WIPO Technology Trends
Technical Annex

Future of Transportation on Land

WIPO

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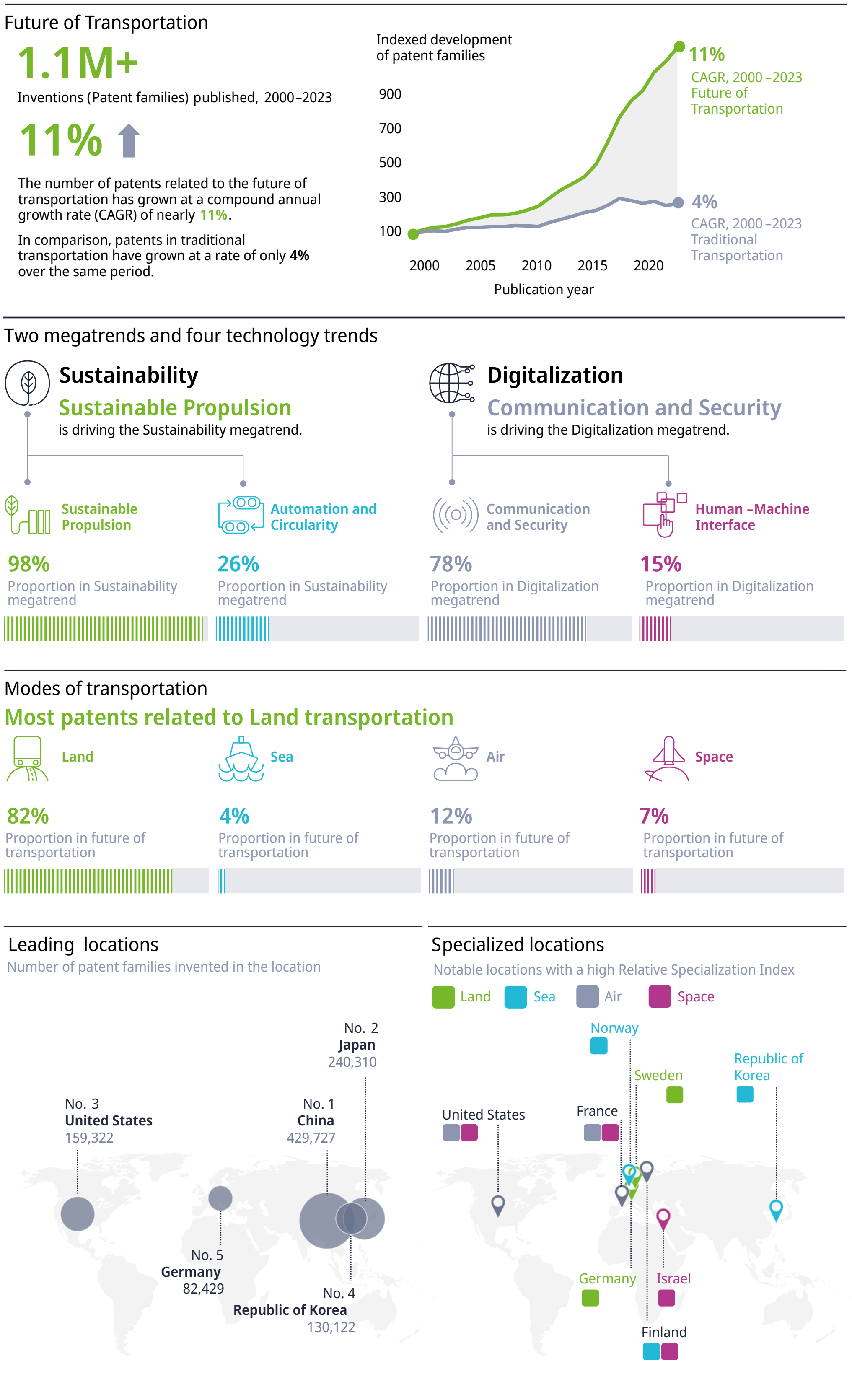
Introduction to land transportation

This technical annex to the WIPO Technology Trends Report on the Future of Transportation provides an in-depth examination of the technological landscape within the domain of land transportation. It is a deep dive analysis of global patenting trends in land transportation affording comprehensive insights into those innovations shaping the future of road and rail transport systems. Full details on the research methodology and different patent indicators used can be found in the Appendix to the report.

By exploring patent data, this annex identifies emerging technologies, key players and evolving trends impacting the development and enhancement of infrastructure, vehicle advancements, smart systems and sustainable transport solutions. The analysis extends to the interconnections between these technologies, assessing their potential to revolutionize mobility, improve efficiency and drive economic and environmental sustainability across the transportation sector.

This annex serves as a valuable resource for those stakeholders – including policymakers, industry leaders, researchers and innovators – seeking to understand the trajectory of technological advancements and their implications for the future of land transportation.

Figure A1 Exploring the main findings of the WIPO Technology Trends report on the Future of Transportation



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

Overview of land transportation

Land transportation involves the movement of people, goods, and animals across the Earth's surface, primarily using road and rail networks. It encompasses various vehicles, including cars, buses, trucks and trains, and relies on infrastructure such as highways, urban roads, and railway tracks. This mode of transportation has evolved from early human and animal-powered methods to modern, technologically advanced systems, playing a crucial role in facilitating daily commutes, logistics and economic activities globally. [1]

Land transportation is indispensable for the overall transportation system due to its accessibility and integration with other modalities. Unlike air and sea transport, which require specific infrastructure like airports and seaports, land transport infrastructure is more widespread and integrated into daily life. This makes it crucial for providing last-mile connectivity, which is essential for both urban and rural areas. [2] Thus, land transport often acts as a feeder to other modes of transportation according to the International Transport Forum. [3] For instance, goods transported by sea are typically moved to their final destination by trucks or trains. Similarly, passengers traveling by air or sea rely on land transportation for the first and last legs of their journey.

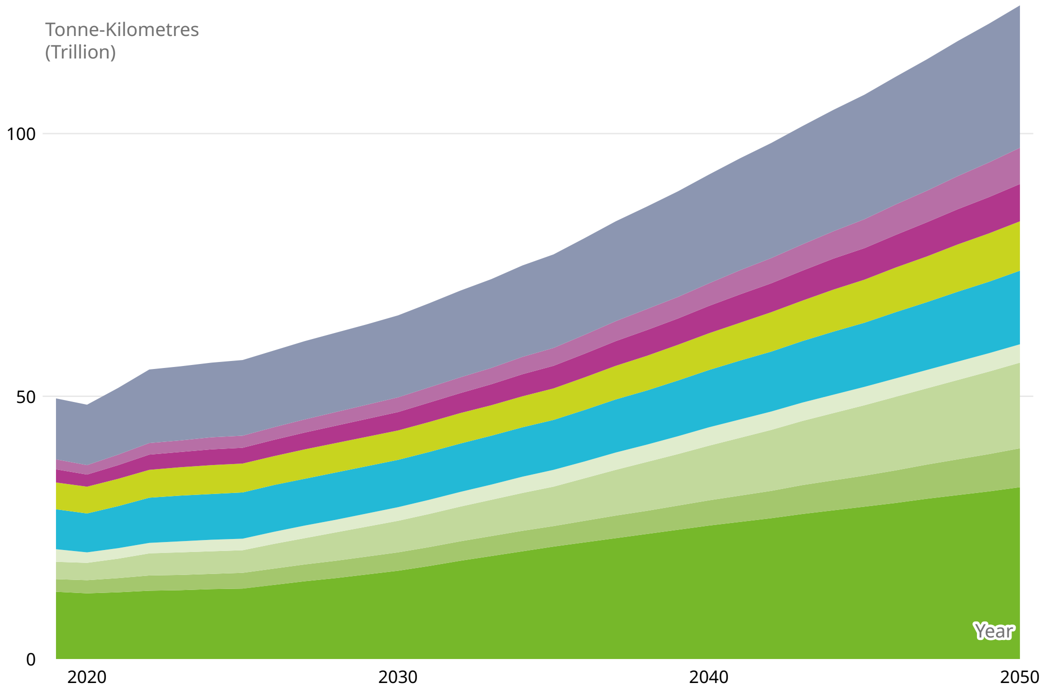
Land transportation plays a crucial role in global trade and passenger mobility, influencing both economic development and environmental sustainability. Freight activity is expected to grow significantly, with worldwide ton-kilometers projected to nearly double between 2019 and 2050 under the International Transport Forum's (ITF) Current Ambition scenario. [4] This highlights an increasing demand for freight transport, driven by economic growth, particularly in emerging regions. Southeast Asia (SEA) and Sub-Saharan Africa (SSA) will see freight demand more than triple, and South and Southwest Asia (SSWA) will experience nearly a five-fold growth. [5]

Freight transport's share of CO_2 emissions is significant and expected to increase under current policies. In 2019, freight transport accounted for 46% of transport emissions. By 2050, under the Current Ambition scenario, freight emissions will constitute 61% of transport emissions, surpassing passenger transport emissions (Figure A2). Even under the ITF's High Ambition scenario, where total emissions are reduced to 20% of 2019 levels, freight emissions will still account for a larger share than does passenger emissions. [6]

1 Encyclopedia Britannica (2024). Transportation: Technology. Available at: www.britannica.com/technology/transportation-technology.
2 Park, J. S., Y. J. Seo, and M. H. Ha (2019). The role of maritime, land, and air transportation in economic growth: Panel evidence from OECD and non-OECD countries. Research in Transportation Economics, 78, 100765.
3 ITF (2023). Key transport statistics 2023 (2022 data). International Transport Forum. Available at: www.itf-oecd.org/key-transport-statistics-2023-2022-data.
4 The Current Ambition Scenario is a forecasting model or analytical framework based on existing policies, plans, and commitments, assuming no new major measures or targets are introduced. In contrast, the High Ambition Scenario assumes the introduction of stricter and more ambitious policies and actions to achieve outcomes far beyond current targets.
5 ITF Transport Outlook (2023). Regional, rural and urban development. Organisation for Economic Co-operation and Development. Available at: www.oecd.org/en/publications/itf-transport-outlook-2023_b6cc9ad5-en.html.
6 ITF Transport Outlook (2023). Regional, rural and urban development. Organisation for Economic Co-operation and Development. Available at: www.oecd.org/en/publications/itf-transport-outlook-2023_b6cc9ad5-en.html.

By 2050, freight emissions are expected to account for 61%under the Current Ambition scenario.

Figure A2 Freight activity forecast by region, 2019–2050



East and Northeast Asia · Southeast Asia · South and Southwest Asia · Transition economies and other Asia-Pacific countries · Europe · Latin America and the Caribbean · Middle East and North Africa · Sub-Saharan Africa · United States, Canada, Australia and New Zealand

Note: Figure depicts ITF modelled estimates Figure depicts ITF modeled estimates forecast under the Current Ambition (CA) scenario. Current Ambition (CA) refers to one of the two policy scenarios modelled, which represent two levels of ambition for decarbonising transport.

Source: ITF Transport Outlook 2023.

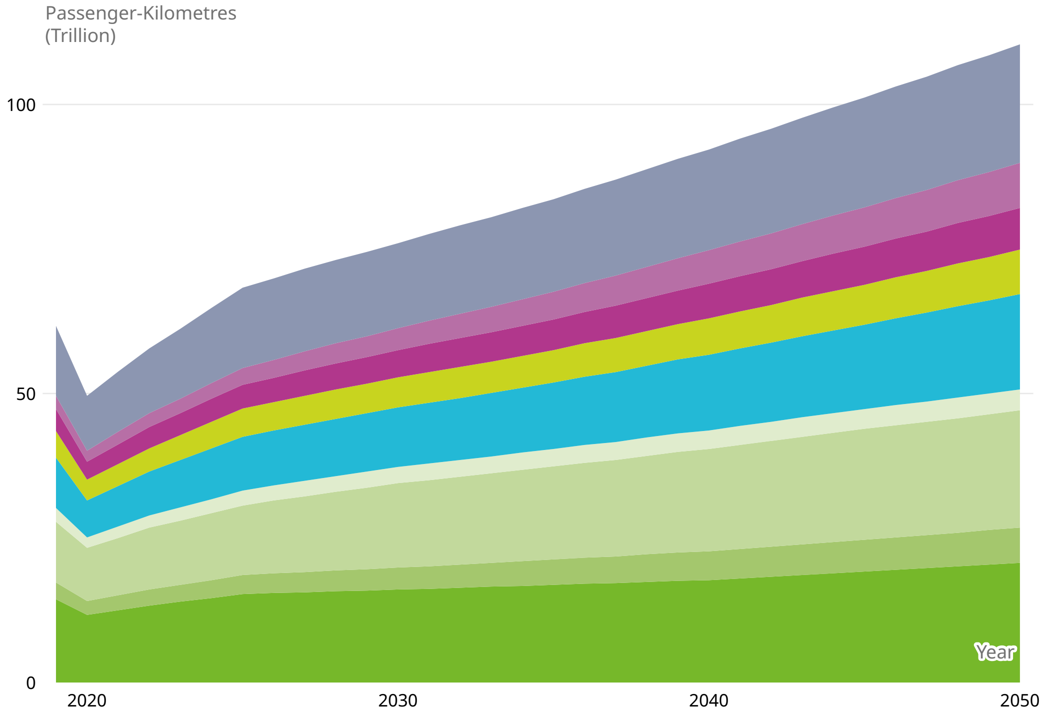
On the other side, passenger transport demand is set to grow significantly by 2050. Under the Current Ambition scenario, global passenger-kilometers are projected to increase from around 61 trillion in 2019 to about 110 trillion in 2050, a growth of approximately 79% (Figure A3). Even under the High Ambition scenario, which includes more stringent decarbonization measures, passenger-kilometers are expected to reach approximately 102 trillion by 2050, indicating a 65% increase from 2019 levels. [7]

Despite a growth in demand, CO_2 emissions from passenger transport are projected to decrease, especially under the High Ambition scenario. By 2050, passenger transport emissions are expected to fall by 30% under the Current Ambition scenario. Under the High Ambition scenario, the reduction is even more significant, with emissions falling by 1,190 trillion tons of CO_2 from 2019 levels, compared to a reduction of only 379 trillion tons of CO_2 under the Current Ambition scenario. [8]

7 ITF Transport Outlook (2023). Regional, rural and urban development. Organisation for Economic Co-operation and Development. Available at: www.oecd.org/en/publications/itf-transport-outlook-2023_b6cc9ad5-en.html.
8 ITF Transport Outlook (2023). Regional, rural and urban development. Organisation for Economic Co-operation and Development. Available at: www.oecd.org/en/publications/itf-transport-outlook-2023_b6cc9ad5-en.html.

Under the Current Ambition scenario, global passenger-kilometers are projected to rise from about 61 trillion in 2019 to 110 trillion in 2050, a growth of roughly 79%.

Figure A3 Passenger transport demand by region under the Current Ambition scenario, 2019-2050



Note: Figure depicts ITF modeled estimates forecast under the Current Ambition (CA) scenario. Current Ambition (CA) refers to one of the two policy scenarios modelled, which represent two levels of ambition for decarbonising transport.
Source: ITF Transport Outlook 2023.

Efforts to decarbonize the transport sector are critical for reducing emissions and achieving sustainable mobility. This includes adopting Sustainable propulsion, improving infrastructure and implementing policies that encourage the use of cleaner transport modes. Together, these measures will help create a more sustainable and efficient transportation system, capable of meeting future demands while minimizing environmental impacts, according to BCG [9] and the International Energy Agency (IEA). [10]

Sustainability and Digitalization are both megatrends that play a vital role in transforming the future of land transport. The focus on sustainability drives innovation toward reducing CO_2 emissions and promoting greener practices. Meanwhile, digitalization enhances operational efficiency through advancements in technology and data analytics, making transportation systems smarter and more adaptive to future challenges. According to the IEA, the transport sector accounts for nearly one-quarter of global energy-related CO_2 emissions. Specifically, road travel, which includes both passenger vehicles and freight trucks, is responsible for approximately 75% of transport emissions. [11]

9 BCG (2024). Accelerating the shift to sustainable transport. Boston Consulting Group. Available at: www.bcg.com/publications/2024/accelerating-the-shift-to-sustainable-transport.
10 IEA (2023). Transport. International Energy Agency. Available at: www.iea.org/energy-system/transport.
11 IEA (2023). CO_2 emissions in 2022. International Energy Agency. Available at: www.iea.org/reports/co2-emissions-in-2022.

The International Transport Forum (ITF) has highlighted the need for ambitious policies to achieve significant reductions in transport emissions, projecting that CO_2 emissions from freight could be cut by 72% and from urban passenger transport by as much as 80% by 2050 with the right measures in place. [12] The International Council on Clean Transportation (ICCT) also emphasizes the potential of accelerating the transition to zero-emission vehicles (ZEVs) and implementing efficiency technologies for both light- and heavy-duty vehicles to achieve significant emission reductions. [13] These commitments reflect a concerted effort by global organizations to address the climate impact of the transportation sector.

Digitalization is revolutionizing the land transport sector by driving significant advancements in efficiency, safety and customer experience. A key driver is the substantial increase in investment in technology, particularly post the COVID-19 pandemic, as companies allocate more resources to digital and tech initiatives. This surge in spending, which has seen tech investments rise by over 10% of market capitalization, underscores the strategic importance of digital transformation in maintaining a competitive edge [14] Digital tools and technologies are streamlining operations, reducing costs and improving service delivery. For instance, operational cost reductions of up to 20% have been reported, showcasing the tangible benefits of adopting digital solutions. [15] Additionally, smart logistics solutions optimize supply chains, reducing waste and improving logistical efficiency by 40%. [16]

Sustainable Propulsion technologies are transforming both passenger and freight transportation:

- **Battery electric vehicles** (BEVs) are a cornerstone of Sustainable Propulsion, offering zero tailpipe emissions and significantly lower operating costs compared to internal combustion engines. The IEA's Global EV Outlook 2024 highlights that the adoption of BEVs is accelerating globally, driven by advancements in battery technology that improve range and reduce charging times. For passenger transport, this includes a wide array of electric cars and buses, while in the freight sector, electric trucks are becoming viable for urban deliveries and regional transport, thanks to their high efficiency and low maintenance costs . [17]
- **Hydrogen fuel cell vehicles** (FCEVs) represent a promising solution for both passenger and freight transport, particularly for long distances and heavy-duty applications. FCEVs generate electricity through a chemical reaction between hydrogen and oxygen, emitting only water vapor. The U.S. National Blueprint for Transportation Decarbonization emphasizes that hydrogen fuel cells are ideal for applications requiring quick refueling and long ranges, such as long-haul trucks and buses. [18] This technology is crucial for reducing emissions within sectors where battery electric vehicles might not be practical, because of weight or range limitations. [19]
- **E-fuels**, or synthetic fuels, are produced by combining hydrogen (generated through renewable energy sources) with captured carbon dioxide. These fuels can be used in existing internal combustion engines with minimal modifications, offering a pathway to reduce emissions from the current vehicle fleet. According to the IEA, e-fuels are particularly important for decarbonizing hard-to-electrify sectors such as aviation, maritime shipping and long-haul trucking. E-fuels provide a drop-in solution for reducing greenhouse gas emissions without requiring extensive new infrastructure. [20]

12 ITF Transportation Outlook (2023). Regional, rural and urban development. Organisation for Economic Co-operation and Development. Available at: www.oecd.org/en/publications/itf-transport-outlook-2023_b6cc9ad5-en.html.
13 ICCT (2023). Vision 2050: Strategies to align global road transport with well below 2°C. The International Council on Clean Transportation. Available at: https://theicct.org/publication/vision-2050-strategies-to-reduce-gap-for-global-road-transport-nov23.
14 BCG (2022). What the data tells us about digital transformation, by industry. Boston Consulting Group. Available at: www.bcg.com/publications/2022/digital-transformation-efforts-report.
15 McKinsey (2021). The new digital edge: Rethinking strategy for the postpandemic era. McKinsey Digital. Available at: www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-new-digital-edge-rethinking-strategy-for-the-postpandemic-era.
16 Deloitte (2022). Transportation Trends 2022. Deloitte Development LLC. Available at: www2.deloitte.com/us/en/pages/public-sector/solutions/mobility-and-transportation.html.
17 IEA (2024). Global EV Outlook 2024: Moving Towards Increased Affordability. International Energy Agency. Available at: www.iea.org/reports/global-ev-outlook-2024.
18 DOE (2022). The U.S. National Blueprint for Transportation Decarbonization: A Joint Strategy to Transform Transportation. United States Department of Energy (DOE). Available at: www.energy.gov/eere/us-national-blueprint-transportation-decarbonization-joint-strategy-transform-transportation.
19 IEA (2023). World Energy Outlook 2023. International Energy Agency. Available at: www.iea.org/reports/world-energy-outlook-2023.
20 IEA (2023). The Role of E-fuels in Decarbonising Transport. International Energy Agency. Available at: www.iea.org/reports/the-role-of-e-fuels-in-decarbonising-transport.

