure B46 Top 20 inventor locations for Communication and Security subgroups, 2000–2023

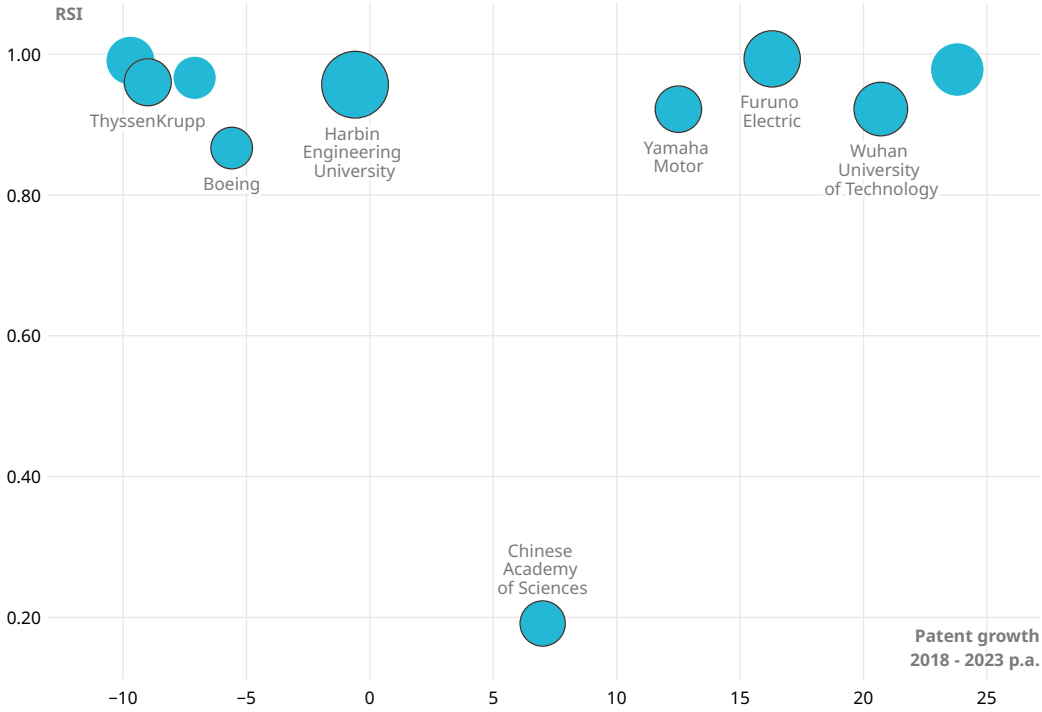
	Device-to-device Patent family publications 2000 - 2023	Navigation Patent family publications 2000 - 2023	Cloud Patent family publications 2000 - 2023	Cyber Security Patent family publications 2000 - 2023	Low latency communication Patent family publications 2000 - 2023
China	1,047	6,096	419	70	444
Republic of Korea	325	2,081	45	30	131
US	227	1,749	131	49	264
Japan	121	1,499	22	8	68
Germany	33	473	7	4	49
UK	23	402	16	4	34
Australia	20	144	5	3	15
Israel	17	52	8	9	17
Canada	15	119	7	3	18
Sweden	14	110	2	2	6
France	13	332	3	5	27
Finland	11	93	6	0	8
Norway	10	132	3	1	2
Italy	8	128	2	0	6
Switzerland	6	30	0		3
Russia	6	296	1	2	18
Spain	5	51	1	1	1
Denmark	5	54	2	0	4
New Zealand	4	44	3	2	3
Netherlands	0	70	1	3	4

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Harbin Engineering University, with 324 patent families published between 2000 and 2023, Furuno Electric, with 229 patent families, Wuhan University of Technology, with 208 patent families, and Dalian Maritime University, with 207 patent families, are the top patent holders in Communication and Security technologies within the maritime sector (Figure B47). Wuhan University of Technology, Furuno Electric and Dalian Maritime University have also achieved very dynamic patent growth rates in recent years. In terms of RSI values, nine of the top 10 applicants have a very high value, indicating a high degree of research specialization in Communication and Security Technologies, the sole exception being the Chinese Academy of Sciences.

Nine of the top 10 applicants have a very high RSI value, indicating strong research specialization in Communication and Security technologies

Figure B47 Communication and Security: comparison of top patent owners, Relative Specialization Index (RSI) (2000–2023) and growth rates (2018–2023)



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

The top patent owners in the five subgroups are as follows (Figure B48):

- Harbin Engineering University is the top patent holder in navigation technologies within the shipping sector.
- Shanghai Maritime University has published most patent families in device-to-device communication.
- Wuhan University of Technology is an innovation leader in cloud technologies.
- Boeing is clearly ahead in research activities in low-latency communication.
- There are several companies and universities with a handful of patent families in cybersecurity, namely, Yamaha Motor, BAE Systems, Boeing, Wuhan University of Technology and Dalian Maritime University.

Harbin Engineering University leads in navigation, Shanghai Maritime University in device-to-device communication, Wuhan University in cloud technologies, and Boeing in low-latency communications

Figure B48 Top 5 patent owners in the subgroups of Communication and Security

Subgroup	Company	Patent family publications
Device-to-device	Yamaha Motor	11
Device-to-device	China Communication Construction Co	23
Device-to-device	Wuhan University of Technology	29
Device-to-device	Dalian University	34
Device-to-device	Shanghai Maritime University	44
Navigation	Brunswick Corp	169
Navigation	Dalian Maritime University	171
Navigation	Wuhan University of Technology	183
Navigation	Furuno Electric Co	228
Navigation	Harbin Engineering University	315
Cloud	Harbin Engineering University	5
Cloud	Brunswick Corp	6
Cloud	Shanghai Maritime University	9
Cloud	Dalian Maritime University	10
Cloud	Wuhan University of Technology	18
Cybersecurity	Dalian Maritime University	3
Cybersecurity	Wuhan University of Technology	3
Cybersecurity	Boeing	3
Cybersecurity	BAE Systems	3
Cybersecurity	Yamaha Motor	4
Low-latency communication	RTX Corp	9
Low-latency communication	Shanghai Maritime University	10
Low-latency communication	Dalian Maritime University	13
Low-latency communication	Chinese Academy of Sciences	18
Low-latency communication	Boeing	50

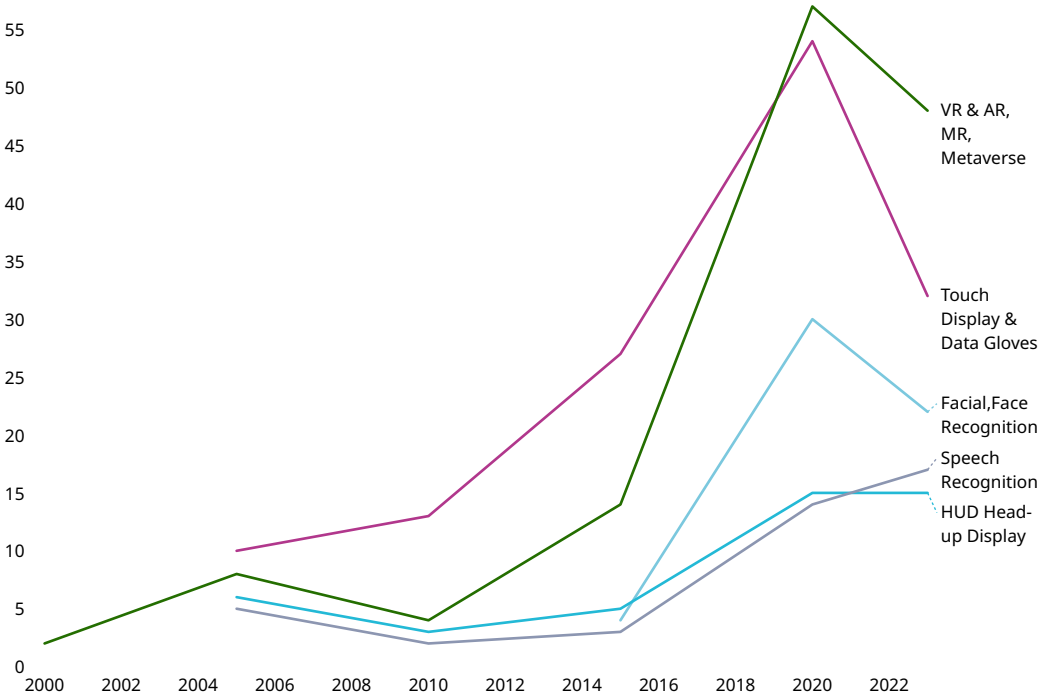
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Human–Machine Interface

HMI technologies are at an early stage of development and adoption within the shipping sector. This is reflected in the limited research activity to date. As a result, the number of patent family publications is relatively low for all five HMI technologies. Patenting activity was the highest for VR/AR/metaverse technologies, with 48 patent family publications in 2023 (Figure B49).