Automation and Circularity technologies are reshaping land transportation by promoting efficient material use, smart production and enhanced recycling practices.[21] [22]

- **Efficient material use** is a key component of the circular economy, aiming to minimize waste and maximize resource efficiency. National strategies focusing on reducing material use, redesigning products for longevity and promoting sustainable practices across industries.[23] [24] [25] Efficient material use involves adopting lightweight materials, utilizing advanced manufacturing techniques to reduce material waste and designing products for disassembly and recycling. These practices ensure that materials are used optimally throughout the product lifecycle, reducing environmental impact and conserving resources.
- **Smart production and robotics** are transforming manufacturing processes by enhancing efficiency, precision and flexibility. Advances in Industry 4.0 technologies, such as the internet of things (IoT), machine learning and cyber-physical systems, are enabling autonomous production lines that can adapt to real-time data and optimize operations.[26] [27] Thus, smart production systems can significantly reduce waste, improve product quality and enable predictive maintenance, thereby extending the lifespan of machinery and equipment. Robotics play a crucial role in automating repetitive tasks, improving accuracy and reducing human error, all of which contribute to more sustainable manufacturing processes.
- **Recycling** is a fundamental aspect of the circular economy, aiming to recover valuable materials from end-of-life products and reintroduce them into the production cycle. The World Economic Forum emphasizes the importance of intelligent automation in enhancing recycling processes such as sorting and processing recyclables more efficiently.[28] Innovative technologies like AI and robotics are being used to improve the accuracy and efficiency of recycling operations, ensuring that more materials are recovered and reused. Additionally, national strategies and regulations are increasingly supporting the development of recycling infrastructure and promoting the use of recycled materials in new products.[29] [30] [31]

Communication and Security technologies paving the way for a new era in land transportation:

- **Advanced navigation systems** are becoming increasingly essential for both passenger and freight transport. These systems leverage GPS technology, real-time traffic data and advanced routing algorithms to optimize travel routes, reduce travel times and improve fuel efficiency. Consulting reports from McKinsey emphasize that the integration of AI into navigation systems is transforming route planning by predicting traffic patterns and suggesting alternative routes in real-time, thereby enhancing the overall efficiency of transport operations.[32]
- **Sensor** technologies play a critical role in enhancing the safety and efficiency of land transportation. Sensors are used for a variety of applications, including vehicle diagnostics, collision avoidance and autonomous driving. Bain's 2023 Technology Report highlights the rapid advancements in LIDAR, radar and camera systems that are crucial for developing

21 EPA (2022). Building a Circular Economy for All: Progress Towards Transformative Change. Environmental Protection Agency. Available at: www.epa.gov/system/files/documents/2022-09/EPA_Circular_Economy_Progress_Report_Sept_2022.pdf.
22 WEF (2021). How intelligent automation can power sustainable economies. World Economic Forum. Available at: www.weforum.org/agenda/2021/09/how-intelligent-automation-can-power-sustainable-economies.
23 EPA (2022). Building a Circular Economy for All: Progress Towards Transformative Change. Environmental Protection Agency. Available at: www.epa.gov/system/files/documents/2022-09/EPA_Circular_Economy_Progress_Report_Sept_2022.pdf.
24 European Commission (2022). Circular economy action plan. Available at: https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en.
25 EllenMacArthur Foundation (2024). The Circular Economy Opportunity for Urban and Industrial Innovation in China. Available at: www.ellenmacarthurfoundation.org/urban-and-industrial-innovation-in-china.
26 Fragapane, G., D. Ivanov, M. Peron, F. Sgarbossa and J. O. Strandhagen, (2022). Increasing flexibility and productivity in Industry 4.0 production networks with autonomous mobile robots and smart intralogistics. Annals of operations research, 308(1), 125–143.
27 Bain (2024). Artificial intelligence rockets to the top of the manufacturing priority list. Bain & Company. Available at: www.bain.com/insights/artificial-intelligence-rockets-to-the-top-of-the-manufacturing-priority-list-global-machinery-and-equipment-report-2024.
28 WEF (2021). How intelligent automation can power sustainable economies. World Economic Forum. Available at: www.weforum.org/agenda/2021/09/how-intelligent-automation-can-power-sustainable-economies.
29 EPA (2022). National Recycling Strategy. Environmental Protection Agency. Available at: www.epa.gov/circulareconomy/national-recycling-strategy.
30 European Commission (2020). A New Circular Economy Action Plan for a Cleaner and More Competitive Europe. COM(2020) 98 final. Brussels: European Commission. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386anduri=COM:2020:98:FIN.
31 National Development and Reform Commission (2021). The National Development and Reform Commission on the Issuance Notice of the "14th Five-Year Plan" for the Development of Circular Economy. Development and Reform Environment [2021] No. 969. Available at: www.ndrc.gov.cn/xwdt/tzgg/202107/t20210707_1285530.html.
32 McKinsey (2023). McKinsey Technology Trends Outlook 2024. McKinsey Digital. Available at: www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-top-trends-in-tech.

reliable autonomous vehicles.[33] These sensors provide real-time data that help vehicles detect and respond to obstacles, pedestrians and other vehicles, significantly reducing the risk of accidents and improving operational efficiency.

- The adoption of **cloud computing** and **low-latency internet** is revolutionizing how data are managed and utilized in land transportation. Cloud platforms enable the collection, storage and analysis of vast amounts of data from connected vehicles and infrastructure. According to BCG, low-latency internet, particularly through 5G networks, facilitates real-time communication between vehicles and traffic management systems.[34] This connectivity is essential for applications like remote diagnostics, fleet management and autonomous vehicle operations, ensuring that data are processed quickly and actions taken promptly to enhance safety and efficiency.
- As land transportation becomes more digitalized, **cybersecurity** has become of paramount concern. Protecting transportation networks from cyber threats is essential to ensuring the safety and reliability of both passenger and freight transport. McKinsey's analysis points out that the rise in digital technologies has made transportation systems more vulnerable to cyberattacks, emphasizing the need for robust cybersecurity measures.[35] Such measures include encryption, secure communication protocols and continuous monitoring to detect and mitigate potential threats. Additionally, companies are increasingly investing in cybersecurity training and awareness programs to protect against human error.[36]

Advanced **Human–Machine Interfaces (HMI)** technologies are driving the evolution of land transportation by making interactions more intuitive, secure, and responsive, thereby improving operational efficiency and user experience.

- **Extended Reality (XR)** technologies, including virtual reality (VR), augmented reality (AR) and mixed reality (MR), are significantly enhancing HMIs by providing immersive and interactive experiences. These technologies are particularly beneficial in automotive and freight sectors for training, maintenance and navigation, offering real-time data overlays and interactive simulations to improve operational efficiency and decision-making. XR applications help create detailed virtual environments that provide users with information-rich and contextually-detailed interactions.[37]
- **Speech recognition** technology is transforming HMIs by enabling hands-free control and communication with vehicles and machines. This technology allows for more natural and efficient interactions, by interpreting and responding to verbal commands.[38] In the automotive sector, companies like Mercedes-Benz and BMW integrate advanced speech recognition systems into their vehicles so as to enhance user experience and safety, enabling drivers to control navigation, climate and infotainment systems through voice commands.[39]
- **Facial recognition** technology enhances security and personalization by identifying and verifying individuals based on their facial features. This technology is used in vehicles for driver authentication, ensuring that only authorized users can start the vehicle, and for monitoring driver attentiveness, thereby improving safety. Companies such as Continental are incorporating facial recognition systems in order to bolster vehicle security and enhance driver monitoring capabilities.[40]
- **Touch displays and data gloves** represent significant advancements in tactile HMIs. Touch displays are widely used in vehicle infotainment systems, providing intuitive and direct interaction with digital interfaces. Data gloves equipped with sensors allow users to control machines through gestures, offering precise control in virtual environments and robotic

33 Bain (2023). Technology Report 2024: Technology Meets the Moment as AI Delivers Results. Bain & Company. Available at: www.bain.com/insights/topics/technology-report.
34 BCG (2023). Accelerating the 5G economy in the US. Boston Consulting Group. Available at: www.bcg.com/publications/2023/accelerating-the-5g-economy-in-the-us.
35 McKinsey (2023). McKinsey Technology Trends Outlook 2024. McKinsey Digital. Available at: www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-top-trends-in-tech.
36 UNECE (2020). UN Regulations on Cybersecurity and Software Updates to pave the way for mass roll out of connected vehicles. United Nations Economic Commission for Europe. Available at: https://unece.org/sustainable-development/press/un-regulations-cybersecurity-and-software-updates-pave-way-mass-roll.
37 MIT Technology Review (2023). The inevitable EV: 10 breakthrough technologies 2023. Available at: www.technologyreview.com/2023/01/09/1064889/the-inevitable-ev-10-breakthrough-technologies-2023.
38 Harvard Business Review (2019). Using voice interfaces to make products more inclusive. Available at: https://hbr.org/2019/05/using-voice-interfaces-to-make-products-more-inclusive.
39 The Verge (2024). Mercedes-Benz’s best-in-class voice assistant is getting an AI boost. Available at: www.theverge.com/2024/1/9/24028012/mercedes-benz-mbux-voice-assistant-ai-llm-mbos-ces.
40 Continental AG (2023). World first: Continental integrates face authentication invisibly behind driver display console. Available at: www.continental.com/en/press/press-releases/20240110-face-authentication-display.

systems. These technologies are particularly useful for enhancing user interaction in modern vehicles and complex industrial applications. [41]

To further understand the technological advancements driving these innovations, the next chapter will dive into the patent data for these technologies, highlighting key developments and trends in the field. This analysis will provide insights into the proprietary innovations shaping the future of land transportation.

41 Tashakori, A., Z. Jiang, A. Servati et al. (2024). Capturing complex hand movements and object interactions using machine learning-powered stretchable smart textile gloves. Nature Machine Intelligence, 6, 106–118. DOI: https://doi.org/10.1038/s42256-023-00780-9.

Global patent trends

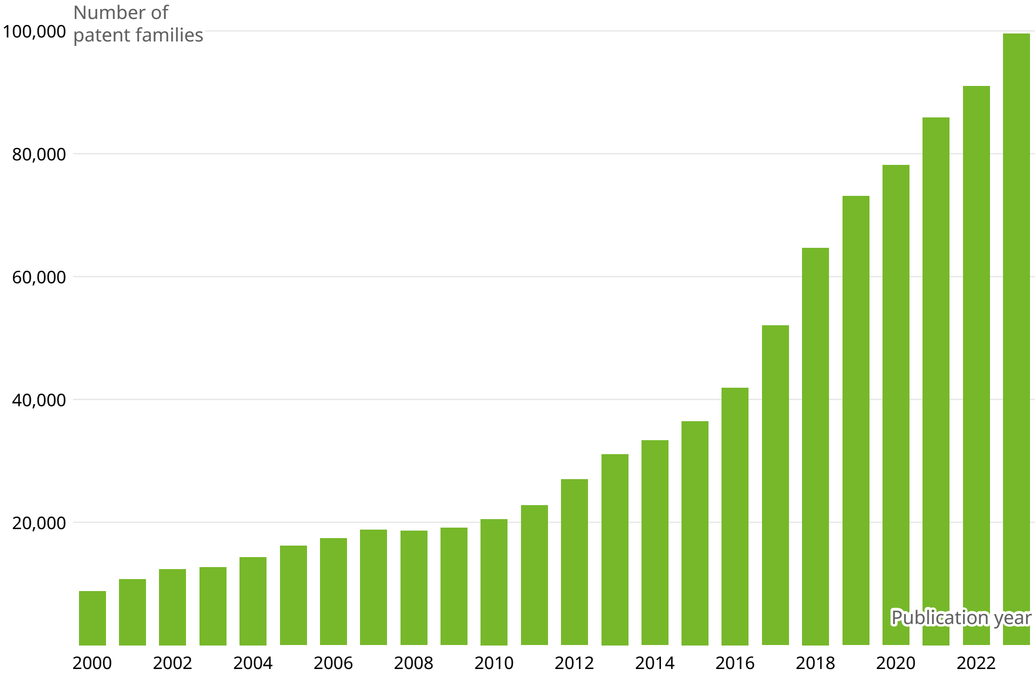
Global patent development

In order to give an overview of the key technological trends that will define the future of land transport, we have collected all patent families that were assigned to both land transport technologies (cars, trucks, trains, busses etc.) and to any of the four key technology trends (Sustainable Propulsion / efficient ship design, Communication and Security, Automation and Circularity, and Human-Machine Interface).

The significant advances in land transport technologies are evident through the sharp increase in patent activity. Since the start of the millennium, the number of patent family publications per year has risen from approximately 8,800 in 2000 to more than 99,500 in 2023 (Figure A4). Consequently, land transport represents by far the largest segment in terms of patent numbers among the four transport modalities.

Since 2000, the number of patent family publications per year has increased from around 8,800 to over 99,500 in 2023.

Figure A4 Development of global patent family publications, 2000-2023



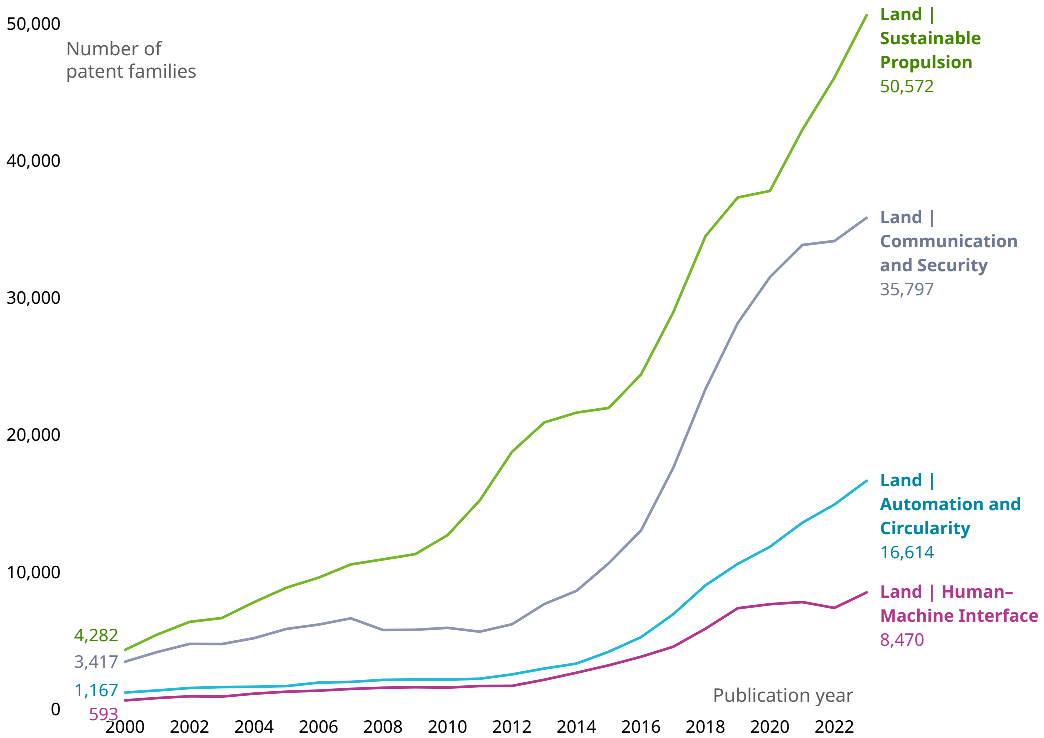
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Overview of the four technology trends

In terms of the four technology trends, the majority of research activity in the field of land transport is focused on Sustainable Propulsion and Communication and Security technologies. In both of these technology trends, the number of published patent families has increased significantly to more than 50,500 in the field of Sustainable Propulsion, and around 35,800 in 2023 in Communication and Security technologies (Figure A5). Another key research area is Automation and Circularity. In this field, the number of annual patent family publications has increased from 1,200 to more than 16,600 since 2000. Research activity in Human–Machine Interface (HMI) technologies increased strongly between 2013 and 2019, plateaued between 2020 and 2022, and has recently picked up speed again, with patent family publications of almost 8,500 in 2023.

In land transport, the majority of research activity is focused on Sustainable Propulsion and Communication and Security technologies.

Figure A5 Development of patent family publications in the four technology trends, 2000-2023



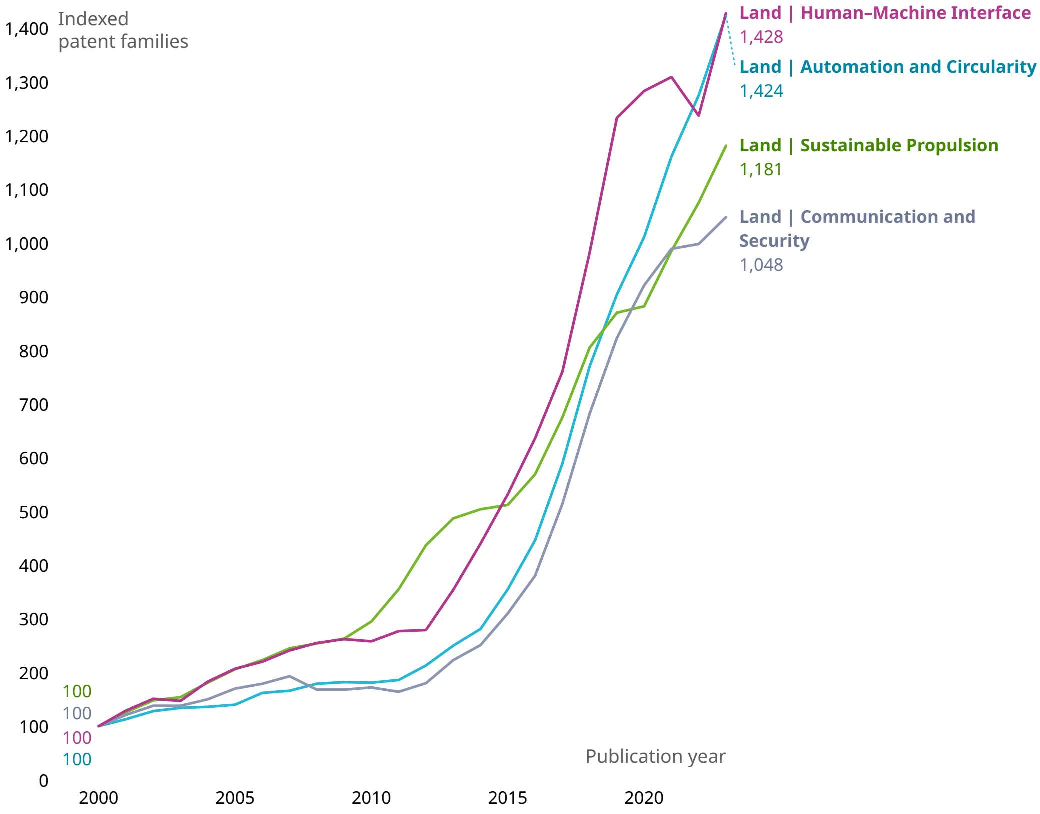
Note: Some patent families are classified in more than one technology trend, therefore the sum of the four technology trends is larger than the total amount of patent family publications.

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

Patent growth has been very dynamic and almost identical in all four technology trends (Figure A6). Between 2000 and 2023, the number of patent families published increased at a compound annual growth rate of around 12% in HMI and Automation and Circularity technologies and around 11% in the fields of Sustainable Propulsion and Communication and Security.

Between 2000 and 2023, patent families in HMI and Automation and Circularity technologies grew at a compound annual rate of around 12%.

Figure A6 Indexed development of patent family publications in the four technology trends, 2000-2023



Note: Indexed development is based on all patent families in the year 2000 being normalized to 100.
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Patent Coverage

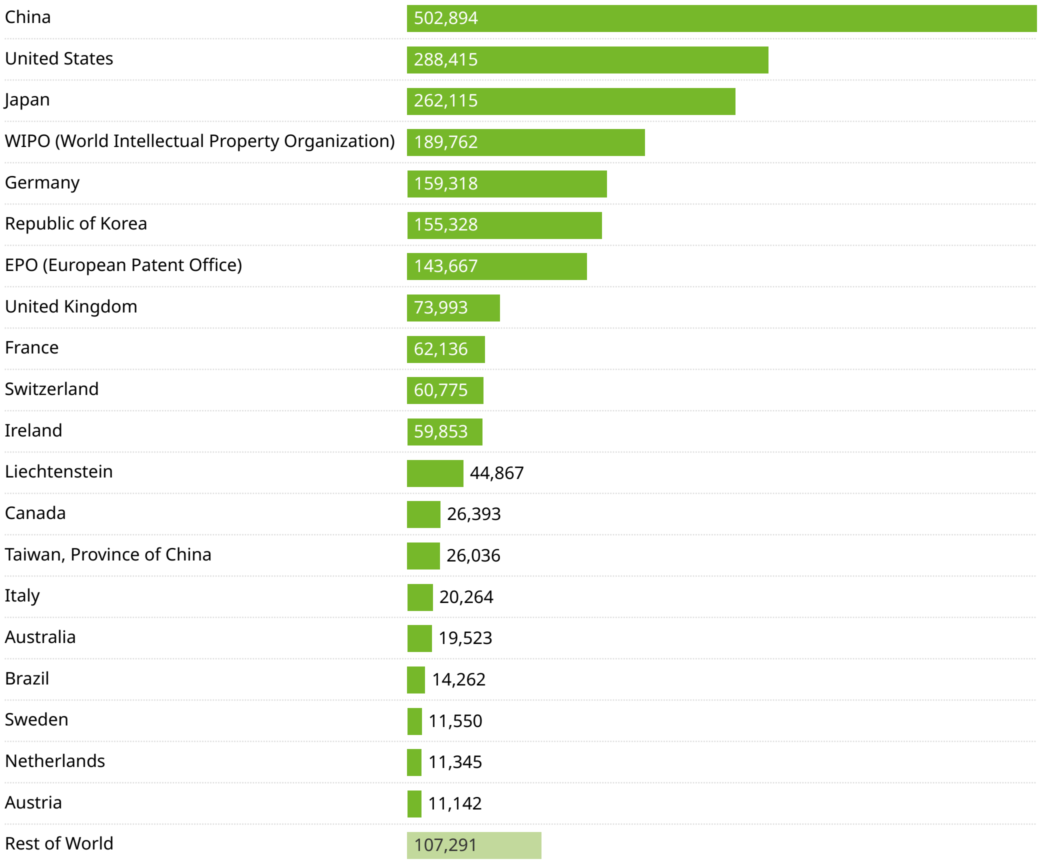
An analysis based on filing authorities of patent families in land transport technologies provides an overview of global filing strategies. Members of patent families can be filed directly in one or more countries, via national patent offices, the Patent Cooperation Treaty (PCT) route administered by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

Figure A7 below shows that China is the top country in terms of patent filings. Between 2000 and 2023, more than 500,000 patent families in land transport technologies were filed in China for seeking patent protection. Japan, the United States and Germany have also attracted many patent filings since 2000.

It is also worth noting that the PCT and the European Patent Convention (EP) are relevant routes for inventors to seek patent protection. Since 2000, there have been almost 190,000 patent filings under the PCT administered by WIPO and more than 143,000 patent filings under the European Patent Convention administered by the EPO.

China leads in patent filings, with over 500,000 patent families in land transport technologies filed between 2000 and 2023.

Figure A7 Total patent publications by different filing authority, 2000–2023



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

Top inventor locations

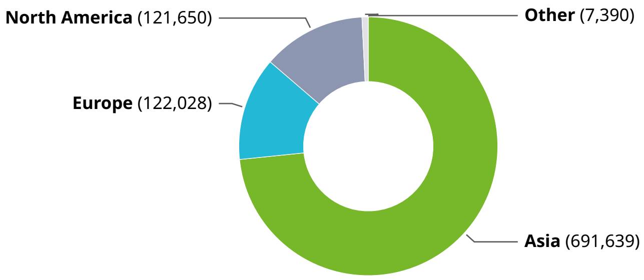
Regional breakdown

The majority of research activity associated with the four technological trends identified as shaping the future of land transportation is concentrated in Asia. Between 2000 and 2023, there have been more than 690,000 patent family publications originating from inventors based in Asia (Figure A8). Europe and Northern America, both with more than 120,000 patent family publications, are other notable research hubs.

The number of patent families originating from other regions, namely Oceania, the Latin America and Caribbean (LAC) countries and the Africa, remains relatively low.

Over 690,000 patent family publications have originated from inventors based in Asia.

Figure A8 Regional breakdown in Land transportation: total patent family publications, 2000–2023



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

Top inventor locations

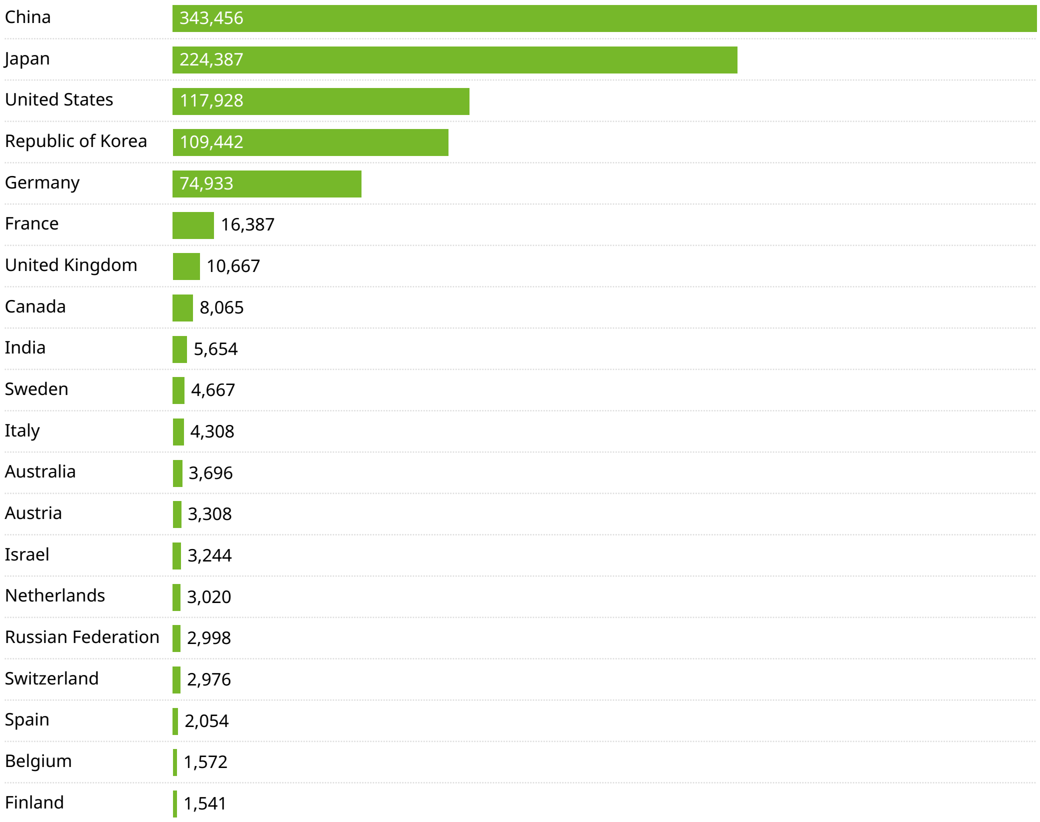
At the national level, China and Japan have led global efforts in the research and development of land transport technology. Between the year 2000 and 2023, inventors in China published a total of over 340,000 patent families, while inventors in Japan published almost 225,000 (Figure A9). Consequently, these two countries collectively account for more than 60% of the global total of patent families.

With a total of approximately 117,928 patent family publications between 2000 and 2023, the United States is the third most significant research location, followed by the Republic of Korea in fourth place, with 109,000 patent family publications. Germany is fifth globally, with almost 75,000 patent families published during the same period.

The remaining countries in the top 20 list of inventor locations have published a markedly lower number of patent families since 2000.

China and Japan together account for over 60% of the global total of patent families.

Figure A9 Top inventor locations in Land transportation: total patent family publications, 2000–2023



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

Development and patent growth since 2000

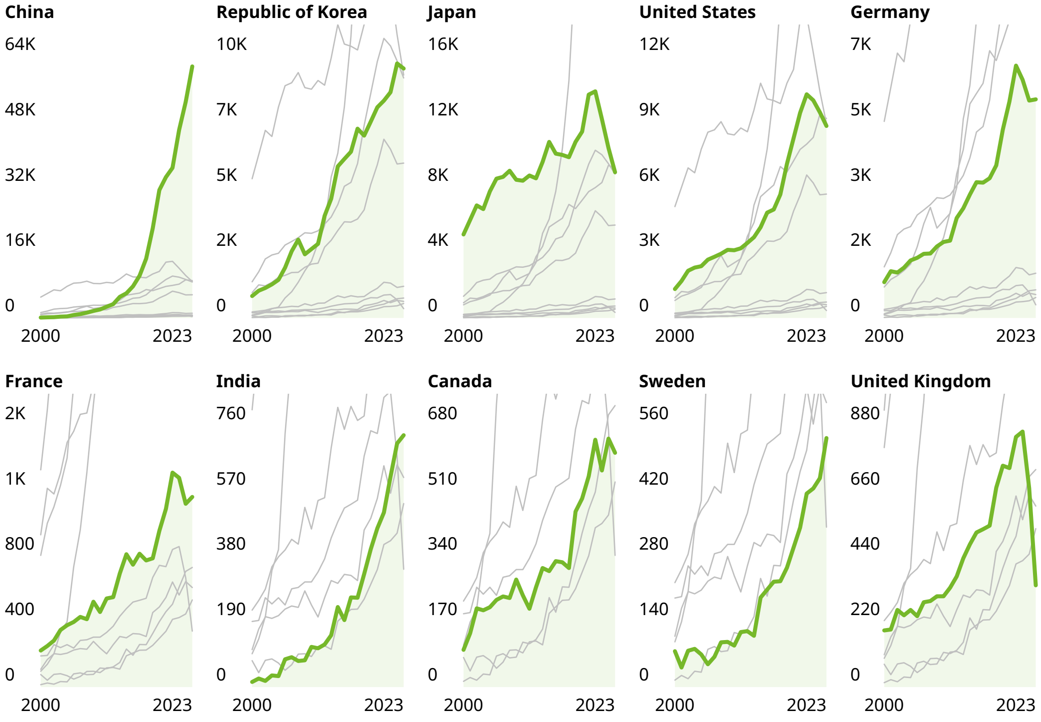
Figure A10 is an illustration of the impressive rise of China as a research location in the field of land transport technologies. From only around 100 patent families published in the year 2000, the number of patent families published from China had risen to almost 62,000 in the year 2023.

The Republic of Korea, Japan and the United States all published around 9,000 patent families in land transport technologies in 2023. Germany is ranked fifth with almost 5,700 patent family publications in 2023.

The research activities of the other countries are still much smaller than those of the top 5.

From about 100 patent families in 2000, China's patent publications surged to nearly 62,000 in 2023.

Figure A10 Top 10 inventor locations in Land transportation: development of patent families by publication year, 2000–2023

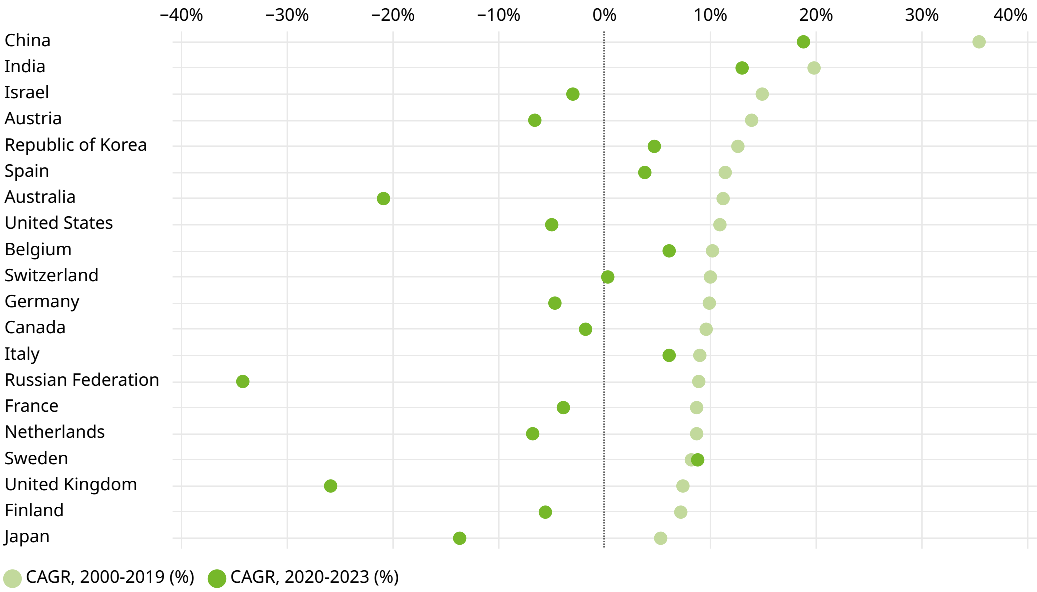


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

In terms of patent family growth rates, China and India show the most dynamic development among the top 20 research locations both between 2000 and 2019, and 2020 and 2023 (Figure A11). The Republic of Korea, Sweden, Belgium, Italy and Spain have also increased their patent family publications at a dynamic pace in both the time periods analysed. Israel and Austria deserve a mention for their very high growth rates of patent family publications between 2000 and 2019. However, patent family publications have declined in these two countries since 2020. In addition, countries such as the Russian Federation, the United Kingdom (UK), Australia and Japan show a significant decrease in patent family publications over the three years from 2020 to 2023.

China and India have shown the most dynamic development among the top 20 research locations, both from 2000 to 2019 and from 2020 to 2023.

Figure A11 Top inventor locations: compound annual growth of patent family publications, 2000–2019 and 2020–2023



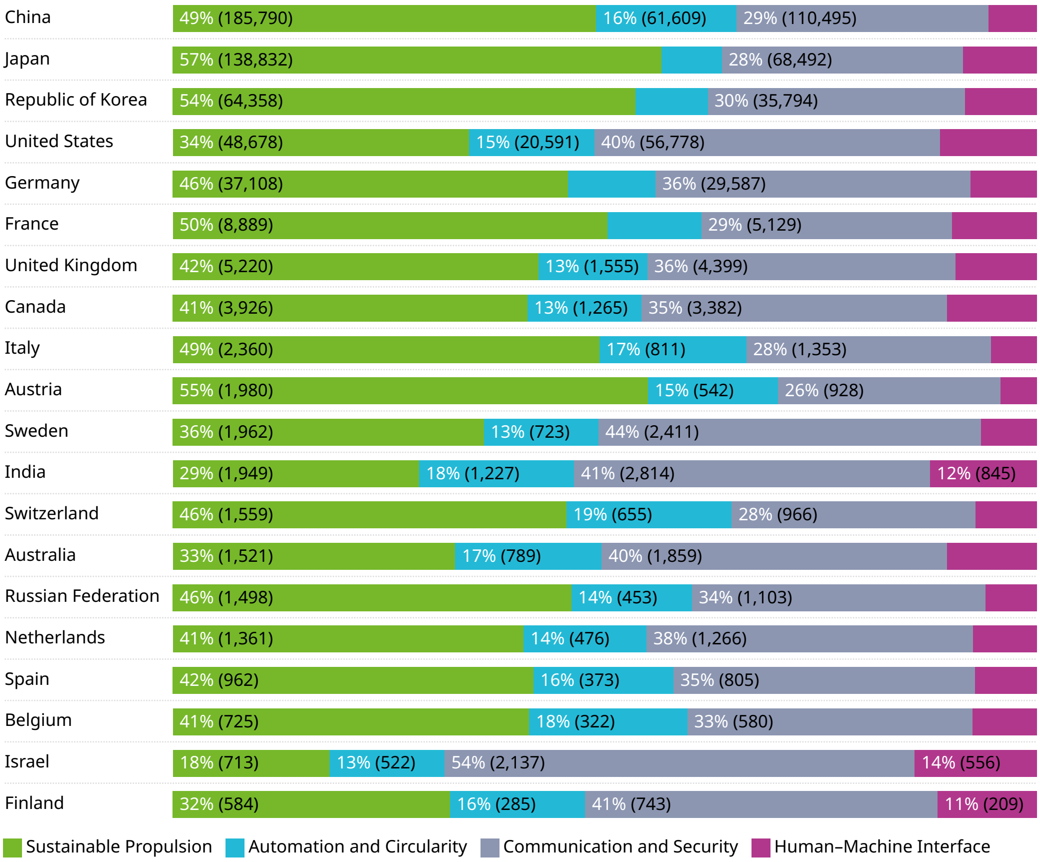
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Research priorities: top 20 countries

A closer look at the research priorities at country level shows that there are similarities between all countries, but also significant differences. For all the top 20 research locations, Sustainable Propulsion and Communication and Security technologies are the two main research areas (Figure A12 and Table A1). However, the relative importance of these two research areas varies considerably. For example, Israel has a clear focus on the development of Communication and Security technologies in land transport, whereas Austria, Japan and the Republic of Korea have the highest relative share of patent families in Sustainable Propulsion.

Israel focuses strongly on Communication and Security technologies in land transport, while Austria, Japan, and the Republic of Korea have the highest relative share of patent families in Sustainable Propulsion.

Figure A12 Top 20 countries: research priorities by share of patent families



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

For the top 20 research locations, Sustainable Propulsion and Communication and Security technologies are the two main research areas.

Table A1: Top 20 countries: research priorities, by volume

	Sustainable Propulsion	Automation and Circularity	Communication and Security	Human–Machine Interface
China	185,790	61,609	110,495	21,233
Japan	138,832	17,184	68,492	20,961
Republic of Korea	64,358	10,043	35,794	9,975
United States	48,678	20,591	56,778	15,892
Germany	37,108	8,222	29,587	6,205
France	8,889	1,915	5,129	1,727
United Kingdom	5,220	1,555	4,399	1,158
Canada	3,926	1,265	3,382	992
Italy	2,360	811	1,353	253
Austria	1,980	542	928	150
Sweden	1,962	723	2,411	352
India	1,949	1,227	2,814	845
Switzerland	1,559	655	966	243
Australia	1,521	789	1,859	484
Russian Federation	1,498	453	1,103	193
Netherlands	1,361	476	1,266	248
Spain	962	373	805	164
Belgium	725	322	580	131
Israel	713	522	2,137	556
Finland	584	285	743	209

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

Top inventor locations for each technology trend

The differences in research priorities described above are also reflected in the country rankings for the four transport technology trends (Figure A13).

China leads in Communication and Security, Automation and Circularity, and Sustainable Propulsion technologies, while China and Japan are on equal footing in HMI research activities.

Figure A13 Top inventor countries by number of patent families in each technology trend, 2000–2023

	Sustainable Propulsion	Automation and Circularity	Communication and Security	Human–Machine Interface
China	185,790	61,609	110,495	21,233
Japan	138,832	17,184	68,492	20,961
Republic of Korea	64,358	10,043	35,794	9,975
United States	48,678	20,591	56,778	15,892
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Finland	584	285	743	209

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

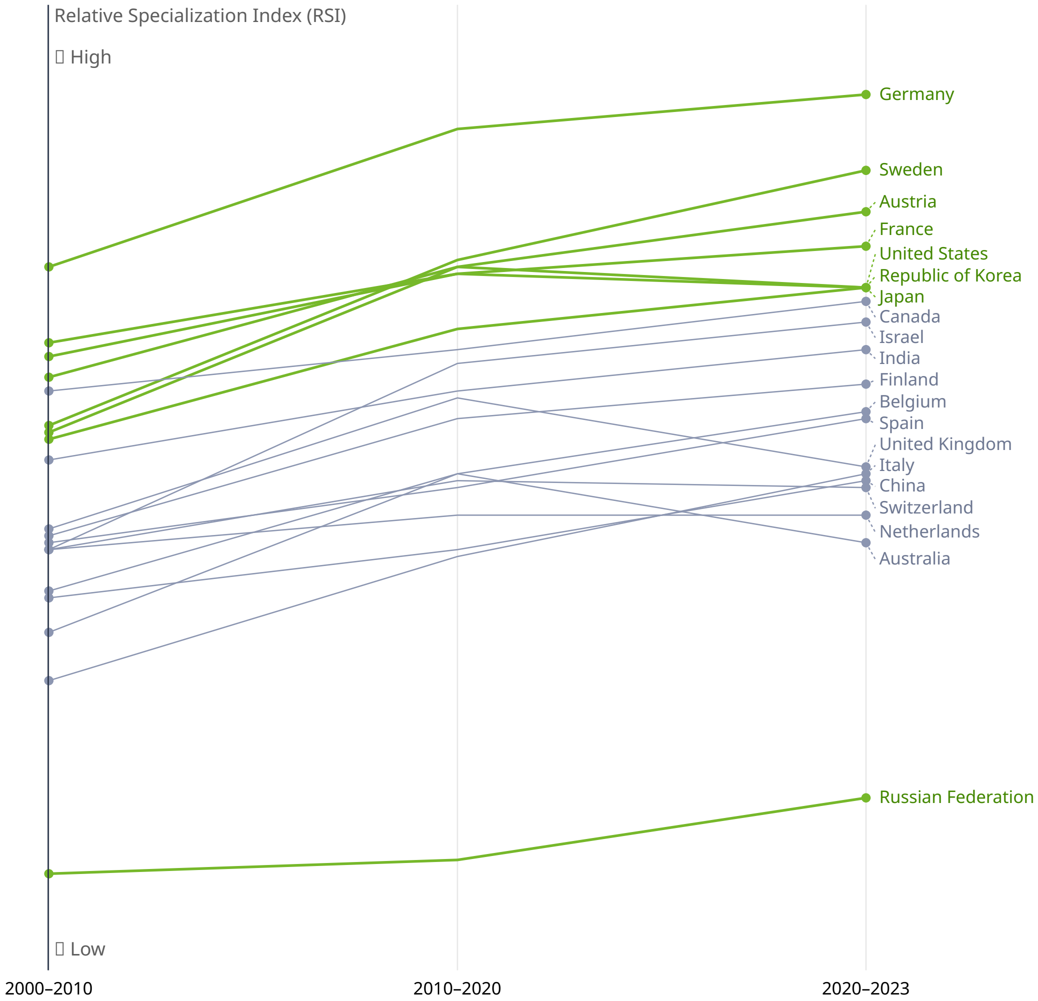
Relative Specification Index

The Relative Specialization Index (RSI) is a metric used to compare a country's (or company's) patenting activity in a specific research field against its overall patenting activity. It shows how much a country specializes in a particular area compared to its overall research profile. A positive RSI indicates that a country is specializing in a particular field more than the global average, while a negative RSI suggests a country is specializing less in a particular field compared to the global average.

The development of RSI values for land transport technologies illustrates that the relevance of land transport technologies as a research focus area has increased in almost all major countries (Figure A14). The RSI also proves the extraordinarily important role of the automobile industry in Germany. Germany reaches a very high RSI index of 0.5 over the last three years, followed by second placed Sweden (RSI of 0.4 in most recent years). Land transport research is also an important research focus in Austria, France, Japan, the Republic of Korea and the United States. At the opposite end of the country ranking of the top 20 nations in land transport research is the Russian Federation, whose clearly negative RSI score indicates a low level of specialization.