HMI technologies are still in the early stages of development and adoption within the shipping sector

Figure B49 Human–Machine Interface: development of global patent family publications, 2000–2023

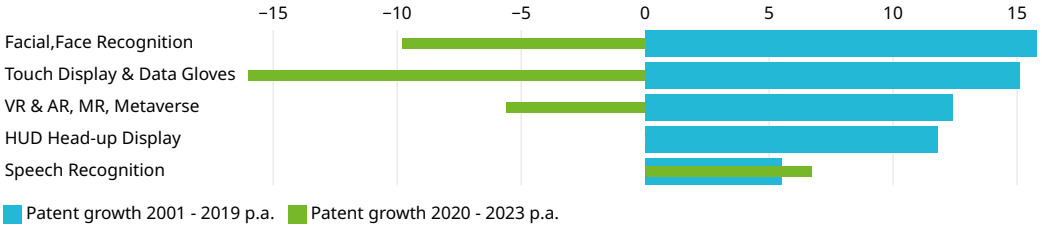


Note: VR is virtual reality, AR is augmented reality and XR is extended reality.
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

After strong patent growth in all HMI technologies between 2000 and 2019, patent growth has been uneven in recent years (Figure B50). While the number of patent families published in speech recognition continues to grow, the number of patent families published annually in head-up displays has stagnated. And the number of patent families published in touch displays/ data gloves, as well as in facial recognition and VR/AR/metaverse, has actually declined.

After strong patent growth in all HMI technologies from 2000 to 2019, growth has been uneven in recent years

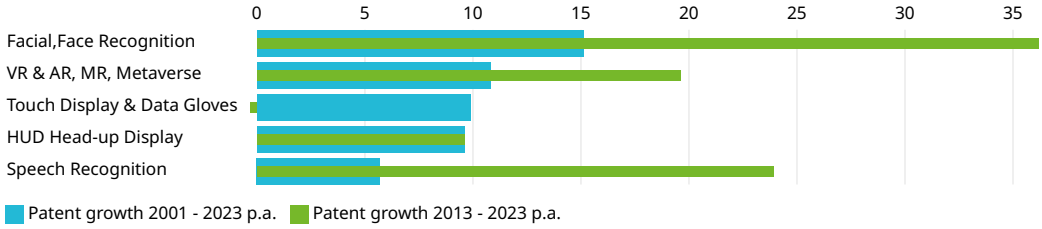
Figure B50 Human–Machine Interface: growth of patent family publications, 2001–2019 and 2020–2023



Note: VR is virtual reality, AR is augmented reality, XR is extended reality.
ource: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Between 2000 and 2019, innovation activity was dynamic across all subcategories, but growth rates have been mixed since 2020

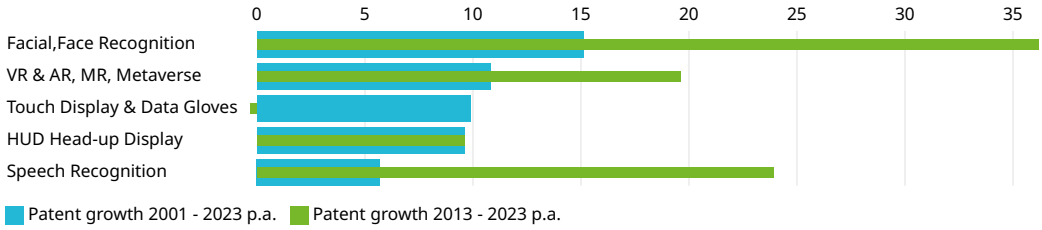
Figure B51 Human–Machine Interface: growth of patent family publications, 2001–2023 and 2013–2023



Note: VR is virtual reality, AR is augmented reality and XR is extended reality.
ource: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Whereas speech recognition patent families continue to grow, annual publications in head-up displays have stagnated

Figure B52 Human–Machine Interface: growth of patent family publications, 2001–2017 and 2018–2023

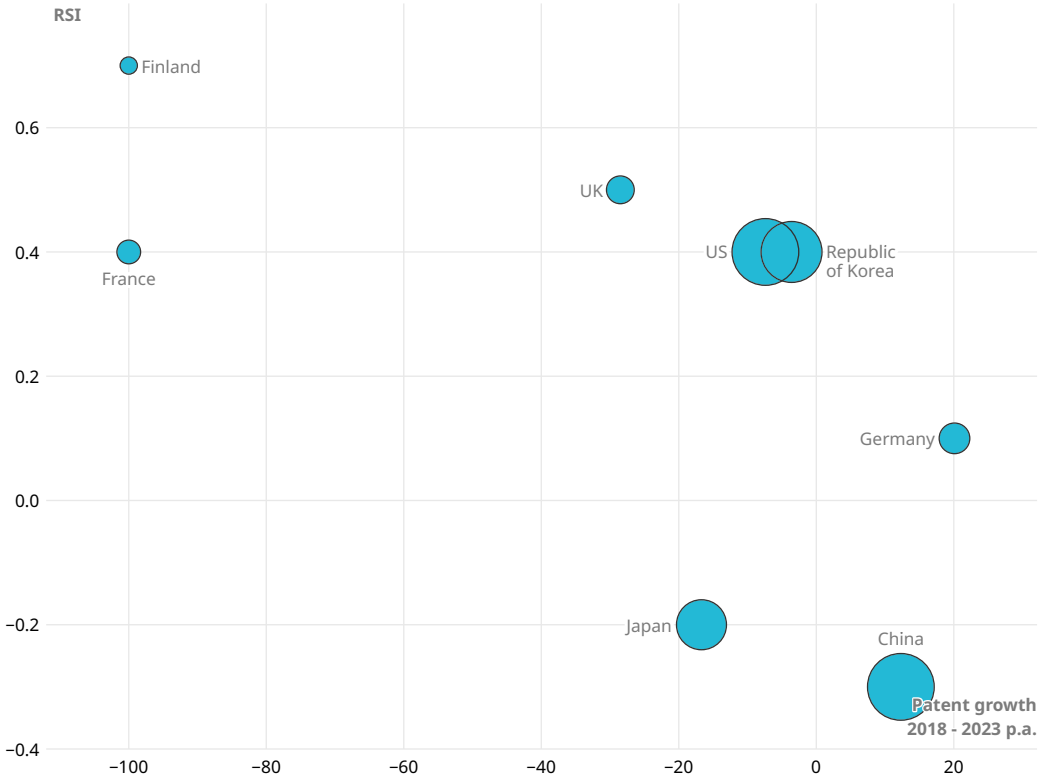


Note: VR is virtual reality, AR is augmented reality and XR is extended reality.
ource: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Figure B53 shows that inventors from China and the United States have published the most patent families in HMI technologies within the marine sector. Furthermore, China has also achieved high patent growth since 2018. However, China's RSI value is below 0, indicating a below average specialization in research activities in HMI technologies. In contrast, the Republic of Korea, the United States and the United Kingdom have a high RSI value.