Germany has achieved a high RSI index of 0.5 over the last three years, followed by Sweden in second place.

Figure A14: Changes in Relative Specialization Index (RSI) across inventor countries in Land transportation, 2000–2023



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

Top patent owners

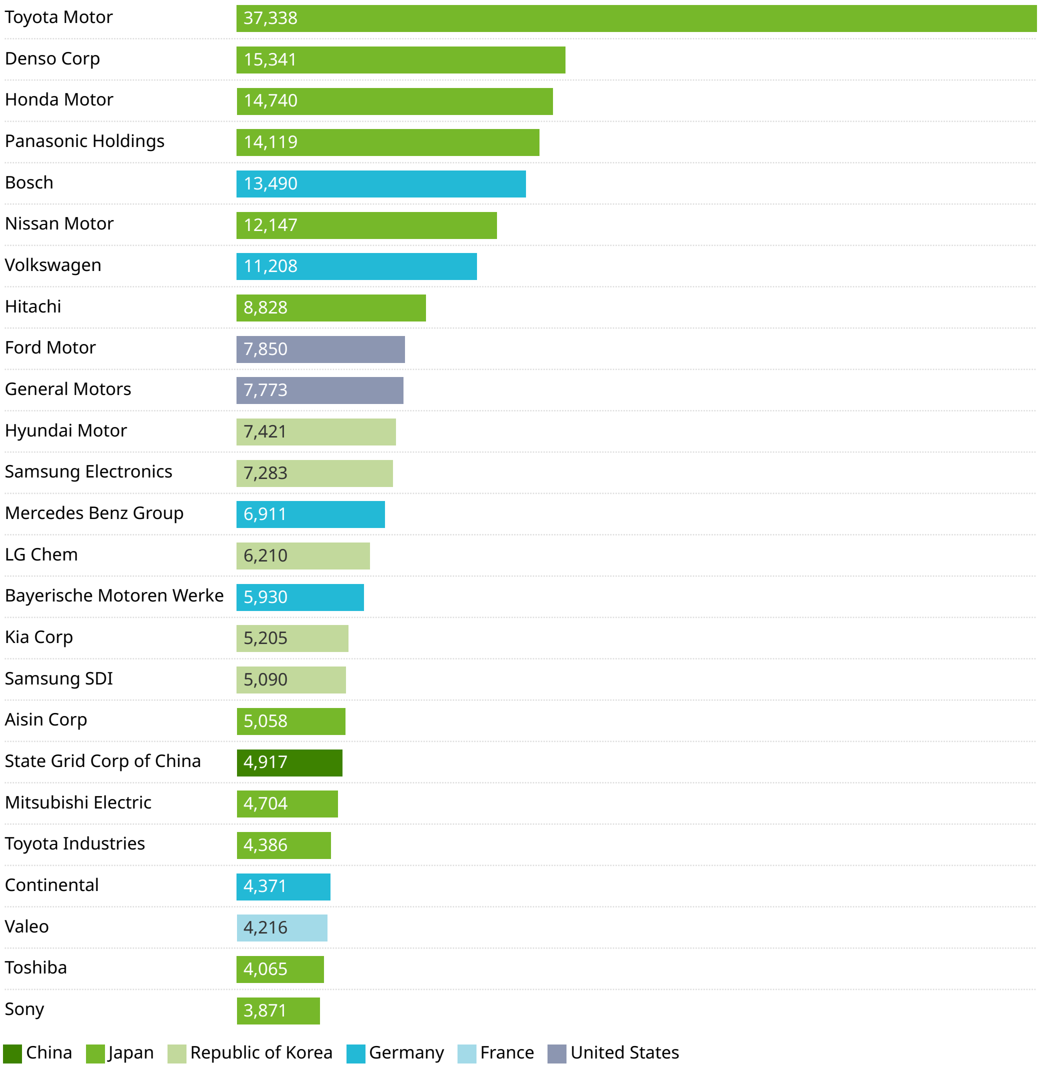
Top patent owners: patent activity

Despite China's impressive rise in land transport technologies in recent years, the top patent holders still come mainly from Japan, Germany and the United States (Figure A15). Six of the top 10 patent holders are Japanese (Toyota Motor (1st), Denso (2nd), Honda Motor (3rd), Panasonic Holdings (4th), Nissan (6th) and Hitachi (8th)), two are from Germany (Bosch (5th) and Volkswagen (7th)) and two from the United States (Ford Motor (9th) and General Motors (10th)). Hyundai Motors is the first Republic of Korea company in 11th place, while the first Chinese company, State Grid Corp of China, only appears in 18th place. US electric vehicle manufacturer Tesla has developed and published 347 patent families since 2000. As a result, the company is not among the top 25 patent owners, but ranked at 203rd.

It is notable that Toyota Motor has by far the largest patent portfolio in land transport technologies with more than 37,000 patent family publications between 2000 and 2023. This is more than twice as many patent family publications as Denso in second place. Another observation is that, unlike in the other transport modalities, there are no universities or research institutes in the list of the top 25 patent owners.

Despite China's impressive rise in land transport technologies, the top patent holders still primarily come from Japan, Germany, and the United States.

Figure A15: Top 25 patent owners in Land transportation, based on the number of patent families, 2000–2023



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

Tesla and BYD: contrasting patent strategies

Tesla and BYD, major players in the electric vehicle (EV) market, have both developed extensive patent portfolios, but their approach appears to differ significantly.

Tesla made headlines in 2014 when Elon Musk introduced the "All our patent are belong to you" initiative, announcing that the company would open-source its patents.[1] According to a now removed blog post, Tesla stated that its decision aimed to benefit humankind and encourage the adoption of sustainable energy technologies. Musk wrote, "We believe that applying the opensource philosophy to our patents will strengthen rather than diminish Tesla's position in this regard." This marked a unique approach to patent use in the EV sector that allowed Tesla to continue maintaining an active patent filing strategy.

Over the past five years, BYD has increased its patent holdings by 72%, reaching approximately 15 times the number of active patents held by Tesla. Most of BYD's patents are, however, concentrated within China, with 82% only active in the domestic market and just 7% active in the United States. In contrast, Tesla's patents are distributed more globally, with over half

1 GTM (2014). Tesla's Elon Musk declares 'All our patent are belong to you'. Greentech Media. Available at: www.greentechmedia.com/articles/read/all-your-clean-energy-insight-and-content-is-now-live-on-woodmac.com.

active in multiple markets and 31% specifically active in China.

Tesla's IP strategy includes its 2014 "Patent pledge," which allows third parties to use Tesla patents under specific conditions. This approach aims to reduce litigation risks, while promoting broader EV adoption. Despite this pledge, Tesla has continued to file patents extensively, particularly in areas such as EV technology, batteries and autonomous driving.

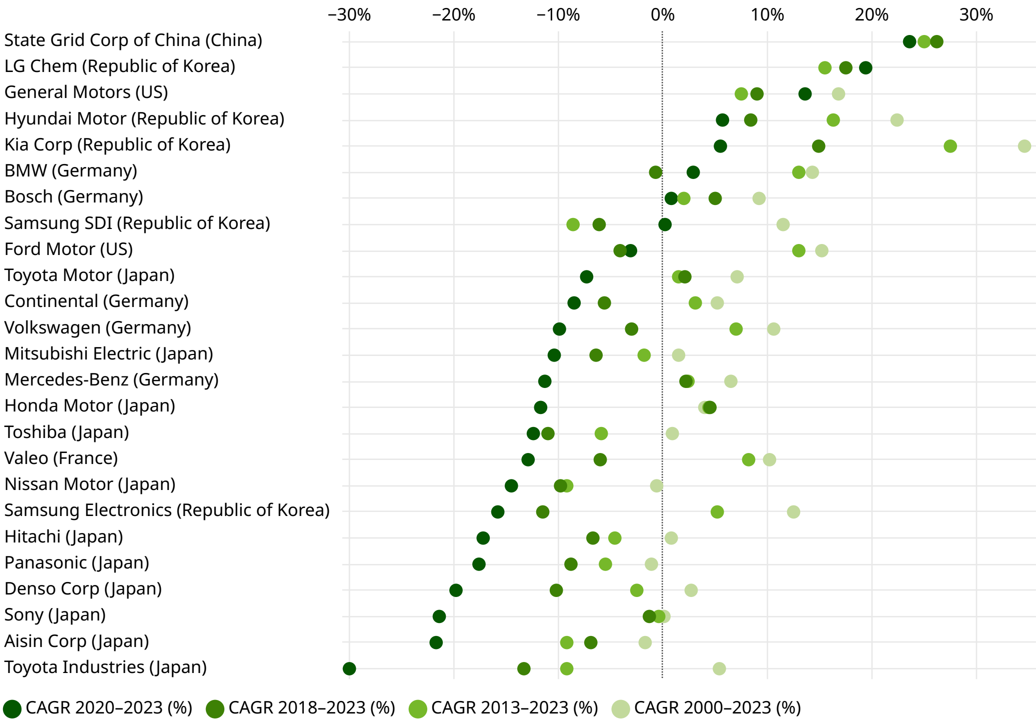
BYD's patent growth may be influenced by domestic policies, including subsidies for filings, which have encouraged high volumes of patents within China. The differences in Tesla and BYD's patent activities reflect broader trends within the EV industry, highlighting evolving strategies in the use of patents, and IP more generally. [2]

Top patent owners: patent growth

Patenting activity in land transport technologies has grown dynamically over the last decades (Figure A16). A majority of top patent owners have increased their patent family publications over the whole period analyzed from 2000 to 2023, with very strong growth coming especially from companies in the Republic of Korea such as Kia and Hyundai. On the other hand, there are some large Japanese companies such as Panasonic, Nissan and Aisin, that published fewer patent families in 2023 than in 2000. It should be noted, however, that the growth picture is more mixed from 2020 onward. While Chinese and Republic of Korea companies, such as State Grid Corp of China and Hyundai, as well as certain Western companies, such as BMW and General Motors, have continued to expand patenting in recent years, many of the other top patent owners from Japan, Europe and the United States have shown a downward trend in annual patent family publications.

State Grid Corp of China, LG Chem, and General Motors have seen the highest growth rates in patent applications in recent years, while Hyundai Motor and Kia Corp have achieved the highest growth rates since 2000.

Figure A16 Compound annual growth rate (CAGR) for top patent owners for different time periods



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

2 Autoevolution (2024). Tesla and BYD face each other in a worldwide patent war, it's not even close. Available at: www.autoevolution.com/news/tesla-and-byd-face-each-other-in-a-worldwide-patent-war-it-s-not-even-close-244105.html.

Top patent owners: research priorities

The research priorities of top patent owners show that large carmakers such as Toyota, General Motors and Volkswagen have their main research focus on the development of Sustainable Propulsion technologies (Figure A17). The research priorities of top patent owners show that large carmakers such as Toyota, General Motors and Volkswagen have their main research focus on the development of Sustainable Propulsion technologies (Figure A17). But at the same time have also developed many patent families in Communication and Security technologies.

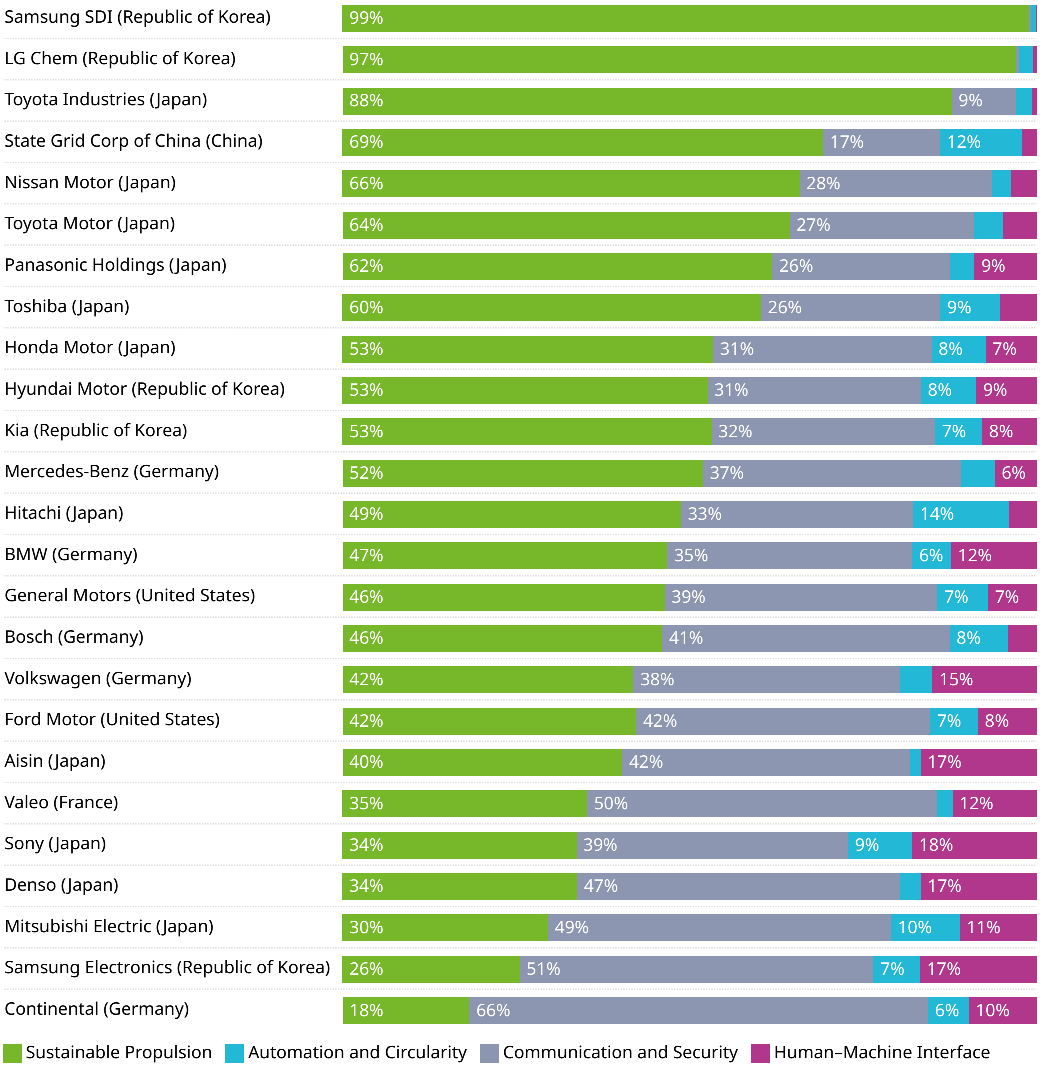
Most automotive suppliers, such as Denso, Continental and Samsung, on the other hand, have developed most of their patent families in Communication and Security technologies. An exception is Bosch, which has developed roughly the same number of patent families in each of these two technologies.

Automation and Circularity technologies is another relevant research area for most top patent owners. Hitachi, State Grid Corp of China and Sony have a particularly high proportion of patent families within this particular technology trend.

Human–Machine Interface (HMI) technologies play a particularly important role for the research priorities of certain automotive suppliers such as Denso, Sony, Samsung Electronics and Aisin. However, there are also some car manufacturers with a large share of HMI patent families such as Volkswagen.

The top patent owners' research priorities reveal that major carmakers like Toyota, General Motors, and Volkswagen primarily focus on developing Sustainable Propulsion technologies.

Figure A17 Top 25 patent owners: research priorities, 2000–2023



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

In absolute terms, Toyota Motors has developed and published the largest number of patent families in all four technology trends (Figure A18). Toyota's lead is particularly large in Sustainable Propulsion, where Toyota has published more than 26,000 patent families since 2000 – almost three times as many as Panasonic Holdings (9,491) in second place. One explanation for Toyota's significant lead in patenting activity is its strategic approach to developing both electric vehicles (EVs) and hydrogen fuel cell vehicles (FCEVs), coupled with in-house battery production.[3] In contrast, many other automakers have focused primarily on EVs, often relying on external battery suppliers.

In Communication and Security technologies, Toyota Motor's lead is smaller, with 10,750 patent families, ahead of Japanese automotive supplier Denso in second place (8,204).

In Automation and Circularity technologies, Toyota Motor, Bosch, Hitachi and Honda Motors are the technology leaders.

3 Toyota Europe (2023). Toyota's new battery and fuel cell electric vehicles to reinforce multi-pathway approach to carbon neutrality. Available at: https://newsroom.toyota.eu/toyotas-new-battery-and-fuel-cell-electric-vehicles-to-reinforce-multi-pathway-approach-to-carbon-neutrality.

In HMI technologies, Denso, Toyota Motor and Volkswagen have developed the largest number of patent families.

Major patent owners in Land transportation are led by Japanese, German, and American companies, with Toyota leading the way by a distance.

Figure A18 Top 25 patent owners in Land transportation: number of patent families by technology trends, 2000–2023

	Sustainable Propulsion	Automation and Circularity	Communication and Security	Human-Machine Interface
Toyota Motor (Japan)	26,080	1,672	10,750	1,975
Panasonic Holdings (Japan)	9,491	542	3,921	1,371
Honda Motor (Japan)	8,737	1,274	5,152	1,197
Nissan Motor (Japan)	8,386	351	3,534	462
Bosch (Germany)	6,667	1,206	5,990	604
LG Chem (Republic of Korea)	6,154	131	25	33
Denso Corp (Japan)	5,961	525	8,204	2,941
Volkswagen (Germany)	5,106	568	4,677	1,828
Samsung SDI (Republic of Korea)	5,077	37	15	3
Hitachi (Japan)	4,730	1,339	3,245	385
Hyundai Motor (Republic of Korea)	4,442	673	2,597	733
General Motors (US)	3,983	626	3,372	598
Toyota Industries (Japan)	3,936	103	413	32
State Grid Corp of China (China)	3,825	650	931	118
Ford Motor (US)	3,783	614	3,786	753
Mercedes-Benz (Germany)	3,759	351	2,692	435
Kia Corp (Republic of Korea)	3,152	402	1,909	464
BMW (Germany)	2,957	353	2,230	778
Toshiba (Japan)	2,673	381	1,145	233
Aisin Corp (Japan)	2,465	91	2,538	1,021
Samsung Electronics (Republic of Korea)	2,142	562	4,279	1,409
Sony (Japan)	1,594	436	1,850	846
Mitsubishi Electric (Japan)	1,589	531	2,651	594
Valeo (France)	1,539	96	2,203	528
Continental (Germany)	851	272	3,075	454

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

Patenting activity in the four technology trends

Sustainable Propulsion

Sustainable Propulsion systems are critical in addressing the pressing issues of climate change, air pollution and energy security within the transport sector. The transition from fossil fuels to cleaner alternatives is essential in order to mitigate the negative impacts of traditional internal combustion engines.

Battery-powered electric vehicles (BEVs) are at the forefront of this transition. This is reflected in the significant rise in patenting activity in both battery and electric propulsion (electric motors, gearings etc.) technologies. Patent family publications for batteries in mobility applications have risen from around 3,000 in 2000 to almost 41,000 in 2023. For electric propulsion, patenting activity increased from around 900 in 2000 to 11,900 in 2023 (Figure A19). BEVs offer significant reductions in greenhouse gas emissions, improved air quality and reduced dependence on fossil fuels. However, challenges, such as battery range and recharging infrastructure need to be further improved for an even more widespread adoption. [1]

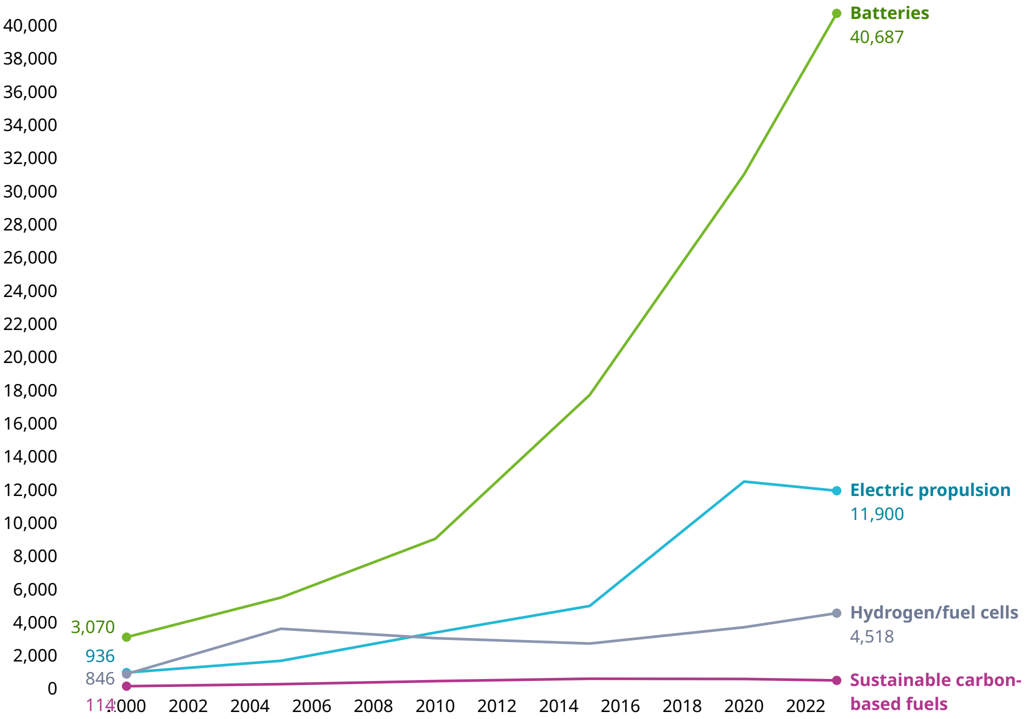
Another important research field within Sustainable Propulsion is hydrogen / fuel cell-powered vehicles (FCEVs). Patent family publications in this technology area have expanded from around 850 to more than 4,500 between 2000 and 2023. Hydrogen-powered vehicles offer an alternative to BEVs. A key advantage compared Hydrogen vehicles offer an alternative to BEVs. A key advantage they have over BEVs is a longer range. However, there are still a number of challenges to their widespread adoption. For example, the infrastructure for hydrogen production, storage and distribution is still in its infancy, leading to higher costs and limited availability. In addition, FCEVs require multiple energy conversion steps – from electricity to hydrogen production, hydrogen storage and transport, and finally electricity generation from the fuel cell – resulting in lower overall energy efficiency compared to BEVs. Despite these hurdles, fuel cell vehicles hold promise for certain niche applications, such as heavy-duty trucks and buses, for which range and payload are critical. [2]

In addition, technological advances in sustainable fuels, for example, biofuels derived from organic matter such as plants, synthetic fuels made from water, carbon dioxide and renewable energy and LNG, continue to be explored. These renewable fuels can be blended with conventional fuels or used as direct replacements with minor modifications. However, the production process of synthetic fuels is energy intensive and the infrastructure for the production and distribution of synthetic fuels still in its infancy. Patenting activity in this area is lower than for BEVs or FCEVs, with only 463 patent families published in 2023.

1 See 'Electric vehicles'. The International Energy Agency, available at: www.iea.org/energy-system/transport/electric-vehicles.
2 See 'Hydrogen'. The International Energy Agency, available at: www.iea.org/energy-system/low-emission-fuels/hydrogen.

Patent family publications for batteries in mobility applications have increased significantly, rising from around 3,000 in 2000 to nearly 41,000 in 2023.

Figure A19 Sustainable Propulsion in Land transportation: development of global patent family publications, 2000–2023

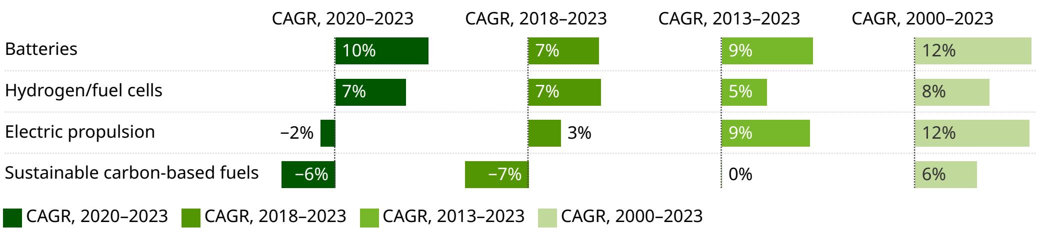


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Looking at the compound annual growth rates over different time periods (Figure A20), innovation activity was dynamic in all subgroups between 2000 and 2019, but growth rates have been mixed from 2020 onward. Whereas the number of patent families in hydrogen/fuel cells and batteries continues to grow dynamically, patenting activity in electric propulsion and sustainable carbon-based fuels has declined somewhat over the last three years.

Patents related to batteries have maintained a high growth rate over the past 20 years.

Figure A20 Sustainable Propulsion in Land transportation: compound annual growth rate (CAGR) of subgroups for different time periods



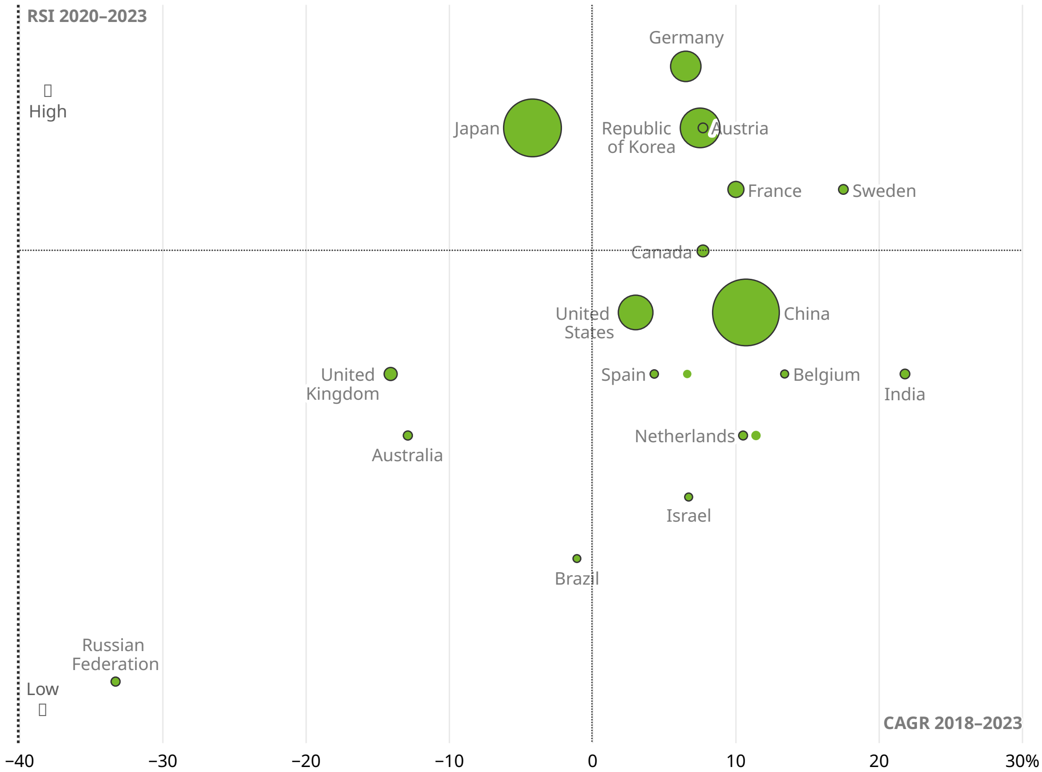
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Figure A21 shows that inventors from Japan and China were responsible for most patent family publications. However, patent growth in China has been much stronger than in Japan. India, Sweden, Belgium and Italy have achieved even more dynamic patent growth rates than China since 2018.

In terms of RSI score, Germany is the highest ranked country, indicating an above average degree of specialization in Sustainable Propulsion technologies.

Inventors from Japan and China account for the majority of patent family publications, with patent growth in China significantly outpacing that of Japan.

Figure A21 Sustainable Propulsion: country comparison, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)



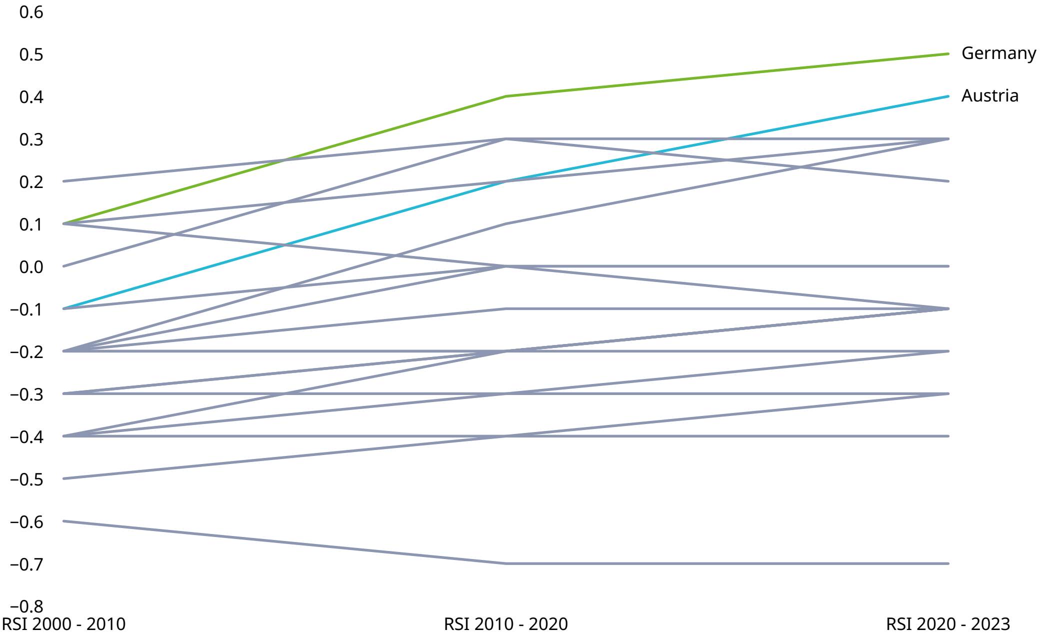
Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Sustainable Propulsion from 2000 to 2023. The compound annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

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

A closer look at RSI values over different time periods for a broader group of countries shows again the high relevance of the automotive industry to Germany (Figure A22). The country has increased its RSI from 0.1 to 0.5 since 2000. Other countries with a very high RSI scores are Austria, Sweden, the Republic of Korea, France and Japan.

Germany has increased its RSI from 0.1 to 0.5 since 2000.

Figure A22: Sustainable Propulsion in Land transportation: changes in Relative Specialization Index (RSI) across inventor countries, 2000–2023



Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Sustainable Propulsion from 2000 to 2023. 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.

An analysis of the top research countries in the different Sustainable Propulsion subgroups reveals the following key findings (Figure A23):

- China is the technology leader in electric propulsion technologies with more than 44,000 patent families published between 2000 and 2023. Japan follows in second place (31,126 patent families).
- The United States and China have developed and published most patent families in sustainable fuels.
- Japan is the clear innovation leader in hydrogen/fuel cell research.

China and Japan are clearly leading in battery research.

Figure A23 Top 20 inventor locations for Sustainable Propulsion sub-groups, 2000–2023

	Battery Patent family publications 2000 - 2023	Electric Propulsion Patent family publications 2000 - 2023	Hydrogen Fuel Cells Patent family publications 2000 - 2023	Sustainable Fuels Patent family publications 2000 - 2023
China	155,256	44,248	15,182	2,586
Japan	107,591	31,126	29,798	1,095
Republic of Korea	51,338	14,761	9,970	901
US	35,192	16,055	10,595	2,735
Germany	24,352	16,705	6,926	1,369
France	6,127	3,504	1,562	386
UK	3,325	1,836	1,094	551
Canada	2,680	1,095	1,209	280
India	1,422	564	370	77
Italy	1,420	1,026	420	186
Sweden	1,330	943	261	116
Austria	1,244	870	342	130
Switzerland	1,073	692	317	63
Russia	1,015	340	340	94
Australia	944	485	367	197
Netherlands	795	463	256	212
Spain	662	314	193	67
Israel	559	217	161	29
Belgium	436	269	155	55
Brazil	336	199	91	89

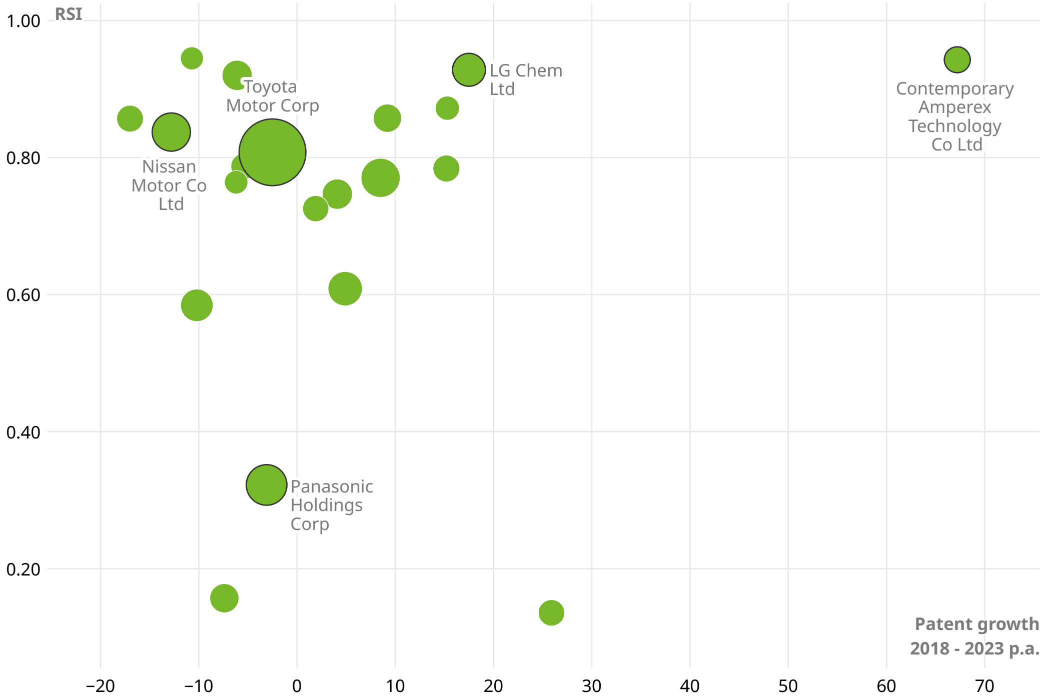
Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Sustainable Propulsion from 2000 to 2023. The compound annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

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

Toyota Motor, Panasonic Holdings and Honda Motor have published the most patent families in Sustainable Propulsion technologies (Figure A24). In terms of patent growth, Chinese battery maker CATL has achieved by far the highest patent growth rates since 2018. Almost all top patent holders also have a very high RSI scores, the only exceptions being Panasonic, Hitachi and State Grid Corp of China.

Almost all top patent holders have very high RSI scores, with the exceptions of Panasonic, Hitachi, and State Grid Corp of China.

Figure A24 Sustainable Propulsion: comparison of top patent owners, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)



Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Sustainable Propulsion from 2000 to 2023. 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.

The top research players in the four subgroups are as follows (Figure A25):

- Toyota Motor is the research leader in terms of patent family publications in batteries, electric propulsion and hydrogen/fuel cells.
- BMW is at the top of the ranking for research into sustainable fuels.

Toyota Motor leads in patent family publications for batteries, electric propulsion, and hydrogen/fuel cells, while BMW ranks highest for research into sustainable fuels.

Figure A25 Top 5 patent owners in the subgroups of Sustainable Propulsion in Land transportation, 2000–2023

Subgroup	Company	Country	Patent Family Publications
Batteries	Honda Motor	Japan	5,510
Batteries	LG Chem	Republic of Korea	6,078
Batteries	Nissan Motor	Japan	6,272
Batteries	Panasonic	Japan	8,381
Batteries	Toyota Motor	Japan	20,121
Electric Propulsion	Bosch	Germany	2,075
Electric Propulsion	Hyundai Motor	Republic of Korea	2,111
Electric Propulsion	Volkswagen	Germany	2,386
Electric Propulsion	Honda Motor	Japan	2,930
Electric Propulsion	Toyota Motor	Japan	7,273
Hydrogen/Fuel Cells	Hyundai Motor	Republic of Korea	1,345
Hydrogen/Fuel Cells	Panasonic	Japan	1,679
Hydrogen/Fuel Cells	Nissan Motor	Japan	2,814
Hydrogen/Fuel Cells	Honda Motor	Japan	3,552
Hydrogen/Fuel Cells	Toyota Motor	Japan	6,976
Sustainable Fuels	Toyota Motor	Japan	128
Sustainable Fuels	Caterpillar	US	133
Sustainable Fuels	Shell	UK	135
Sustainable Fuels	Volkswagen	Germany	144
Sustainable Fuels	BMW	Germany	251

Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Sustainable Propulsion from 2000 to 2023. 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.

Automation and Circularity

Automation and Circularity is a key technology trend reshaping land transport. Robotics, a cornerstone of automation, has long been an integral part of car manufacturing, with assembly lines relying heavily on robotic precision and speed. In addition, circularity principles are increasingly being applied to addressing the environmental impact of transport. By designing vehicles and their components with end-of-life recyclability in view, manufacturers can minimize waste and conserve resources.

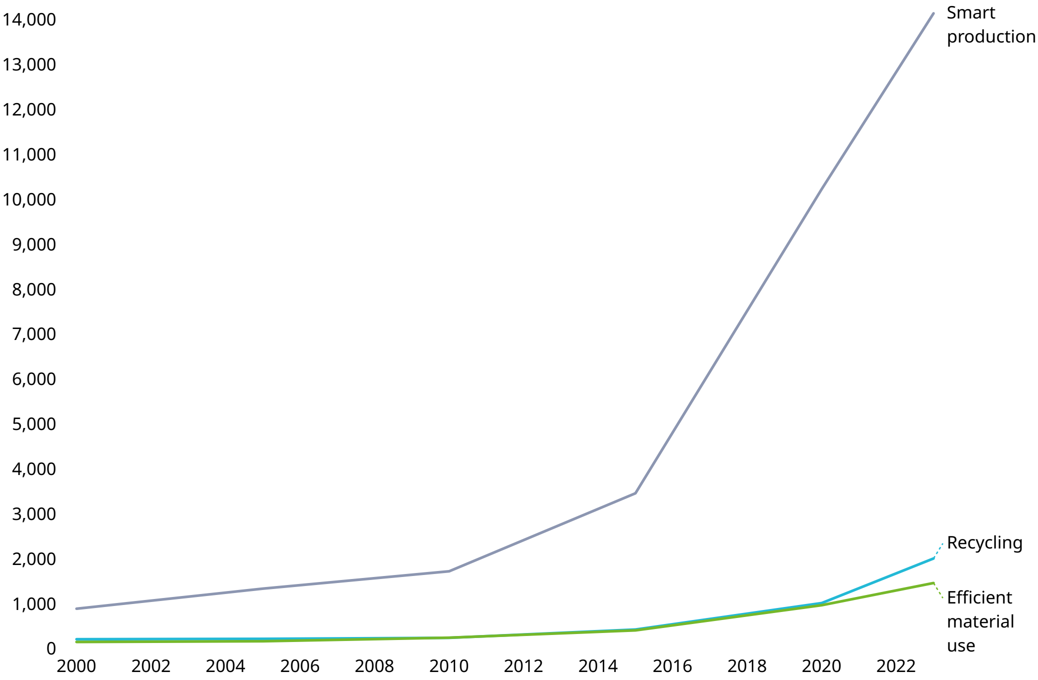
Smart production is the main area of research within Automation and Circularity technologies. This is reflected in the significant increase in patenting activity in this area over the past few decades. Patent family publications for smart production technologies, such as industrial robots, smart factory and predictive maintenance, have increased from around 880 in 2000 to more than 14,000 in 2023 (Figure A26).

The number of patent families in the area of efficient material use (including additive manufacturing, use of biopolymers and climate-efficient metal processing) has also increased significantly from 136 patent families in 2000 to around 1,450 in 2023.

Research efforts into recycling are also growing dynamically. From 197 patent family publications in 2000 to almost 2,000 in 2023, patenting activity has increased particularly in the last 10 years.

Smart production is the primary research focus within Automation and Circularity technologies.

Figure A26 Automation and Circularity: development of global patent family publications, 2000 –2023

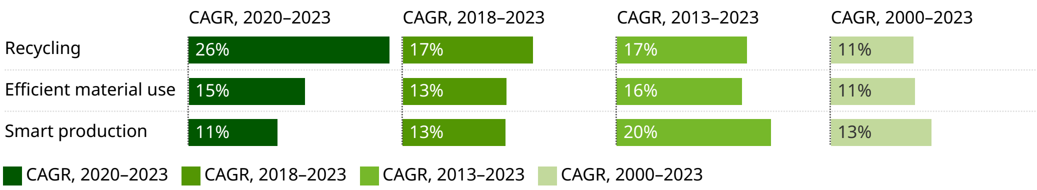


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Contrary to the development of the other technology trends, the innovation dynamic of Automation and Circularity has not slowed since 2020; indeed, patent family publications in recycling and efficient use of materials have even accelerated since then.

In contrast to other technology trends, the innovation dynamic in Automation and Circularity has not slowed down since 2020, with patent family publications in recycling and efficient material use accelerating during this period.

Figure A27 Automation and Circularity in Land transportation: compound annual growth rate (CAGR) of subgroups for different time periods



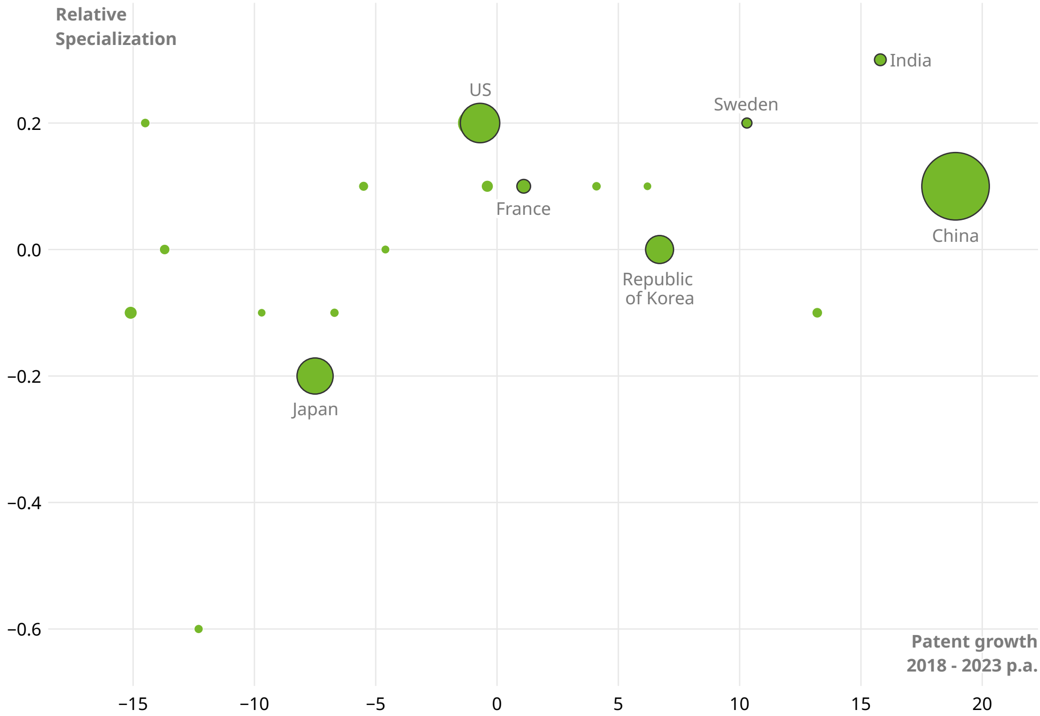
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Figure A28 shows that inventors from China are responsible for by far the most patent family publications, followed by the United States , Japan, the Republic of Korea and Germany. Additionally, patent growth in China has been stronger than in any other top research country.