Patent growth in China has outpaced all other countries since 2018, yet its RSI is slightly negative, reflecting a below-average specialization in security and communication technologies

Figure B53 Human–Machine Interface: country comparison, Relative Specialization Index (RSI) (2000–2023) and growth rates (2018–2023)



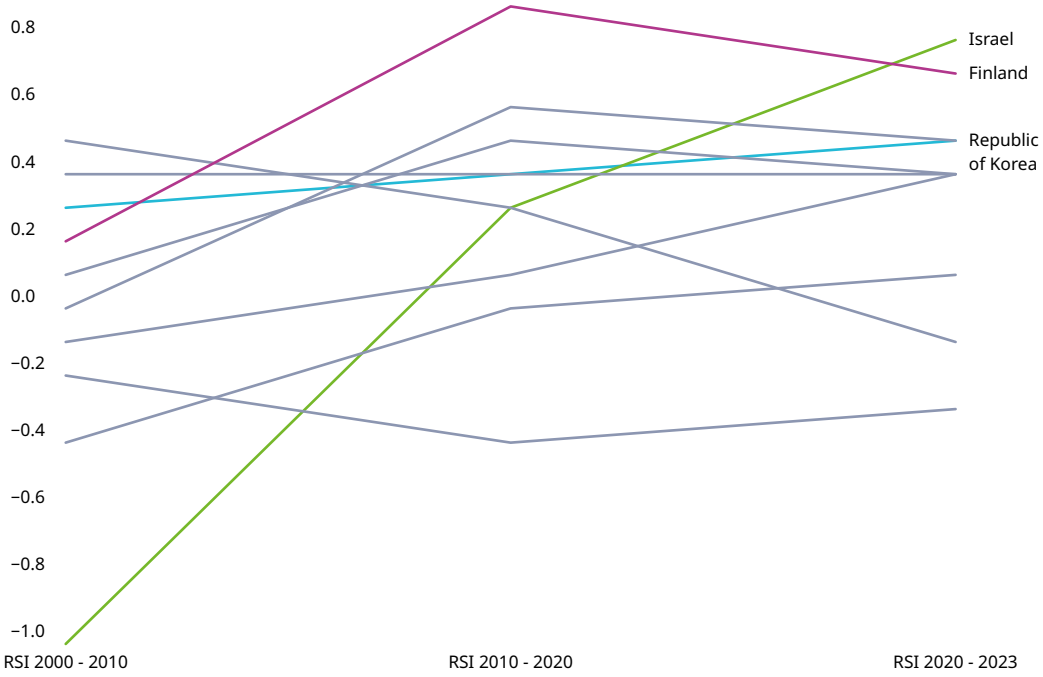
Notes: The size of the bubbles reflects the number of patent family publications at the country level in the field of HMI technologies. The average annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Looking more closely at RSI values over the different time periods shows that Israel has increased its RSI value in HMI technologies significantly over the last two decades (Figure B54). Finland is another country with a very high RSI value.

Israel has significantly increased its RSI value in HMI technologies over the past two decades

Figure B54 Human–Machine Interface: top 10 countries' Relative Specialization Index (RSI), 2000–2023



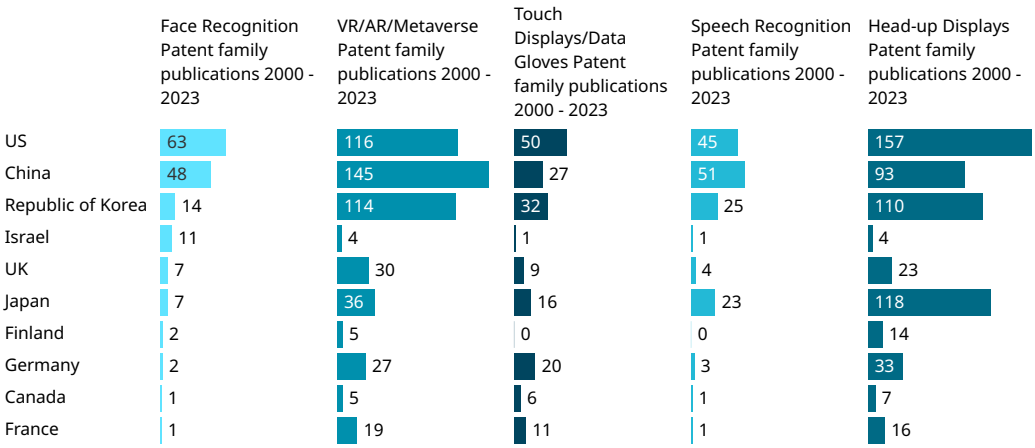
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Analysis of the top research countries in the different subgroups of the HMI technology trend provides the following key results (Figure B55):

- China and the United States lead in terms of patent family publications both in facial and speech recognition applications.
- China is also ahead in VR/AR/metaverse patent families, but both the United States and the Republic of Korea are not far behind.
- The United States is the technology leader in the development of head-up displays.
- The United States also leads in touch displays/data gloves, but Japan, the Republic of Korea and China also have significant research activities in this field.

China and the United States lead in facial and speech recognition patents, with China ahead in VR/AR/metaverse, whereas the United States leads in head-up and touch displays development

Figure B55 Top 20 inventor locations for Human–Machine Interface subgroups, 2000–2023

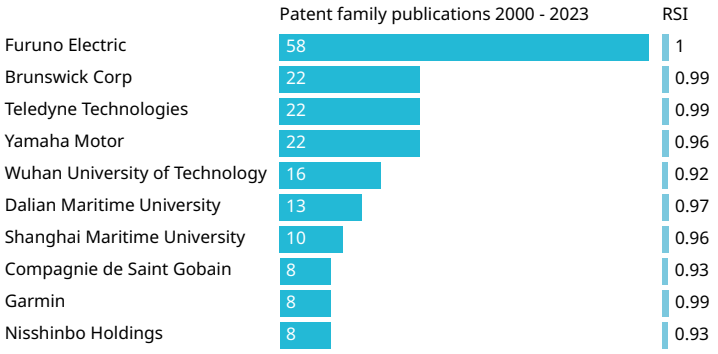


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Furuno Electric is the leading research institution in HMI applications technologies within the maritime sector, with 58 patent families published to date, far ahead of Brunswick Corp, Teledyne Technologies and Yamaha Motor, with 22 patent family publications each (Figure B56).

Furuno Electric is the leading research institution in HMI application technologies

Figure B56 Human–Machine Interface: comparison of top applicants



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

The top applicants in the five subgroups are as follows (Figure B57):

- Windward has published most patent families in the field of facial recognition in maritime applications.
- Teledyne Technologies and Furuno Electric are the leaders in VR/AR/metaverse.
- Furuno Electric has also published many patent families in touch displays/data gloves and head-up displays.
- In the field of speech recognition, there are several companies that have published a few patent families, including Motorola, Mitsubishi Heavy Industries, Dalian Maritime University and Shanghai Maritime University.