In terms of the RSI, India, Sweden and Germany are the highest ranked countries, indicating an above-average degree of specialisation in Automation and Circularity technologies.

The inventors from China are by far the leading contributors to patent family publications, followed by the US, Japan, the Republic of Korea, and Germany.

Figure A28 Automation and Circularity: country comparison, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)



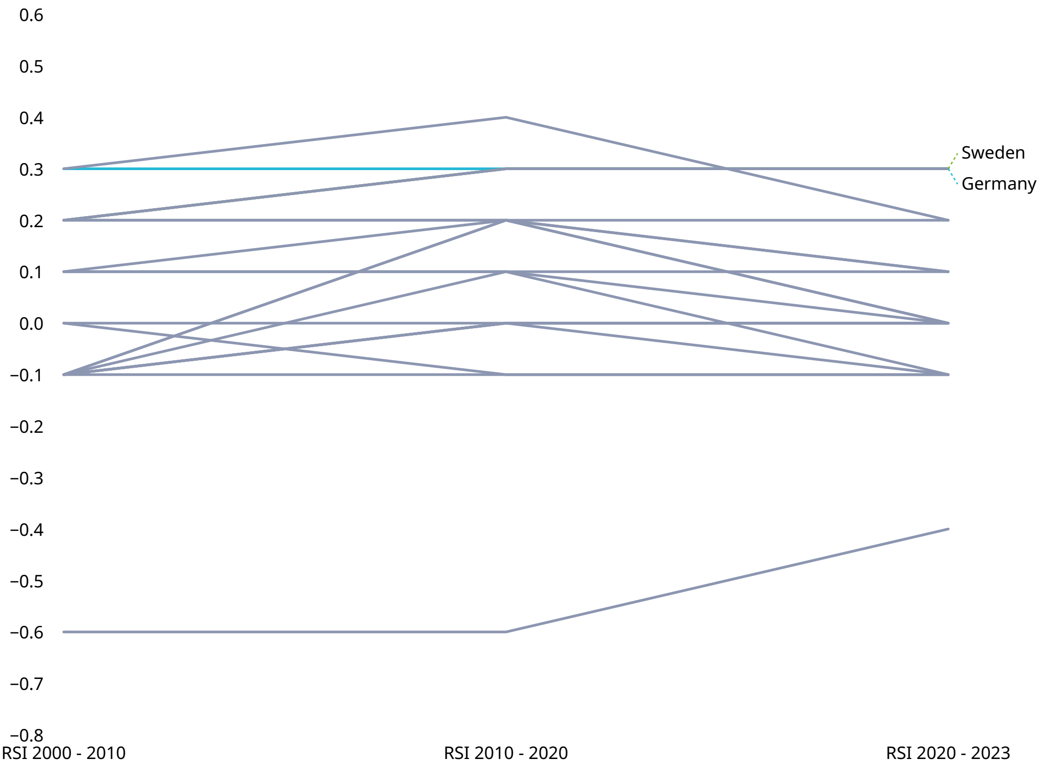
Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Automation and Circularity from 2000 to 2023. The compound annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

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

A closer look at RSI values over different time periods for a broader group of countries shows the high relevance of the automotive industry to Sweden and Germany (Figure A29). Both these countries have maintained a very high RSI value since 2000.

The significant importance of the automotive industry in Germany and Sweden is evident.

Figure A29 Automation and Circularity in Land transportation: changes in Relative Specialization Index (RSI) across inventor countries, 2000–2023



Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Automation and Circularity from 2000 to 2023. 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.

An analysis of the top research countries in the different Automation and Circularity subgroups reveals the following key findings (Figure A30):

- China is the technology leader in all three Automation and Circularity subgroups.
- Japan and the United States have published many patent families on efficient material use, particularly in additive manufacturing technology.
- Japan has also undertaken significant research into recycling technologies related to land transport.

China is the technology leader in all three subgroups of Automation and Circularity.

Figure A30 Top 20 inventor locations for Automation and Circularity sub-groups, 2000–2023

	Efficient Material Use Patent family publications 2000 - 2023	Recycling Patent family publications 2000 - 2023	Smart Production Patent family publications 2000 - 2023
China	5,186	7,885	51,498
US	1,714	852	18,526
Japan	1,674	2,285	13,942
Germany	976	363	7,020
Republic of Korea	942	1,379	8,017
France	275	186	1,509
UK	170	107	1,330
Italy	144	84	627
Canada	138	121	1,063
Australia	122	92	624
India	114	61	1,094
Switzerland	83	37	555
Russia	78	90	316
Belgium	76	44	223
Netherlands	71	30	383
Austria	69	35	456
Brazil	58	64	219
Spain	50	38	293
Sweden	43	19	671
Israel	27	19	489

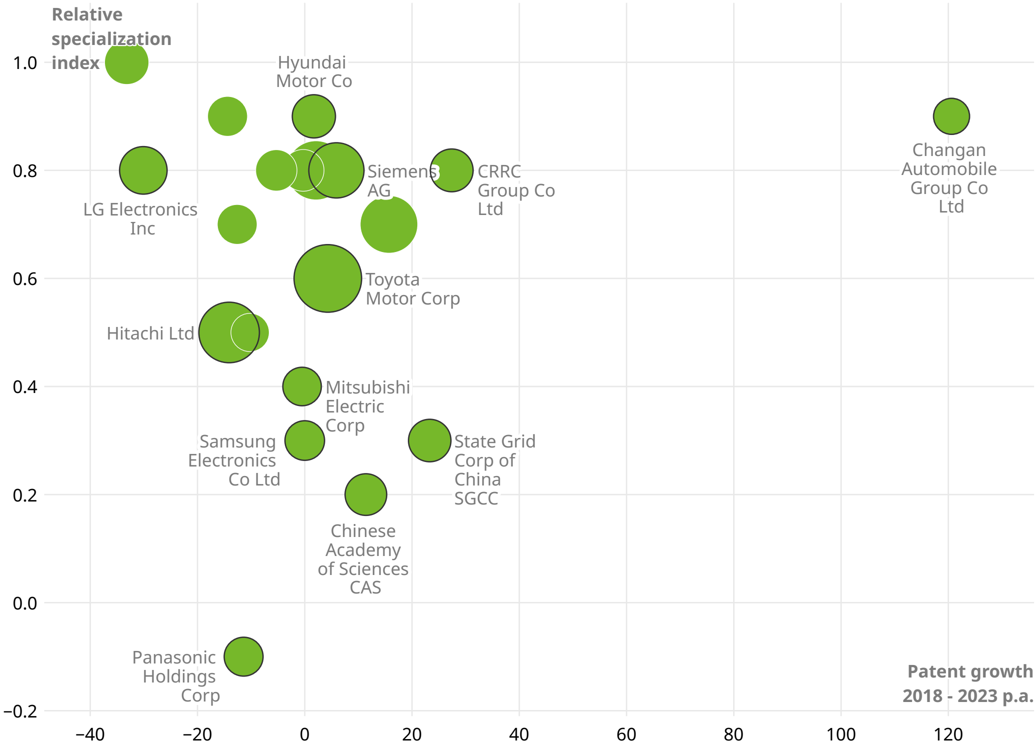
Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Automation and Circularity from 2000 to 2023. The compound annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

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

Toyota Motors, Hitachi, Honda Motor, Bosch and Siemens are the top research companies in Automation and Circularity in land transport in terms of patenting activity (Figure A31). However, China's Changan Automobile Group has had by far the fastest patent growth rate since 2018. Most top patent holders also have a high RSI score, the exceptions being Panasonic Holdings, the Chinese Academy of Sciences and State Grid Corp of China.

Most top patent holders also have high RSI scores, with the exceptions being Panasonic Holdings, the Chinese Academy of Sciences, and State Grid Corp of China.

Figure A31 Automation and Circularity: comparison of top patent owners, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)



Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Automation and Circularity from 2000 to 2023. 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.

The top research players in the three subgroups are as follows (Figure A32):

- Toyota Motor is the research leader in terms of patent family publications in smart production technologies.
- Toyota Motor is also a key research player in recycling technologies, only behind the Chinese Academy of Sciences.
- Sumitomo Metal Mining and Nippon Steel have published the most patent families in efficient material use.

Toyota Motor leads in smart production technologies and is a key player in recycling, while Sumitomo Metal Mining and Nippon Steel lead in efficient material use.

Figure A32 Top 5 patent owners in the subgroups of Automation and Circularity in Land transportation, 2000–2023

Subgroup	Company	Country	Patent Family Publications
Efficient Material Use	Volkswagen	Germany	90
Efficient Material Use	China Baowu Steel Group	China	92
Efficient Material Use	JFE Holdings	Japan	100
Efficient Material Use	Nippon Steel	Japan	136
Efficient Material Use	Sumitomo Metal Mining	Japan	144
Recycling	Nippon Steel	Japan	91
Recycling	CATL	China	140
Recycling	Sumitomo Metal Mining	Japan	166
Recycling	Toyota Motor	Japan	192
Recycling	Chinese Academy of Sciences	China	196
Smart Production	Siemens	Germany	1,083
Smart Production	Bosch	Germany	1,141
Smart Production	Honda Motor	Japan	1,199
Smart Production	Hitachi	Japan	1,263
Smart Production	Toyota Motor	Japan	1,434

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

Communication and Security

Communication and Security technologies are fundamental to the development of modern land transport systems. They underpin the development of advanced driver assistance systems and autonomous vehicles, and are essential for traffic management, optimizing traffic flow and reducing congestion. In this connected landscape, protecting sensitive vehicle and driver data from cyber-attacks is critical.

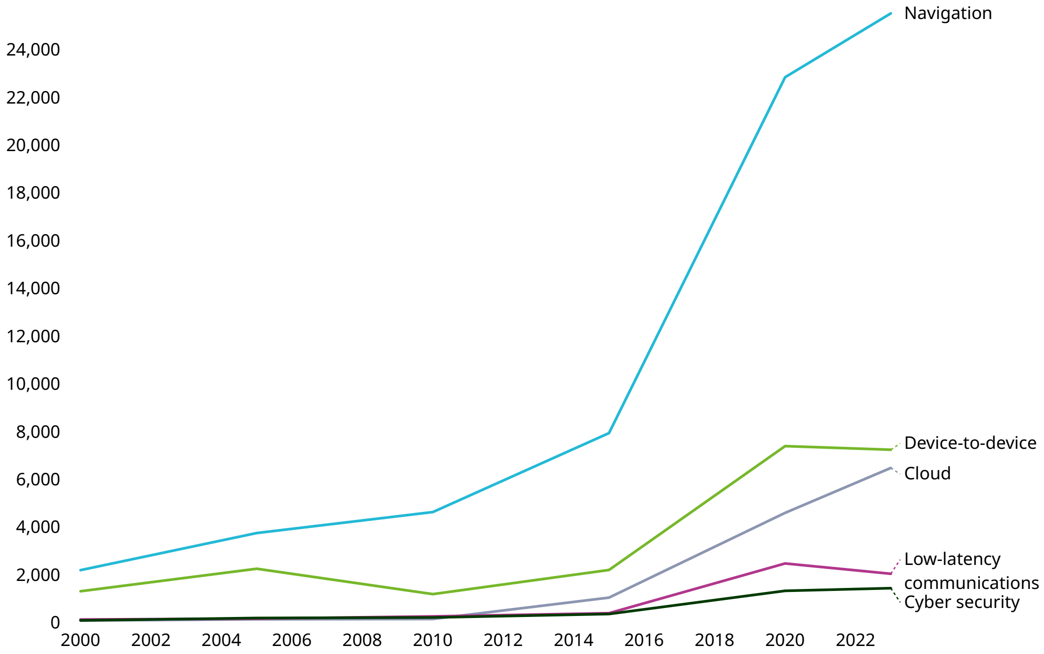
For the purpose of this report, Communication and Security technologies consist of the following five sub-categories: device-to-device communication, navigation, cloud, cybersecurity, and low-latency communication.

Navigation is by far the most important of these subgroups in terms of patent family publications. The number of patent family publications in this area has increased from around 2,200 in 2000 to around 25,500 in 2023 (Figure A33). The field of navigation includes several different technologies such as GPS, lidar (Light Detection and Ranging) and vehicle vision. Lidar uses laser pulses to create a 3D map of the environment, enabling vehicles to detect objects and obstacles. Vehicle vision, based on cameras and image processing, complements lidar by providing colour information and context. Together, these technologies enable advanced driver assistance systems and autonomous vehicles.[3]

3 Foresight (2023). The power of two: The benefits of combining LIDAR and cameras for autonomous vehicles. Available at: www.foresightauto.com/combining-lidar-and-cameras-for-autonomous-vehicles.

Navigation is by far the most important area in terms of patent family publications, showing significant growth in recent years.

Figure A33 Communication and Security: development of global patent family publications, 2000–2023



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

Research activities in device-to-device communication and cloud technologies have also increased significantly. Device-to-device communication enables direct communication between vehicles, infrastructure and pedestrians. By sharing information, vehicles can work together to avoid accidents and optimize traffic flow. By harnessing the power of cloud computing, transport systems can collect, store and analyze vast amounts of data gathered from connected vehicles, infrastructure and passengers. Annual patent family publications in device-to-device communication expanded from 1,300 to 7,200 between 2000 and 2023, while patenting activity in cloud technologies rose from only 55 in 2000 to almost 6,500 in 2023 (Figure A34).

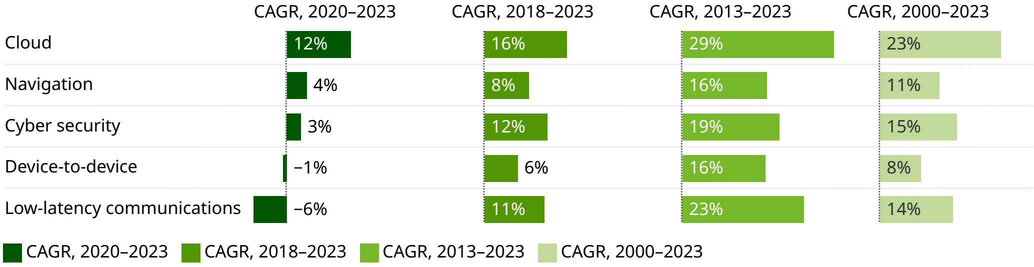
Patenting activity in cybersecurity and low-latency communications is lower than in the other three subgroups, but the number of patents has also grown dynamically. The number of cybersecurity patent family publications in land transport applications increased from just 62 in 2000 to more than 1,400 in 2023. Robust encryption, authentication and intrusion detection systems are essential to ensuring the integrity and confidentiality of information exchanged between vehicles and infrastructure. The number of annual patent family publications in low-latency communications has increased from 100 to more than 2,000 since 2000. Low-latency communication ensures near instantaneous data exchange between vehicles, infrastructure and other road users. This is essential for applications like autonomous driving, for which real-time decision-making is paramount. Technologies like 5G provide the low latency required for such applications. [4]

Looking at compound annual growth rates over different time periods, innovation activity was dynamic in all five subgroups between 2000 and 2019, but growth rates have been mixed from 2020 onward (Figure A34). Whereas the number of patent families in cloud technologies continues to grow dynamically, patenting activity in low-latency communication has declined over the last three years.

4 Monserrat, J. F., A. Diehl, C. Bellas Lamas and S. Sultan (2020). Envisioning 5G-Enabled Transport. Washington, DC: World Bank. Available at: https://openknowledge.worldbank.org/entities/publication/f272ba72-abfa-59cf-8797-728b08ee49ff.

Innovation activity was dynamic in all subgroups between 2000 and 2019, but growth rates have varied since 2020.

Figure A34 Communication and Security in Land transportation: compound annual growth rate (CAGR) of subgroups for different time periods

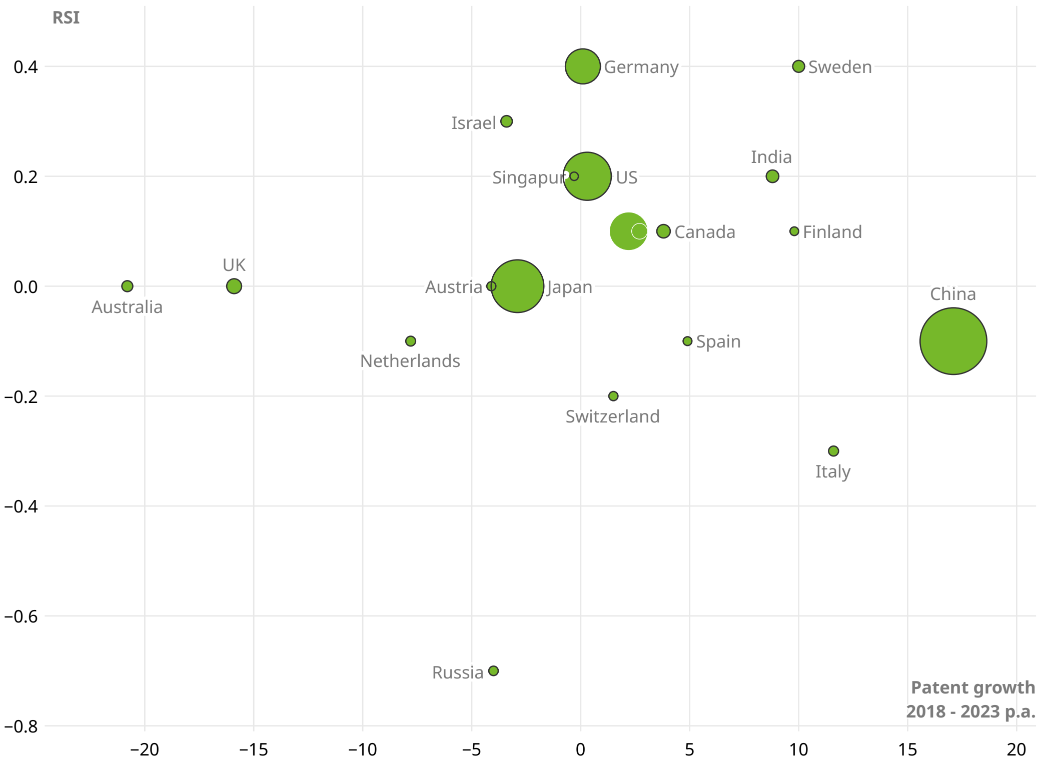


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Figure A35 shows that inventors from Japan, China and the United States were responsible for most patent families. However, patent growth in China has been much stronger than in any other country since 2018. Nonetheless, China's RSI is slightly negative, indicating a below average specialization in communication and security technologies. In contrast, Germany, Sweden and Israel have the highest RSI scores.

Patent growth in China has outpaced all other countries since 2018; however, its RSI remains slightly negative, indicating below-average specialization in security and communication technologies.

Figure A35 Communication and Security: country comparison, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)



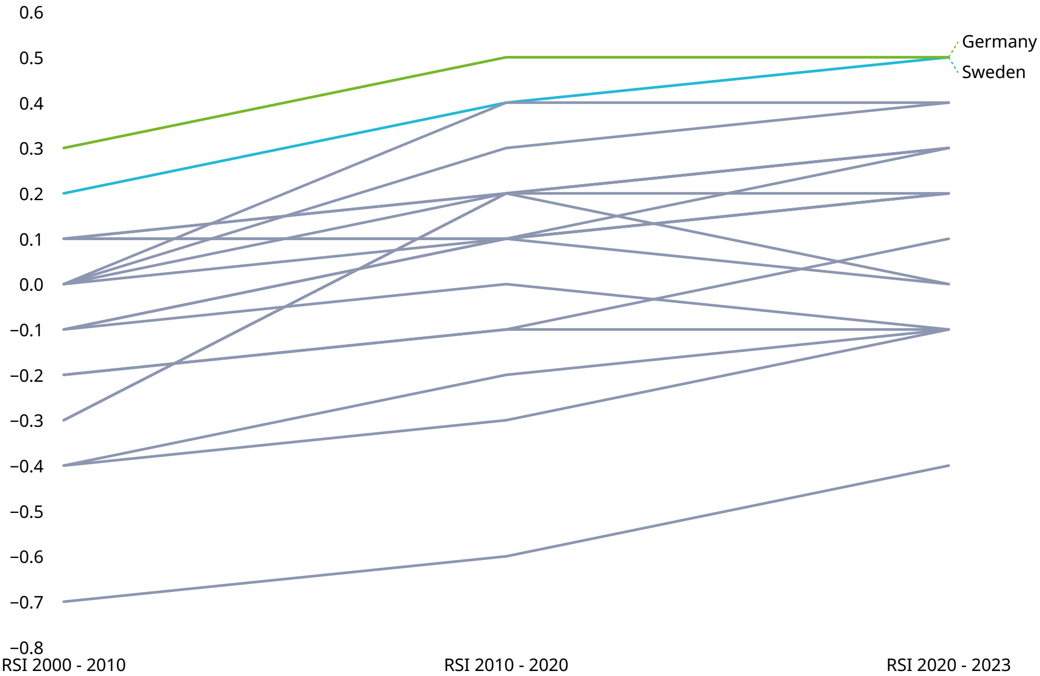
Note: The size of the bubbles shows the number of patent family publications at the country level in the field of Automation and Circularity from 2000 to 2023. The compound annual patent growth rates are for 2018–2023, and the Relative Specialization Index (RSI) for the whole period analyzed, 2000–2023.