Windward leads in facial recognition patents for maritime applications, whereas Teledyne Technologies and Furuno Electric are pioneers in VR/AR/metaverse

Figure B57 Top 5 patent owners in the subgroups of Human–Machine Interface

Subgroup	Company	Patent family publications
Facial recognition	Brunswick Corp	2
Facial recognition	Garmin	2
Facial recognition	International Business Machines	2
Facial recognition	China Ship Development and Design Centre	3
Facial recognition	Windward	5
VR/AR/Metaverse	Brunswick Corp	5
VR/AR/Metaverse	Wuhan University of Technology	10
VR/AR/Metaverse	Dalian Maritime University	10
VR/AR/Metaverse	Furuno Electric	16
VR/AR/Metaverse	Teledyne Technologies	16
Head-up displays	Naval Group	3
Head-up displays	US Department of Navy	3
Head-up displays	Furuno Electric	5
Head-up displays	BAE Systems	5
Head-up displays	Compagnie de Saint Gobain	5
Speech recognition	Yamaha Motor	2
Speech recognition	Shanghai Maritime University	3
Speech recognition	Dalian Maritime University	3
Speech recognition	Mitsubishi Heavy Industries	3
Speech recognition	Motorola Solutions	3
Touch displays/data gloves	BAE Systems	6
Touch displays/data gloves	Teledyne Technologies	11
Touch displays/data gloves	Brunswick Corp	19
Touch displays/data gloves	Yamaha Motor	20
Touch displays/data gloves	Furuno Electric	47

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

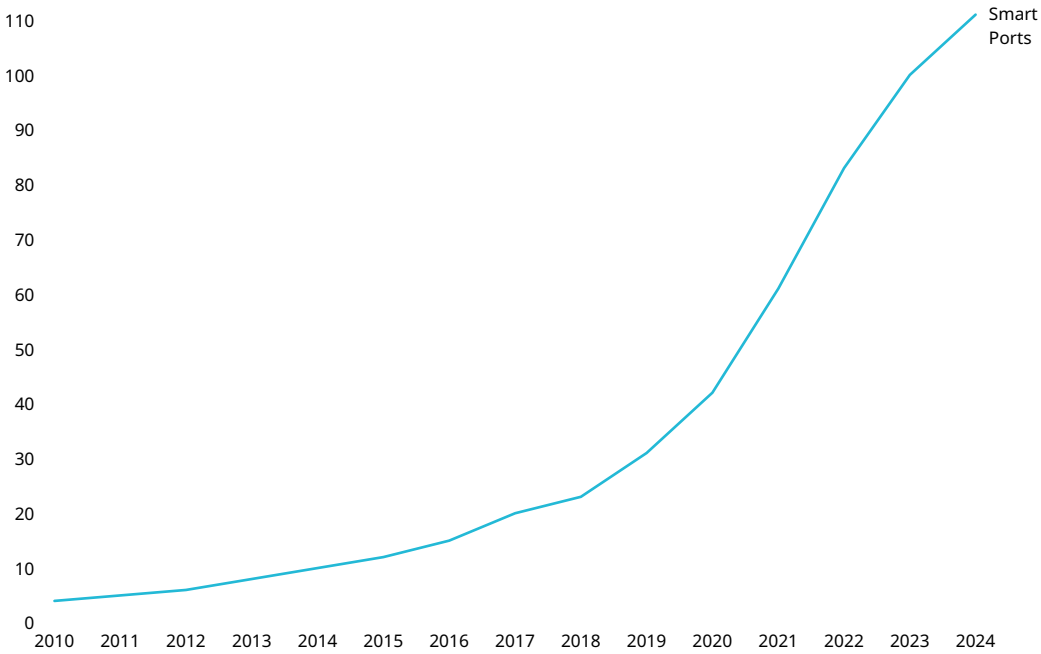
Emerging technology in detail: smart ports

Smart ports: scientific publications

The scientific community's engagement with smart ports has also seen a noticeable uptick in research activity. Since 2016, there has been a marked increase in peer-reviewed journal articles focusing on various facets of smart port technologies (Figure B58). This growing academic interest highlights a shift toward exploring and addressing the complex challenges and opportunities that smart ports present. Such research endeavors are often foundational, paving the way for practical applications and technological breakthroughs.

Since 2016, the scientific community has shown a marked increase in research activity

Figure B58 Development of global scientific publications related to smart ports, 2010–2023



Source: WIPO, based on publication data from Scopus, October 2024.

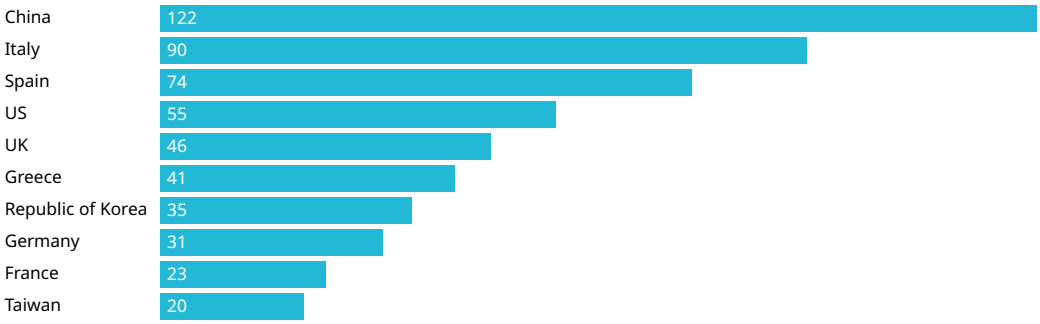
Studies such as those by Notteboom and Haralambides reflect this trend, indicating a surge in academic publications related to smart ports.[1] Such articles often explore innovative topics like automation, data analytics and sustainability measures within port operations, underscoring a rich field of exploration. This academic focus is crucial as it signals the potential directions in which port technologies could evolve and provides a valuable indicator as to those areas where future patents may emerge as the technologies mature and find practical application.

1 Notteboom, T. E. and H. E. Haralambides (2020). Port management and governance in a post-COVID-19 era: Quo vadis? Maritime Economics & Logistics, 22, 329–352.

Analysis of regions and countries reveals that China, Italy and Spain are leading in the scientific sphere (Figure B59).

China, Italy, and Spain are leading in the scientific sphere of smart port technologies

Figure B59 Origin countries for scientific publications related to smart ports



Source: WIPO, based on publication data from Scopus, October 2024.

A McKinsey analysis from 2018 reveals that ports have been slower to adopt automation compared to sectors like mining and warehousing, though the trend is now gaining momentum. Automated ports offer significant advantages, including improved safety, reduced human-related disruption and a more predictable performance. However, the transition faces substantial barriers, including high initial capital costs and operational challenges like skill shortages, poor data quality, isolated operations and difficulties in handling exceptions.[2]

Despite these obstacles, automation has the potential to substantially reduce operating expenses and increase productivity, although current returns on invested capital fall below industry averages.[3]

The long-term vision for ports is a transition toward "Port 4.0," which represents a shift from being primarily asset operators to becoming service orchestrators, aligning with a broader move toward Industry 4.0. This evolution promises increased value for port operators, suppliers and customers, though it requires innovative business models and collaboration in order to be fully realized. The history of port automation dates back to the first automated container port established in Europe in the early 1990s.[4] Since then, over 20 ports have adopted automation within the last several years, with almost 53 container terminals now partially or fully automated worldwide.[5]

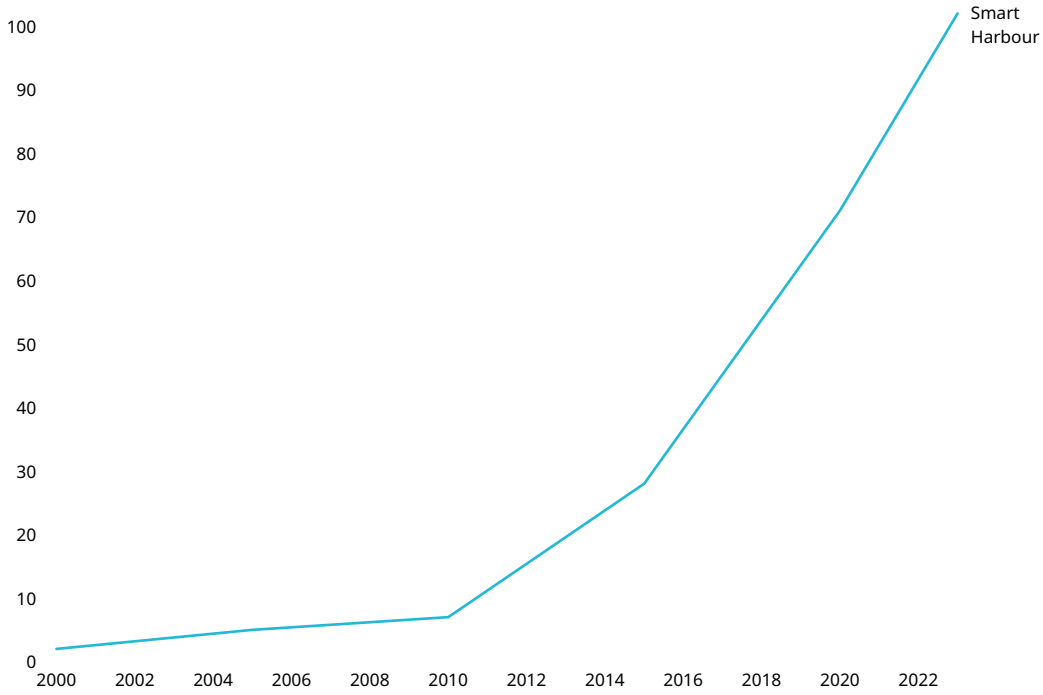
Smart ports: patent data

Examination of the patent landscape reveals that patenting activity in the field of smart ports has picked up speed over the last few years. The number of published patent families has increased from only 20 in 2016 to 102 in 2023 (Figure B60).

2 McKinsey (2018). The future of automated ports. McKinsey & Company. Available at: www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/the-future-of-automated-ports.
3 Othman, A., S. El-gazzar and M. Knez (2022). A framework for adopting a sustainable smart sea port index. Sustainability, 14(8), 4551.
4 Konecranes (2021). The case for automated RTG container handling. Available at: www.konecranes.com/sites/default/files/download/case_for_automated_rtg_container_handling.pdf.
5 ITF (2021). Container Port Automation: Impacts and Implications. International Transport Forum Policy Papers, No. 96. Paris: OECD Publishing.

Patenting activity in smart ports has accelerated in recent years, with the number of published patent families having risen from just 20 in 2016

Figure B60 Development of global patent family publications related to smart ports, 2000–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

At a country level, almost all smart port patent families published were from inventors in China (556 patent families between 2000 and 2023) (Figure B61).

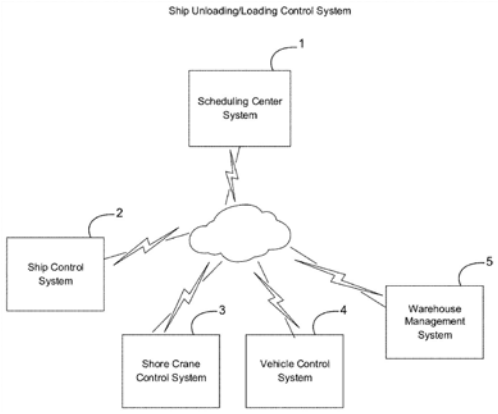
China leads the field of smart port patenting, with inventors publishing 556 patent families between 2000 and 2023

Figure B61 Patent family publications related to smart ports, 2000–2023

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Smart ports: patent examples

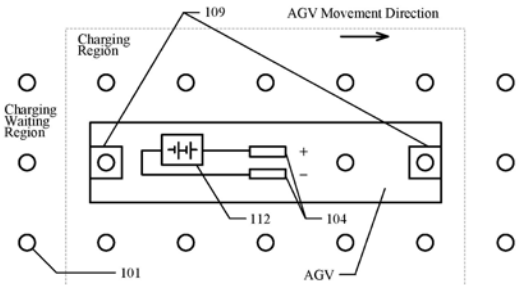
The invention detailed in the patent application US20200140242A1 filed by Shanghai Tusen Weilai Artificial Intelligence Technology Co., Ltd. is a system designed to control the unloading and loading of ships using advanced technology. It includes a ship unloading control system, ship loading control system and related apparatuses, which work together to optimize the entire process. This system is aimed at improving the efficiency and coordination of maritime cargo handling, by utilizing scheduling systems, shore crane control systems and vehicle control systems. It relies on technologies such as AI, big data and automated scheduling and task management, integrating with warehouse management systems to streamline operations.



Source: US20200140242A1.

This invention highlights technological components of a smart port, because it aligns with the concept of port automation and efficiency, central to the idea of a smart port. By integrating various technological components like scheduling systems and crane control systems, it enables ports to manage loading and unloading processes more autonomously and efficiently. Such integration facilitates real-time data sharing and decision-making, which are key elements of a smart port's operations, leading to increased productivity, reduced operational costs and enhanced safety – characteristics that define smart port capabilities.

Another invention example focuses on the automation of container terminal operations. The invention presented in the patent application US10833515B2 filed by Shanghai Maritime University is an automatic charging device for an Automated Guided Vehicle (AGV) on a container terminal. The system involves a vehicle-mounted device and a ground device working together to charge the AGV efficiently and reliably. The setup utilizes radio frequency identification (RFID) technology for precise positioning and safety within the charging region. The design aims to enhance the connection rate between the power supply and the AGV, improving the operational efficiency of the AGV and ensuring the safety of the charging process.



Source: US10833515B2.

The highlighted technologies in this patent application are central to the development of a smart port, because they enable automation and efficiency in container terminal operations. RFID technology for precise positioning and safety, along with an automated charging system for AGVs, facilitate uninterrupted and efficient container handling. These technologies contribute to creating an integrated, automated and intelligent port environment, improving operational efficiency and safety – key attributes of a smart port.

The smart port projects in Shanghai, Busan, Rotterdam and Hamburg exemplify the cutting-edge integration of technology in maritime logistics. These projects serve as lighthouse projects, illuminating the path for the future of port operations. They leverage innovations from recent patents, including advanced automation, data analytics and IoT, to enhance efficiency, safety and sustainability, signaling a transformative leap toward the digitalization and intelligent management of maritime trade hubs.

Smart port projects that incorporate advanced technologies are being initiated worldwide. In China, the port of Shanghai has been involved in smart port initiatives, particularly with its

Yangshan Deep Water Port's automated terminals.[6] The Republic of Korea's port of Busan has also been investing in smart technologies, becoming one of the most technologically advanced ports with its Busan New Port.[7] In the Kingdom of the Netherlands, the Port of Rotterdam's SmartPort initiative collaborates with universities and industry partners to develop innovative projects.[8] Germany's Hamburg Port Authority runs the smartPORT initiative, which includes various projects aimed at enhancing port efficiency through digitalization.Hamburg [9]

The convergence of advanced technologies evidenced by the example inventions, along with the pioneering smart port projects in leading maritime nations, underscores the critical role of smart ports in the future of sea transportation. These initiatives serve as beacons, showcasing the potential of digitalization, automation and efficient energy use, setting a standard for ports globally.

As the demand for more efficient, sustainable and safer sea transport grows, the move toward smart ports is not just a trend–it is an imperative. The industry is witnessing a shift from traditional port operations toward a future where ports are not just transit points, but intelligent systems that can think, decide and act autonomously, marking a new era in maritime technology and logistics.

6 South China Morning Post (2023). Shanghai port operator aims to expand capacity of its automated terminal at Yangshan and help shippers reduce waiting time and costs. Available at: www.scmp.com/business/china-business/article/3234313/shanghai-port-operator-aims-expand-capacity-its-automated-terminal-yangshan-and-help-shippers-reduce.

7 American Journal of Transportation (2023). Port of Busan will open its first automated terminal in 2023 using Korean cranes. Available at: www.ajot.com/insights/full/ai-port-of-busan-will-open-its-first-automated-terminal-in-2023-using-korean-cranes.

8 Port of Rotterdam (2024). Port of Rotterdam developing into major digital platform. Available at: www.portofrotterdam.com/en/to-do-port/futureland/the-digital-port.