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

A closer look at RSI values over different time periods for a broader group of countries shows again the high relevance of the automotive industry to Germany's research efforts (Figure A36). This country has increased its RSI in Communication and Security technologies for land transport from 0.3 to 0.6 since 2000. Other countries with very high RSI values are Sweden, Israel and the United States. In contrast, the Russian Federation clearly has the lowest relative specialization in research, although its RSI has increased over the past two decades.

Germany has raised its RSI in Communication and Security technologies for land transport from 0.3 to 0.6 since 2000.

Figure A36 Communication and Security in Land transportation: changes in Relative Specialization Index (RSI) across inventor countries, 2000–2023



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

An analysis of the top research countries in the different Communication and Security subgroups reveals the following key findings (Figure A37):

- China and the United States have developed and published most patent families in cyber security for land transport applications.
- China, the United States and the Republic of Korea are the innovation leaders in low-latency communication research.
- Japan has a strong research position in navigation technologies.

China is the technology leader in device-to-device communication, navigation, and cloud technologies.

Figure A37 Top 20 inventor locations for Communication and Security sub-groups, 2000–2023

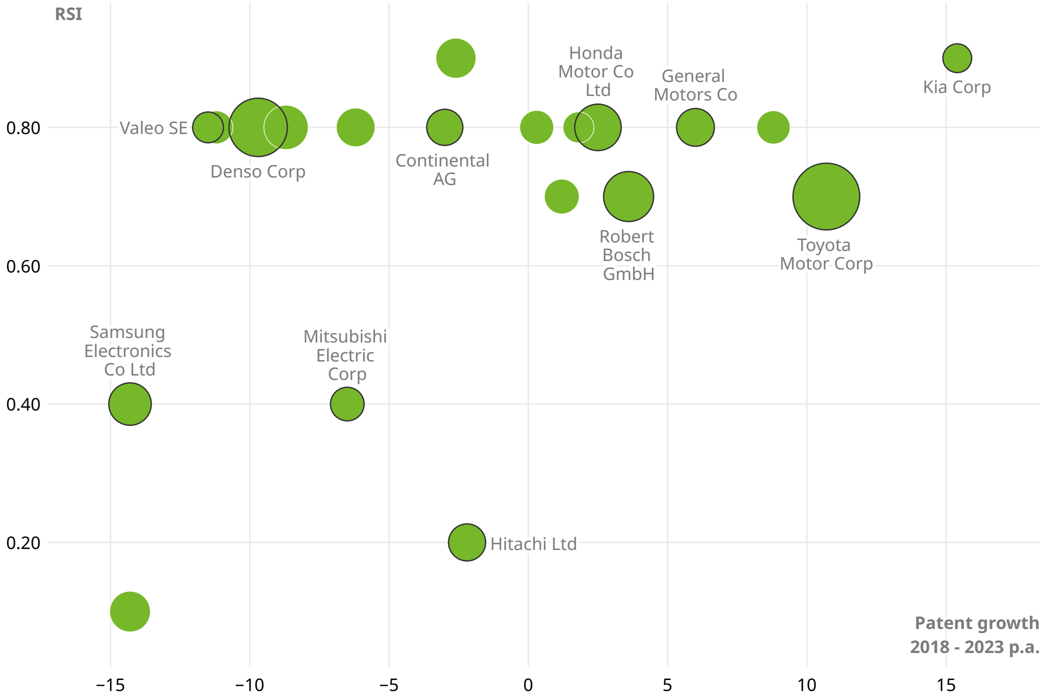
	Device-to-device communications Patent family publications 2000 - 2023	Navigation Patent family publications 2000 - 2023	Cloud Patent family publications 2000 - 2023	Cyber Security Patent family publications 2000 - 2023	Low-latency communication Patent family publications 2000 - 2023
China	24,677	73,688	22,315	4,040	5,621
US	17,708	37,570	9,090	3,653	5,005
Japan	12,586	57,832	1,480	1,410	937
Republic of Korea	12,422	21,902	1,883	1,008	4,641
Germany	6,378	23,794	1,211	1,052	757
France	1,414	3,558	310	292	289
UK	1,395	2,879	545	325	383
Canada	1,315	1,962	566	217	351
India	1,026	1,433	626	202	466
Sweden	690	1,815	155	68	219
Australia	689	1,142	293	144	218
Israel	568	1,510	288	242	133
Netherlands	419	832	78	71	115
Italy	384	915	122	83	110
Finland	328	384	125	36	131
Switzerland	311	624	105	72	52
Spain	255	465	144	61	163
Austria	226	707	50	40	28
Russia	202	790	60	60	129
Singapur	176	469	87	47	30

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

The Japanese carmaker Toyota Motor, the Japanese auto parts supplier Denso and the German auto parts supplier Bosch published the most patent families in Communication and Security technologies (Figure A38). Since 2018, Toyota Motor, Kia and Hyundai have achieved the highest patent growth rates. The majority of top patent holders have a very high RSI score, the exceptions being the large electronics conglomerates Panasonic, Hitachi, Mitsubishi Electric and Samsung Electronics.

Toyota Motor, Denso, and Bosch published the most patent families in Communication and Security technologies.

Figure A38 Communication and Security: comparison of top patent owners, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)



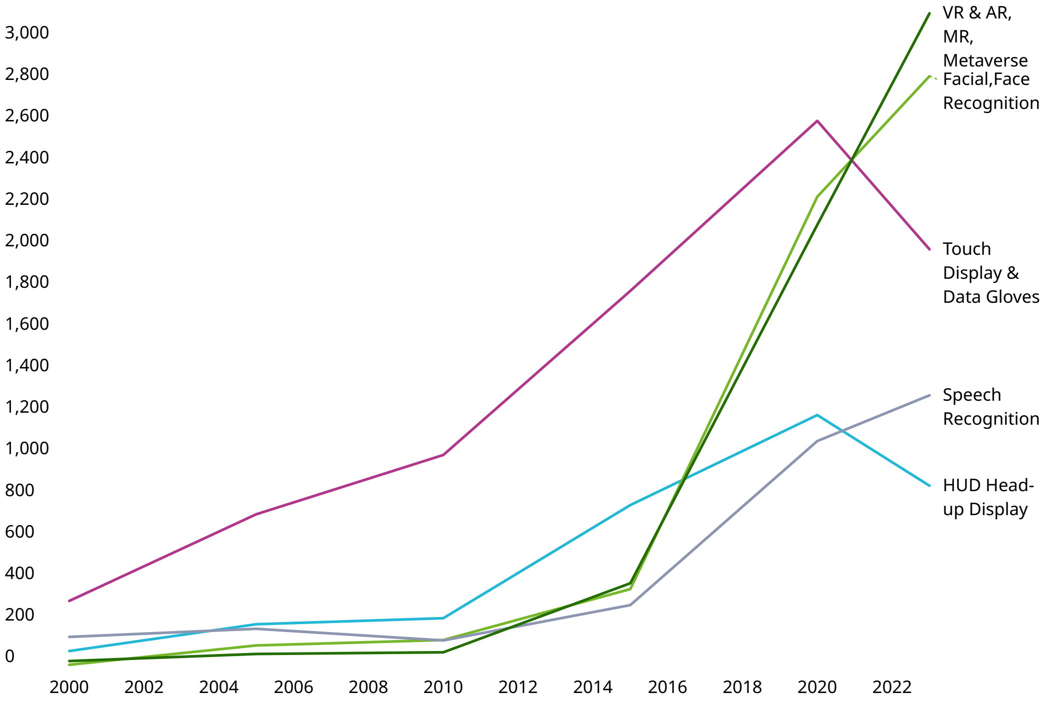
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

The top research players in the five subgroups are as follows (Figure A39):

- Toyota Motor and Denso are the research leaders in terms of patent family publications in navigation technologies.
- Toyota Motor is also at the top spot for device-to-device communication research activities.
- Intel, Bosch and Panasonic Holdings are at the top of the ranking for cyber security research in land transport applications.
- Intel and Ford Motor have published most patent families in cloud technologies.
- Samsung Electronics and LG Electronics are technology leaders in low-latency communication.

Toyota Motor and Denso lead research in navigation technologies, while Toyota Motor also ranks first in device-to-device communication research activities.

Figure A39 Top 5 patent owners in the subgroups of Communication and Security in Land transportation, 2000–2023



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

Human–Machine Interface

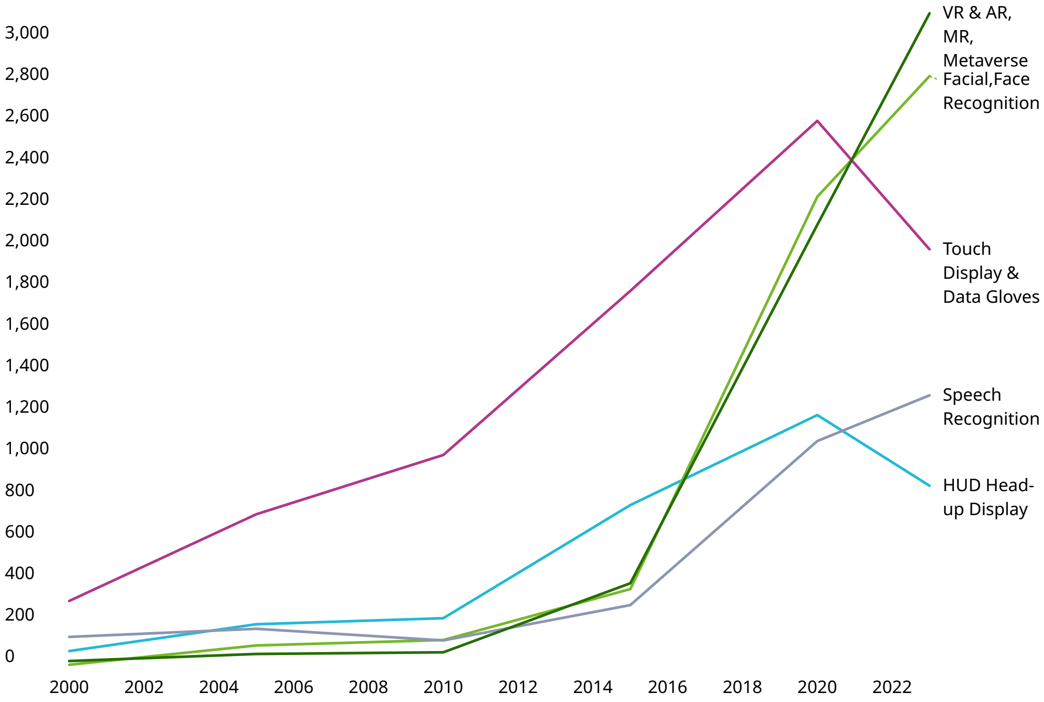
Advanced Human–Machine Interfaces (HMIs) are significantly improving land transport, by making interactions more intuitive, safer and more responsive, thereby ensuring a safe, efficient and enjoyable driving experience.

Patenting activity has been particularly strong in Virtual Reality (VR)/Augmented Reality (AR)/ metaverse technologies[5] in recent years. The number of patent families has increased from only 38 in 2000 to more than 3,150 in 2023, with a sharp increase in the number of patents in 2023 (Figure A40). A similarly strong innovation dynamic can be observed in the field of facial recognition, where the number of patent family publications has jumped from 20 in 2000 to 2,851 in 2023. In terms of annual patenting activity, the field of touch displays and data gloves has long been the largest HMI subgroup. However, the number of publications in this patent family has started to decline over recent years after having reached a peak of 2,656 in 2019. The same is true for research activities in the development of head-up displays for land vehicles, which have also declined recently after peaking at 1,418 patent family publications in 2019. Speech recognition is another important area of research. Patent family publications in this field increased from around 150 in 2000 to more than 1,300 in 2023.

5 Virtual reality (VR): a fully virtual 3D environment generated by computer technology, where users can immerse themselves and interact through devices like VR headsets. Augmented reality (AR): a technology that overlays virtual content onto the real world. Using devices like smartphones or AR glasses, users can see both the real environment and virtual elements seamlessly integrated. Metaverse: a shared digital space that combines virtual and real-world elements, often incorporating VR, AR and other technologies. The metaverse enables activities such as socializing, entertainment, work and shopping within a vast and interconnected digital ecosystem.

Patenting activity in VR/AR/Metaverse technologies has been particularly strong in recent years.

Figure A40 Human–Machine Interface: development of global patent family publications, 2000–2023



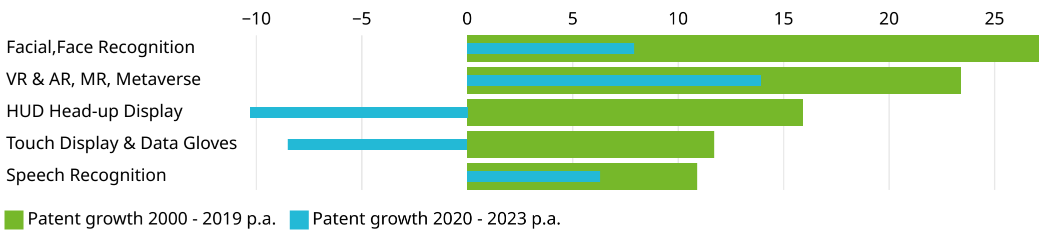
Note: VR is virtual reality, AR is augmented reality, MR is mixed reality.
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

As a result, patenting activity in recent years indicates a shift in research priorities away from head-up displays and touch displays/data gloves toward the development of more immersive and intuitive VR/AR/metaverse applications and further advances in facial and speech recognition.

Looking at the compound annual growth rates over different time periods, we can again see that the fields of VR/AR/metaverse and facial recognition have seen the strongest and most consistent increase in research activity (Figure 41). In contrast, patent growth rates for head-up displays and touch displays/data gloves have turned negative over recent years.

Looking at the compound annual growth rates over different time periods, it is clear that VR/AR/Metaverse and face recognition have experienced the strongest and most consistent increase in research activity.

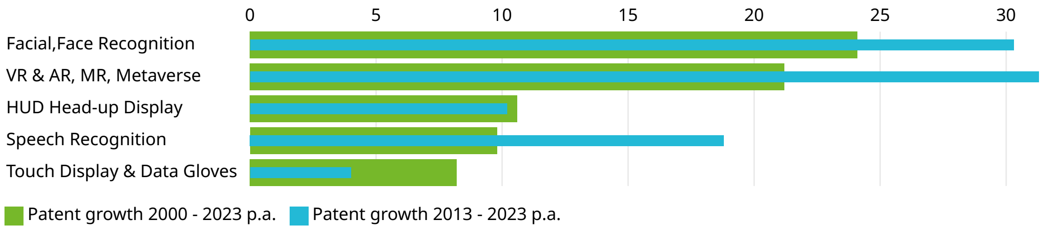
Figure A41a Growth of patent family publications, part 1



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

In contrast to other fields, patent growth rates for head-up displays and touch displays/ data gloves have turned negative in recent years.

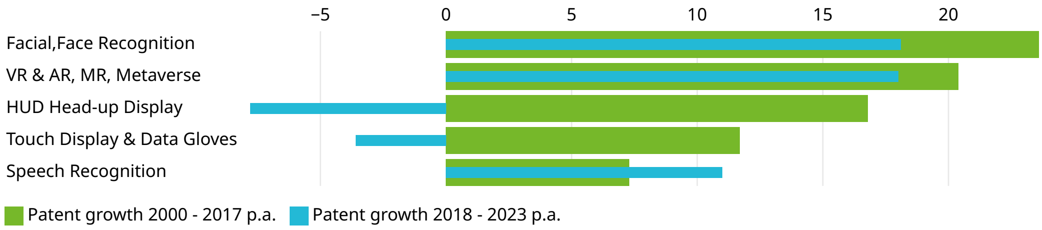
Figure A41b Growth of patent family publications, part 2



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

Patent growth rates for head-up displays and touch displays/data gloves have significantly declined in the last five years.

Figure A41c Growth of patent family publications, part 3



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

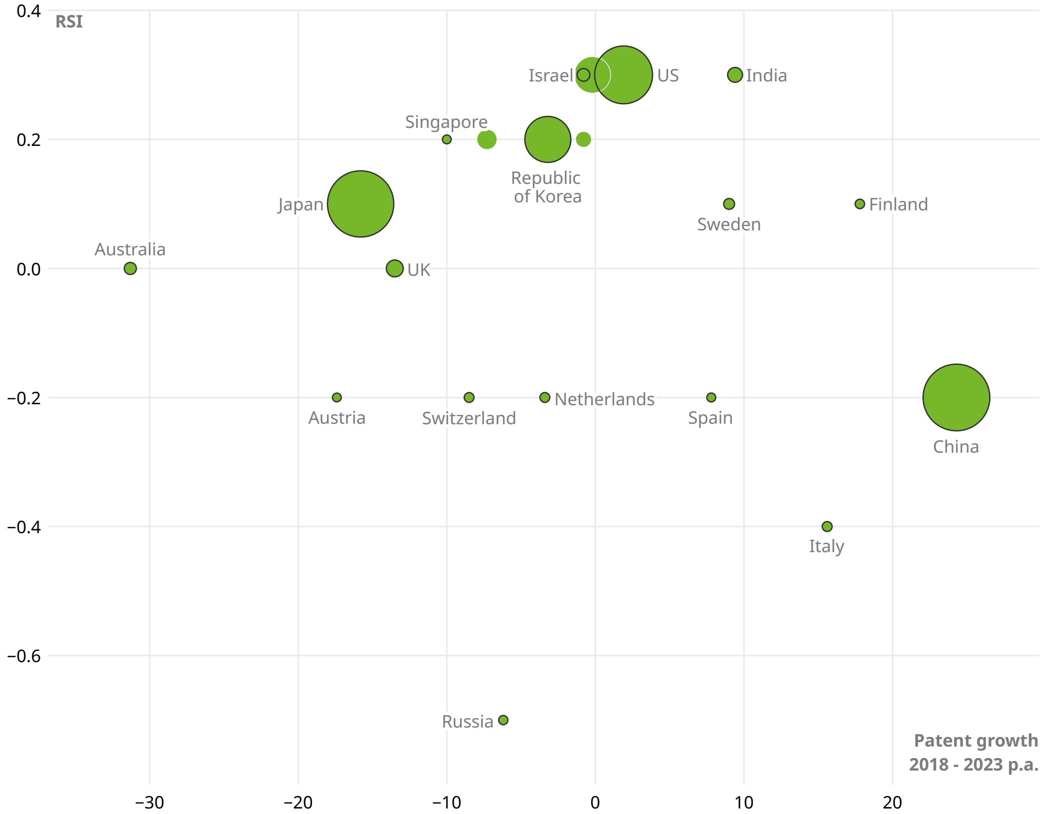
The country comparison in the field of HMI technologies in land transport applications shows the size of patent family publications at country level (size of bubbles), the compound annual patent growth rates between 2018 and 2023 and the relative specialisation index (RSI) for the whole period analysed, 2000 to 2023.

The resulting graph shows that inventors from Japan, China and the US are responsible for most patent families. Germany and the Republic of Korea are other relevant research locations. Patent growth since 2018 has been highest in China, Finland and Italy.

In terms of RSI, Germany, India and the United States show a high level of specialisation in HMI technologies.

The inventors from Japan, China, and the US account for the majority of patent families, with Germany and the Republic of Korea also being significant research locations.