9 Port Authority (2024). HPA goes smartPORT. Available at: www.hamburg-port-authority.de/fileadmin/user_upload/150422_tl_messe_lowres.pdf.

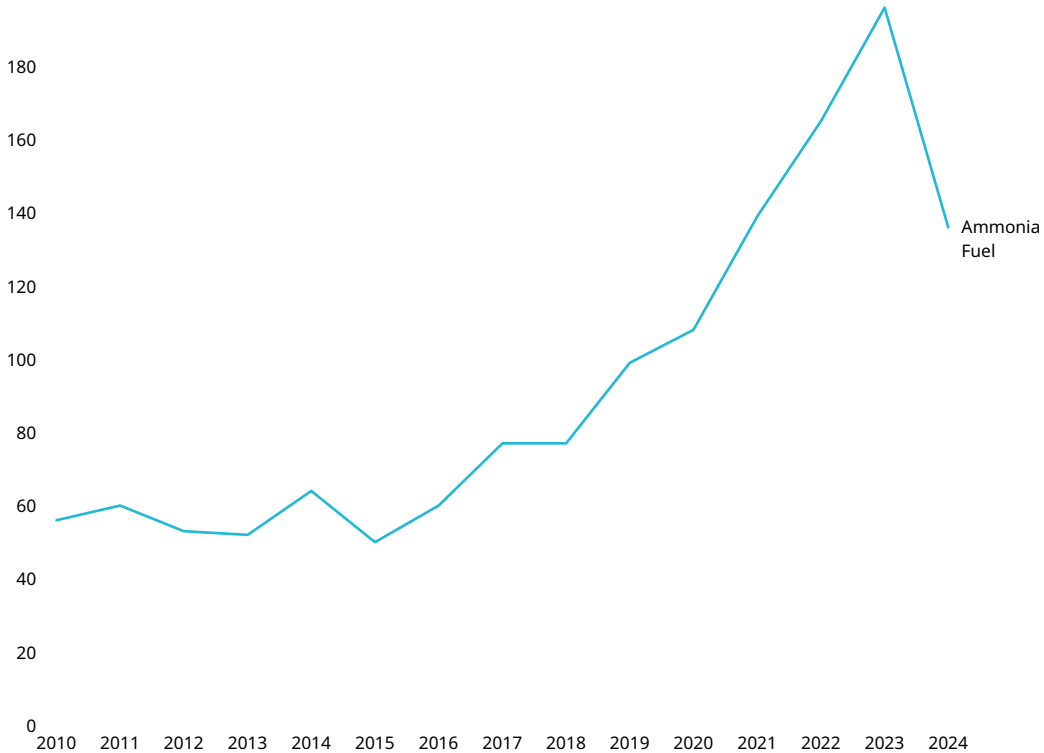
Emerging technology in detail: ammonia as a marine fuel

Ammonia as a marine fuel: scientific publications

Ammonia as a marine fuel has increasingly become a focal point of scientific research, driven by an urgent need for sustainable and low-carbon alternative fuels within the maritime industry. Over the past decade, there has been a significant rise in publications exploring the potential of ammonia, reflecting its growing importance in the global push toward decarbonization. This surge in research is not only widespread across multiple countries, but also gaining momentum, as indicated by the substantial increase in the number of studies, particularly within the last few years.

Over the past decade, publications on the potential of ammonia have surged, reflecting its increasing significance in global decarbonization efforts, with research gaining momentum, especially in recent years

Figure B62 Development of global scientific publications related to ammonia as a marine fuel, 2014–2024



Source: WIPO, based on publication data from Scopus, October 2024.

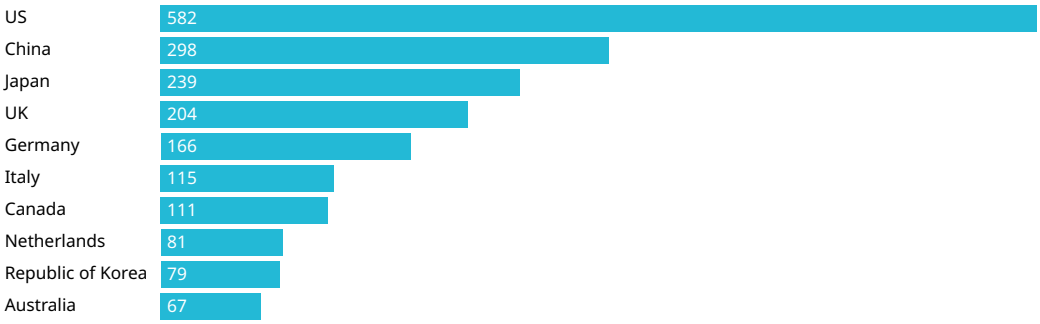
Figure B62 presents the number of scientific publications related to ammonia as a marine fuel from 2010 to 2024. Data reveal a steady increase in research activity over time, with a significant rise starting around 2018. This upward trend likely reflects growing interest and urgency in

finding alternative, sustainable marine fuels as the maritime industry faces increasing pressure to decarbonize. The peak in 2023, with over 200 documents, marks the highest level of research output in this field. However, there was a notable decline in 2024, which could indicate either a temporary dip in research activity or a shift toward application and implementation phases after intensive initial research.

The geographical distribution of scientific publications reveals that major industrialized nations like the United States, China, Japan and the United Kingdom are leading the way, underscoring the global recognition of ammonia's potential to transform maritime fuel systems (Figure B63). This expanding body of literature highlights both the challenges and opportunities associated with ammonia as a marine fuel, positioning it as a key player in the future of sustainable maritime transport.

Major industrialized nations, including the United States, China, Japan and the United Kingdom are leading the way

Figure B63 Origin countries for scientific publications related to ammonia as a marine fuel



Source: WIPO, based on publication data from Scopus, October 2024.

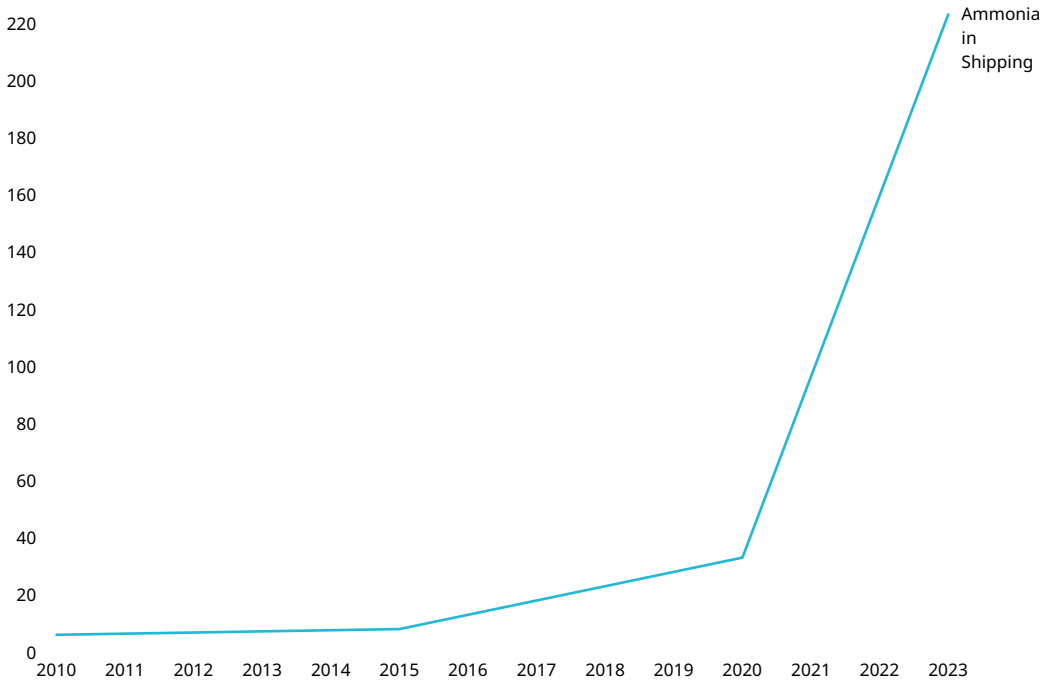
China and the United States are leading contributors, each with close to 225 documents, indicating their strong focus on this emerging technology. The United Kingdom and Japan follow, showing substantial research efforts as well. The Republic of Korea, Germany and Italy are also notable contributors, reflecting a widespread global interest in this technology. The presence of other countries like Canada, India and the Kingdom of the Netherlands, although with fewer publications, underscores the global recognition of ammonia as a marine fuel's potential.

Ammonia as a marine fuel: patent data

Patenting activity in the field of ammonia as a marine fuel has recently picked up speed. From only 33 patent family publications in 2020, the number of patent publications jumped to 223 in 2023 (Figure B64).

Patenting activity in the field of ammonia as a marine fuel has recently accelerated

Figure B64 Development of global patent family publications related to ammonia as a marine fuel, 2010–2023



Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

At the country level, most patent families were published by inventors from the Republic of Korea and China (Figure B65).

The majority of patent families were published by inventors from the Republic of Korea and China

Figure B65 Patent family publications related to ammonia as a marine fuel, 2000–2023

Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

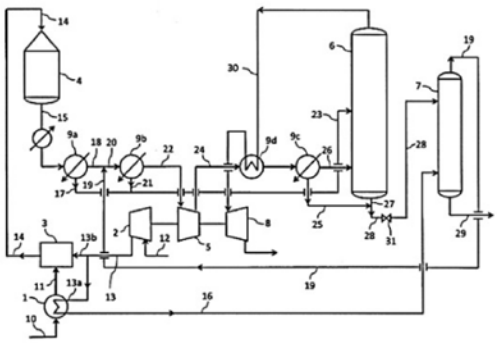
Ammonia as a marine fuel: patent examples

Interest in green ammonia, especially, has increased over the past years. Yara, a global leader in crop nutrition and industrial solutions, is heavily involved in the development and production of green ammonia. The company has made significant investment in green ammonia production, using renewable electricity to produce hydrogen through electrolysis, which is then combined with nitrogen to create green ammonia.

The company's patent EP4211076A1 from 2020 describes a dual pressure plant for the production of nitric acid that integrates advanced components to enhance efficiency and sustainability. The process begins with air being compressed to a low pressure, which is then mixed with ammonia and oxidized to produce a low-pressure mixture of nitrogen oxides (NOx) and steam. This mixture is then compressed to a higher pressure, where it reacts with water in an absorber unit to produce nitric acid and dissolved nitrogen oxides. A high-pressure bleacher unit strips these nitrogen oxides from the nitric acid using an oxygen-rich gas provided by

a high-pressure water electrolyzer. The gas, now loaded with NOx, is recycled back into the system, optimizing efficiency and reducing energy consumption.

The inclusion of a high-pressure water electrolyzer is particularly significant as it generates the oxygen-rich gas used in the stripping process, potentially lowering the energy requirements of the entire plant. Additionally, the plant may include a flash vessel to further enhance gas recovery and recycling, making the overall process more economical and environmentally friendly.

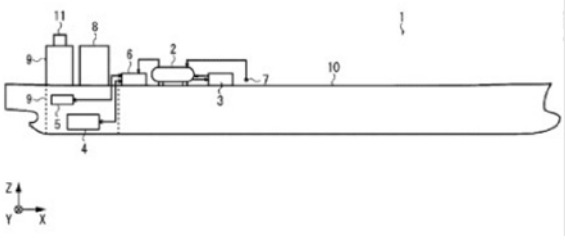


Source: EP4211076A1.

Vessel designs play a vital role in respect to the leakage and toxicity concerns associated with ammonia. Nihon Shipyard Co., Ltd., a prominent Japanese shipbuilding company, is actively involved in the development of ammonia-powered ships as part of its efforts to contribute to the global transition toward greener maritime transport. Nihon Shipyard's patent WO2023210390A1 from 2023 for an ammonia-fueled ship is a significant innovation that addresses the critical safety challenges associated with using ammonia as a marine fuel, particularly its toxicity and corrosiveness. The design features an advanced engine room layout that is divided into several distinct areas, according to the risk of ammonia gas leakage. These areas are separated by specially designed partitions that prevent the spread of ammonia gas, effectively containing any potential leakage within specific zones and minimizing the risk to other parts of the ship.

The partitions can be configured to either completely seal off areas or to only partition the upper spaces, depending on the level of risk and operational requirements. Additionally, in an emergency, these partitions are designed to allow water to pass through, providing a means of controling or neutralizing leakages.

The engine room is thoughtfully divided into specific regions; for example, there is one that houses the generator using ammonia as fuel and another that contains the engine. A key safety feature is the inclusion of a designated area through which ammonia fuel does not pass, thereby further reducing the risk of critical components being exposed to ammonia.



Source: WO2023210390A1.

To further mitigate the risk of ammonia leakage, the patent proposes that areas with a higher likelihood of leakages be maintained at a lower internal pressure compared to those at a lower risk. This pressure differential helps contain any ammonia gas within high-risk zones, preventing it from spreading. Each region is also equipped with an independent ventilation system designed to effectively remove ammonia from the air. Ventilation systems are optimized

with exhaust ports positioned higher than air supply ports, so as to ensure the efficient removal of lighter ammonia gas, complemented by ventilation fans that actively manage air circulation.

This patent plays a crucial role in advancing the use of green ammonia as a marine fuel by addressing the significant safety concerns that have been a barrier to its adoption. By implementing these advanced safety features, Nihon Shipyard is making it feasible to safely operate ammonia-fueled ships, thereby supporting the broader transition to this zero-carbon fuel. As the maritime industry seeks to reduce its carbon footprint, innovations like this patent are essential for making ammonia a viable and safe alternative to traditional fossil fuels, facilitating the industry's shift toward sustainable energy sources.

Appendix: Methodology for patent analysis

Data collection, patent counting

- Simple published patent families are counted as a proxy for individual inventions in the report. A simple patent family is a set of patents in various countries in relation to a single invention. The technical content covered is considered to be identical. All patent documents have the same priority date or combination of priority dates. The first publication by a member of a patent family counts as the publication year.
- Most analysis in the report refers to numbers of patent families. Only published patent families have been studied.
- Patent families generally include only patents and not utility models, without assessing their legal status.
- The origin of the inventor (inventor's location or residence) is used as a proxy for the source of innovations. For patents with multiple inventors, we count the different locations listed and count the location for multiple inventors of the same origin once.

Utility models have been excluded from the patent analysis in this report, because the regional differences and lower inventive threshold for utility models can affect the accuracy and relevance of the analysis.[1] Utility models are not available in every country or region, therefore their inclusion can create inconsistencies in global studies, such as this report, for which comparability across countries and between regions is essential. The requirements for obtaining a utility model are also less stringent than those for a patent and they often cover incremental improvements rather than significant innovations,therefore including them can dilute the focus on more substantial technological advancements.

Patent indicators

Patent application

To obtain a patent, an application must be filed at the appropriate IP office together with all the necessary documents and fees. The IP office will conduct an examination to decide whether to grant or reject the application. Patent applications are generally published 18 months after the earliest priority date of the application. Prior to publication, the application remains confidential.

Patent classification

Patent classification is a system for examiners of IP offices or other people to code documents, such as published patent applications, according to the technical features of their content. The International Patent Classification (IPC) is agreed internationally. The European Patent Office (EPO) and United States Patent and Trademark Office (USPTO) launched a joint project to create the Cooperative Patent Classification (CPC) in order to harmonize the patent classifications systems between the two offices.

1 See, Utility models, available at: www.wipo.int/web/patents/topics/utility_models.

Patent applicant/owner

Patents are filed by an applicant, which can be an organization or a natural person. Applicants are not inventors, even if sometimes they are similar. The applicant is in most jurisdictions and in most cases published with the patent and remains always the applicant. The applicant is not automatically the owner of a patent at a given time, even if that is often the case. Patents can be transferred or sold, or the applicant itself can be sold as a company in a merger or takeover. Therefore the "owner" of a patent might change over time and is not always published. For proper analysis, to consolidate incorrect spelling and to include merger and acquisition information in the analysis, the report used the ultimate owner concept in the IFI Claims global patent database. The most probable entity was then named as owner.

Patent family

A patent family is a collection of patent applications covering the same or similar technical content and all sharing one or more priority documents. Families are used to count inventions and not several patents corresponding to the same subject matter and filed in different jurisdictions. There are several definitions of patent families, including simple and extended patent families, depending on the number of priority documents shared (ranging from one to all priority documents). Patent family members are the individual patents filed in those jurisdictions where a patent applicant is seeking patent protection (e.g., WIPO, EPO) and all publications in relation to these. In the present study, we counted simple patent families (using a representative patent family member for each patent family), unless otherwise specified.

Granted patent

Once examined by the IP office, an application becomes a granted patent or is rejected. If granted, the patent gives his owner a temporary right for a limited time period (normally 20 years) to prevent unauthorized use of the technology outlined in the patent. Procedure for granting patents varies widely between locations according to national laws and international agreements. Note that in the same patent family, an application can be granted in one location and rejected in another.

Inventor country/location

The origin of the inventor (inventor's location or residence) is used as a proxy for the source of innovation. For patents with multiple inventors, we counted the different locations listed and counted the location for multiple inventors of the same origin once. If no inventor address was available, the patent priority country/location was used as a proxy for the source of innovation.

Priority country/location

The first location in which a particular invention has a patent application filed, also known as the office of first filing.

Filing country/location

The filing country/location is the legal jurisdiction in which a member of a patent family filed a patent application to seek patent protection.

PCT (WO)

The Patent Cooperation Treaty (PCT) is an international patent law treaty concluded in 1970, administered by the World Intellectual Property Organization (WIPO), between more than 140 Paris Convention locations. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of locations by filing a single "international" patent application instead of filing several separate national or regional patent applications. The granting of patents remains under the control of the national or regional patent offices, which is referred to as the "national phase."

European patent (EP)

A European patent can be obtained for all the European Patent Convention (EPC) locations by filing a single application at the European Patent Office (EPO). European patents granted by the EPO have the same legal rights and are subject to the same conditions as national patents (granted by the national patent office). A granted European patent is a "bundle" of national patents, which must be validated at the national patent office to be effective in member locations. The validation process could include submission of a translation of the specification, payment of fees and other formalities at the national patent office. Once a European patent is granted, competence is transferred to the national patent offices. Other regional patents or procedures also exist: the Eurasian patent (EA), ARIPO patent (AP) for English-speaking Africa and OAPI patent (OA) for French-speaking Africa.

Relative Specialization Index

The Relative Specialization Index (RSI) compares the published patenting activity in two or more locations within the same technology area. RSI is a measure of a location's share of patent families in a particular field of technology as a fraction of that location's share of patent families in all fields of technology. It accounts for the fact that some locations file more patent applications than others in all fields of technology.

In other words, RSI has the advantage of providing a comparison of two locations' patenting activity in a technology relative to those locations' overall patenting activity. The effect of this is to highlight locations which have a greater specialism of the technology area studied than expected from their overall level of patenting, and which might otherwise appear further down in the top inventor location lists, often unnoticed. A positive RSI value indicates that a location has a higher specialization in this field than would be expected, whilst a negative value indicates a lower specialization than expected for that location.

The Relative Specialization Index (RSI) is calculated as follows:

$$RSI = \frac{X - 1}{X + 1}$$

where X is given by,

$$X_{c,t} = \frac{n_{c,t}/N_c}{N_t/N}$$

and

$n_{c,t}$ is the number of published patent families in country c for technology t,

$N_c = \sum_t n_{c,t}$ is the number of published patent families in country c in all technologies,

$N_t = \sum_c n_{c,t}$ is the number of published patent families in technology t in all countries, and

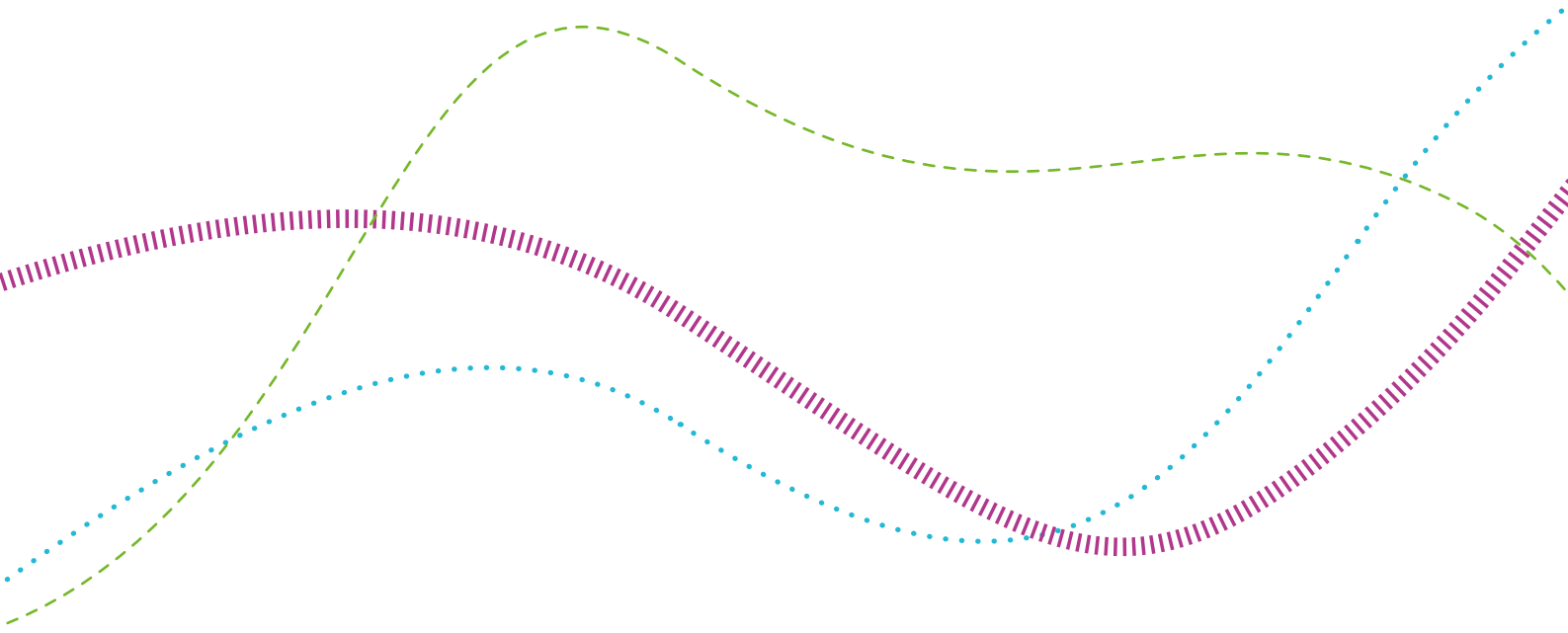
$N = \sum_c \sum_t n_{c,t}$ is the number of published patent families in all technologies and all countries.

Patent searches

Full details of the patent search strategies used to define the technology areas analyzed in this report can be accessed and downloaded from the WIPO Technology Trends webpages. [2]

2 See, WIPO technology trends, available at: www.wipo.int/web/technology-trends.

This technical annex to the *WIPO Technology Trends* Report on the Future of Transportation delves into the dynamic and evolving field of sea transportation, offering a detailed analysis of global patenting trends within the maritime industry.



WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

wipo.int