Figure A42 Human–Machine Interface: comparison of top patent owners, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)

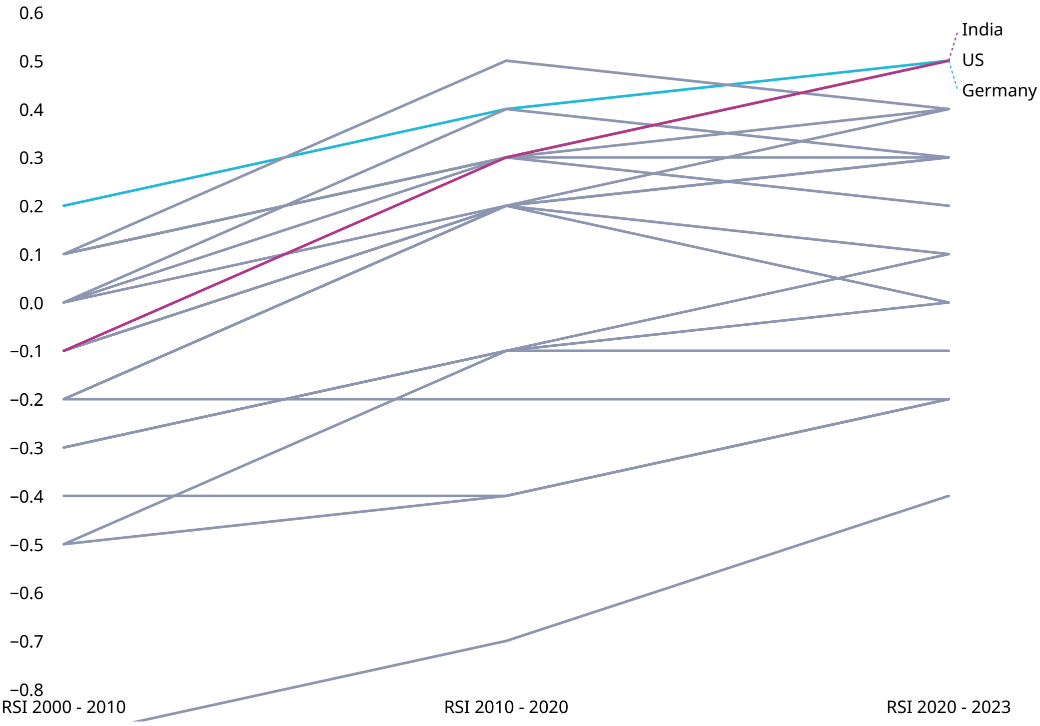


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

A closer look at the RSI values over the different time periods for a broader group of countries reveals the above-average specialisation of the US and Germany. Both countries have increased their RSI values significantly since 2000. In general, RSI values have increased in almost all countries since 2000, showing the increasing importance of HMI in land transport.

In general, RSI values have increased in almost all countries since 2000, highlighting the growing importance of HMI technologies in land transport.

Figure A43 Human–Machine Interface in Land transportation: changes in Relative Specialization Index (RSI) across inventor countries, 2000–2023



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

An analysis of the top research countries in the different HMI subgroups reveals the following key findings:

- Japan is the technology leader in both touch display/data gloves and head-up displays.
- China clearly ranks first in terms of patenting activity in speech recognition.
- China and the US lead the ranking in face recognition and VR/AR/Metaverse.

Japan is the technology leader in both touch displays/data gloves and head-up displays, while China and the US lead in face recognition and VR/AR/Metaverse technologies.

Figure A44 Top 20 inventor locations for Human–Machine Interface subgroups, 2000–2023

	Face Recognition Patent family publications 2000 - 2023	VR/AR/Metaverse Patent family publications 2000 - 2023	Touch Display/data gloves Patent family publications 2000 - 2023	Head-Up Display Patent family publications 2000 - 2023	Speech Recognition Patent family publications 2000 - 2023
China	6,618	5,758	6,315	1,567	4,329
US	5,168	5,290	6,436	1,692	2,135
Japan	2,569	1,890	11,290	6,202	1,626
Republic of Korea	1,424	2,716	4,955	1,351	1,715
Germany	669	1,413	3,118	1,733	670
India	314	387	262	63	104
UK	263	366	540	186	116
Canada	244	331	430	78	159
Israel	211	219	176	69	76
France	145	362	850	495	139
Australia	135	113	272	21	67
Switzerland	90	88	89	25	26
Sweden	70	121	164	65	36
Italy	67	61	106	38	27
Singapur	61	49	58	14	15
Spain	57	50	66	13	17
Russia	50	79	68	39	11
Netherlands	49	67	129	20	29
Finland	42	84	96	21	18
Austria	30	59	59	21	13

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

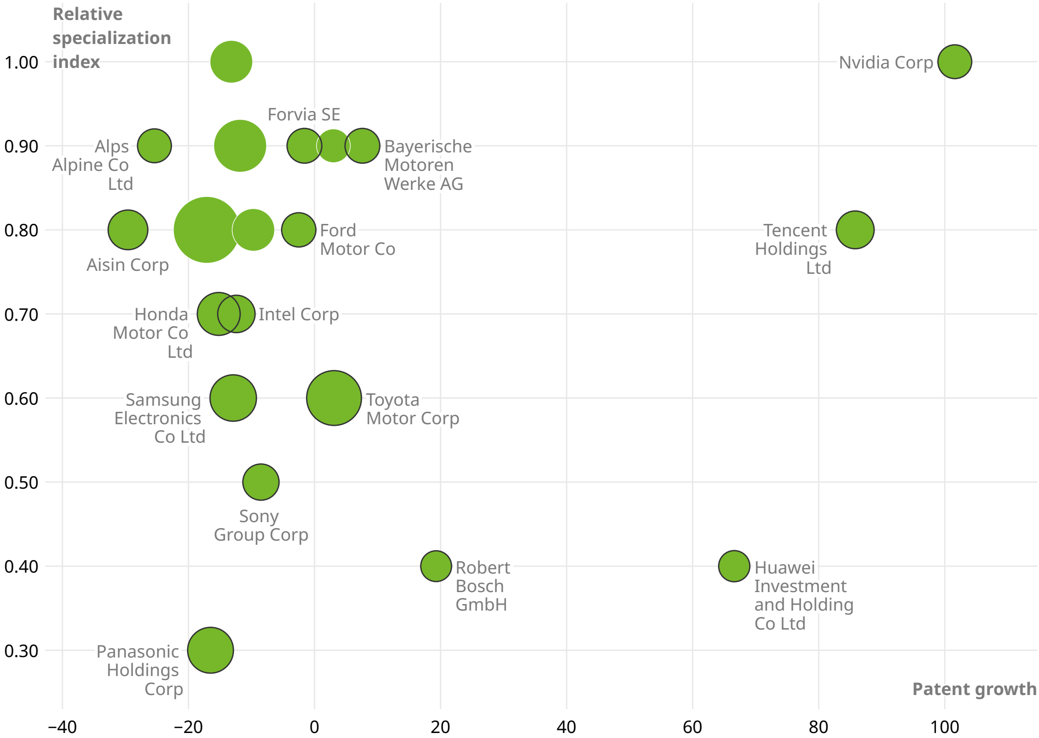
Japanese car supplier Denso is by far the largest patent holder in HMI technologies in land transport application, ahead of Toyota Motor and Volkswagen.

US chip company Nvidia leads the growth ranking since 2018, ahead of Tencent Holdings.

Most top patent holders also have high RSI scores, the only exceptions being Panasonic Holdings, Bosch and Huawei.

In the field of HMI technologies for land transport, Denso stands as the leading patent holder, surpassing Toyota Motor and Volkswagen.

Figure A45 Human–Machine Interface: comparison of top patent owners, number of patent families (2000–2023), Relative Specialization Index (2000–2023) and compound annual growth rate (2018–2023)



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

The top research players in the five sub-groups are as follows:

- Denso is the research leader touch displays / data gloves in terms of patent families published.
- Japanese display manufacturer Nippon Seiki is the top researcher in head-up displays, just ahead of Denso.
- Samsung Electronics ranks first in speech recognition patent families.
- Korea's LG Electronics leads in VR/AR/Metaverse patenting activity.
- The two US chip companies Intel and Nvidia and the Chinese gaming giant Tencent are among the top research companies in both face recognition and VR/AR/Meta in land transport applications.

Samsung Electronics leads in speech recognition, LG Electronics in VR/AR/Metaverse, and Intel, Nvidia, and Tencent are top in face recognition and VR/AR/Metaverse for land transport.

Figure A46 Top 5 patent owners in the subgroups of Human–Machine Interface in Land transportation, 2000–2023

Subgroup	Company	Country	Patent Family Publications
Face Recognition	Huawei	China	254
Face Recognition	Toyota Motor Corp	Japan	357
Face Recognition	Intel Corp	US	483
Face Recognition	Tencent Holdings Ltd	China	508
Face Recognition	Nvidia Corp	US	553
VR/AR/Meta	Samsung Electronics	Republic of Korea	445
VR/AR/Meta	Nvidia	US	531
VR/AR/Meta	Intel	US	570
VR/AR/Meta	Tencent Holdings	China	638
VR/AR/Meta	LG Electronics	Republic of Korea	765
Speech Recognition	Denso	Japan	179
Speech Recognition	LG Electronics	Republic of Korea	204
Speech Recognition	Honda Motor	Japan	215
Speech Recognition	Volkswagen	Germany	221
Speech Recognition	Samsung Electronics	Republic of Korea	263
Head-Up Displays	Yazaki	Japan	372
Head-Up Displays	Volkswagen	Germany	423
Head-Up Displays	Panasonic Holdings	Japan	428
Head-Up Displays	Denso	Japan	869
Head-Up Displays	Nippon Seiki	Japan	1,087
Touch Displays/Data Gloves	Panasonic Holdings	Japan	710
Touch Displays/Data Gloves	Aisin	Japan	839
Touch Displays/Data Gloves	Toyota Motor	Japan	1,177
Touch Displays/Data Gloves	Volkswagen	Germany	1,190
Touch Displays/Data Gloves	Denso	Japan	1,816

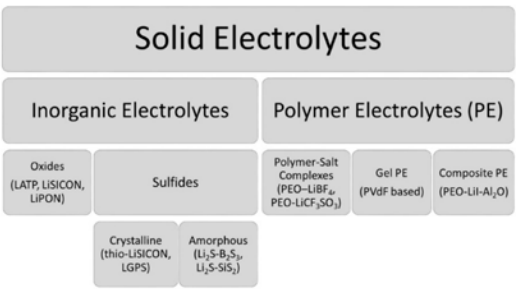
Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

Emerging technology in detail: solid state batteries

Solid-state batteries (SSBs) represent a significant advancement in battery technology, leveraging solid electrodes and a solid electrolyte instead of the liquid or polymer gel electrolytes found in conventional lithium-ion or lithium-polymer batteries (Janek and Zeier, 2023).[1] These solid electrolytes can be made from various materials, including ceramics, glass, and sulfides, providing a stable medium for ion transport within the battery. The design of SSBs offers several key benefits over traditional batteries, making them a promising candidate for future applications in electric vehicles (EVs) and other land transportation modes (Janek and Zeier, 2023).[2]

Solid-state batteries are particularly relevant for both freight and passenger vehicles due to their potential to enhance performance and safety (Gao et al. 2018).[3] For passenger vehicles, SSBs can significantly extend driving ranges, reduce charging times, and improve overall vehicle safety. In freight transport, which demands high energy capacity and robustness for long travel distances and heavy loads, SSBs offer increased durability and energy efficiency. This is essential for reducing operational costs and environmental impact, aligning with the growing demand for sustainable transportation solutions.

According to Karabelli et al. (2021) several types of solid-state batteries that hold promise for future land transportation.[4] Lithium metal solid-state batteries use lithium metal as the anode and various types of solid electrolytes, offering higher energy densities compared to conventional lithium-ion batteries. Sulfide-based solid-state batteries utilize sulfide-based solid electrolytes, which have high ionic conductivity and are relatively easier to process. Oxide-based solid-state batteries use oxide materials as the solid electrolyte, known for their stability and safety, although they generally have lower ionic conductivities compared to sulfide-based electrolytes.



Source: Karabelli et al. (2021).

1 Janek, J. and W. G. Zeier (2023). Challenges in speeding up solid-state battery development. Nature Energy, 8(3), 230–240.
2 Janek, J. and W. G. Zeier (2023). Challenges in speeding up solid-state battery development. Nature Energy, 8(3), 230–240.
3 Gao, Z., H. Sun, L. Fu, F. Ye, Y. Zhang, W. Luo and Y. Huang (2018). Promises, challenges, and recent progress of inorganic solid-state electrolytes for all-solid-state lithium batteries. Advanced materials, 30(17), 1705702.
4 Karabelli, D., K. P. Birke and M. Weeber (2021). A performance and cost overview of selected solid-state electrolytes: race between polymer electrolytes and inorganic sulfide electrolytes. Batteries, 7(1), 18.
5 Karabelli, D., K. P. Birke and M. Weeber (2021). A performance and cost overview of selected solid-state electrolytes: race between polymer electrolytes and inorganic sulfide electrolytes. Batteries, 7(1), 18.

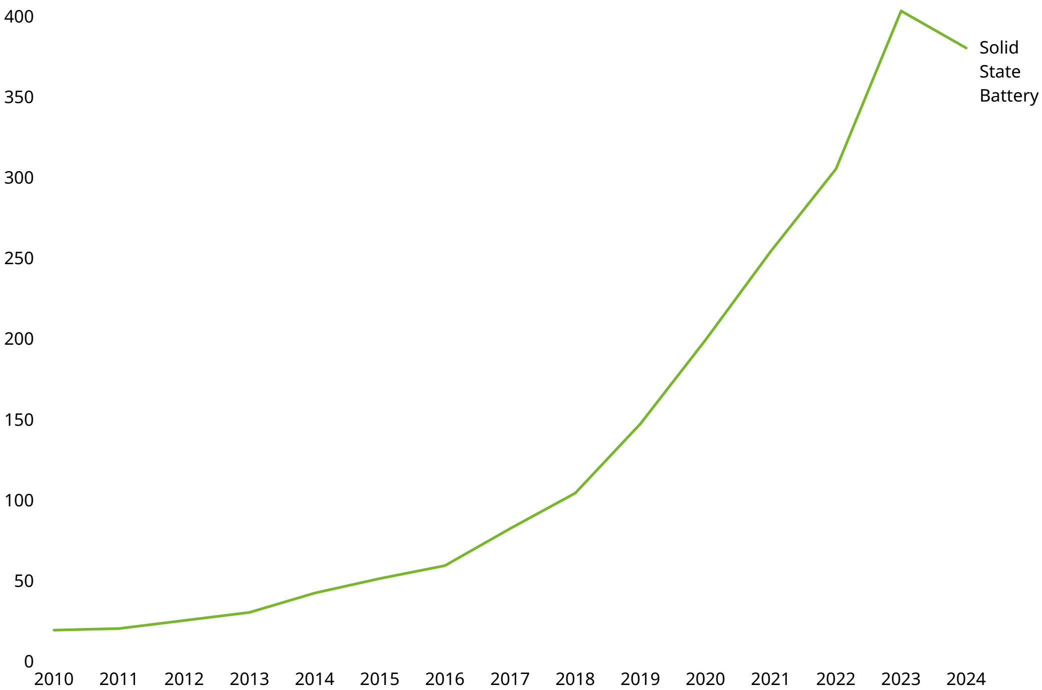
The core benefits of solid-state batteries include enhanced safety, higher energy density, longer lifespan, and fast charging capability. Solid-state batteries are inherently safer because solid electrolytes are non-flammable, significantly reducing the risk of thermal runaway and fires, a crucial benefit for automotive applications (Mauger et al. 2019).[6] They can achieve higher energy densities, meaning they can store more energy in a given volume compared to conventional batteries, which translates to longer driving ranges for EVs. SSBs can achieve energy densities of up to 500 watt-hours per kilogram, which is about double that of conventional lithium-ion batteries (ASME 2021).[7] Finally, solid-state batteries can support higher charging rates because the solid electrolytes can handle higher currents without degrading, reducing the charging time of EVs and making them more convenient for users (Ali et al. 2023).[8]

Solid-state batteries (SSBs) have several current limitations despite their advantages. Commercial-scale production of SSBs presents significant challenges, such as maintaining material purity and achieving uniformity in solid electrolytes. The manufacturing processes for SSBs are more complex and costly compared to traditional lithium-ion batteries. Ensuring the stability of solid electrolytes and their interfaces with electrodes is crucial for long-term performance and reliability, but this remains a significant hurdle. Many solid electrolytes suffer from chemical degradation and poor contact with electrodes, and some may exhibit poor performance at lower temperatures, impacting the battery's efficiency and lifespan in different climatic conditions. These issues are current topics in the increased scientific literature, as displayed in the following analysis of a scientific literature analysis.

Solid-state batteries: scientific publications

From 2004 to 2016, solid-state battery publications grew gradually, but from 2017 to 2023, there was a significant surge, reflecting growing interest in overcoming commercialization challenges.

Figure A47 Development of global scientific publications in solid-state batteries, 2010–2023



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

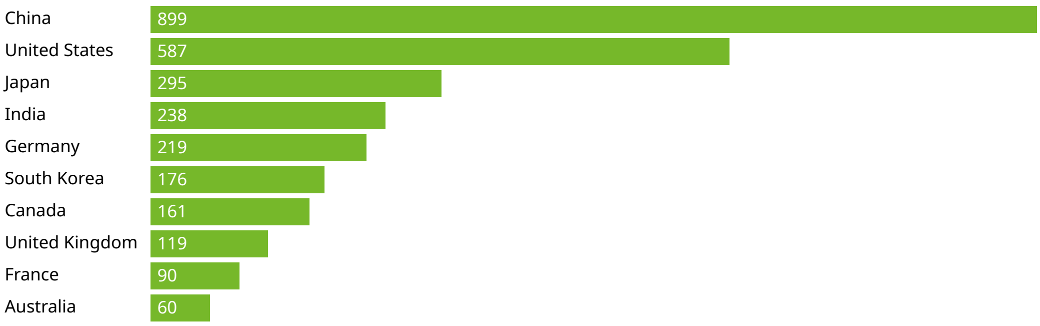
The visualization displays the number of scientific documents related to solid-state batteries published annually from 2004 to 2023. The data shows a steady increase in the number of

6 Mauger, A., C. M. Julien, A. Paolella, M. Armand and K. Zaghib (2019). Building better batteries in the solid state: A review. Materials, 12(23), 3892.
7 ASME (2021). Advancing battery technology for modern innovations. American Society of Mechanical Engineers. Available at: www.asme.org/topics-resources/content/advancing-battery-technology-for-modern-innovations.
8 Ali, Z. M., M. Calasan, F. H. Gandoman, F. Jurado and S. H. A. Aleem (2023). Review of batteries reliability in electric vehicle and E-mobility applications. Ain Shams Engineering Journal, 102442.

documents over the years, with a significant surge starting around 2017. Between 2004 and 2016 the number of documents related to solid-state batteries remains relatively low and increases gradually. Within 2017 to 2023 a noticeable spike in the number of publications can be observed, indicating a growing interest and focus in the scientific community on solid-state batteries overcoming the mentioned challenges for commercializing solid state batteries.

China leads in solid-state battery publications with around 850, followed by the United States with approximately 600, highlighting significant investment in the field.

Figure A48 Origin countries for scientific publications in solid-state batteries



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

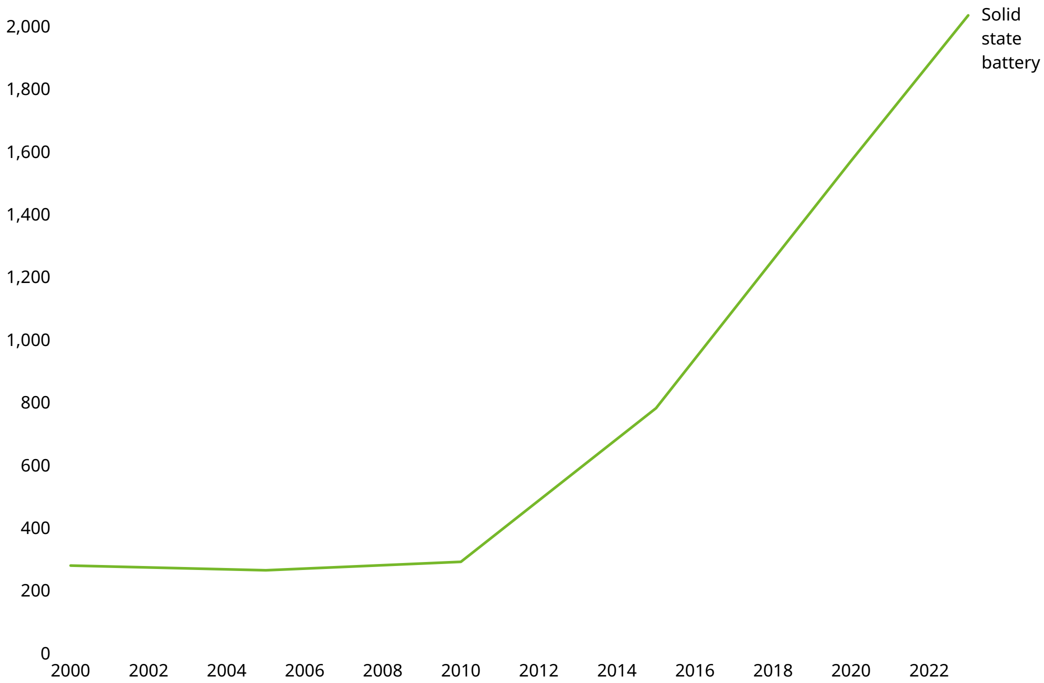
The visualization shows the number of scientific publications on solid-state batteries by country. China leads with approximately 850 publications, followed by the United States with around 600, reflecting strong emphasis and investment in this field. Japan has about 300 publications, showcasing its ongoing innovation in battery technology. India and Germany each contribute around 200 publications, indicating substantial research efforts. South Korea, driven by its electronics and automotive industries, has approximately 180 publications. Canada and the United Kingdom each have around 100 publications, while France and Australia have slightly fewer. Overall, the chart highlights the global effort in solid-state battery research, with China and the United States at the forefront.

Solid state batteries: patent data

The patent analysis also reveals an increase in patenting activity in solid state batteries. The number of published patent families has increased from only 290 in 2010 to 2033 in 2023.

A significant increase in patenting activity in solid state batteries is observed.

Figure A49 Development of global patent family publications in solid-state battery technologies, 2000–2023

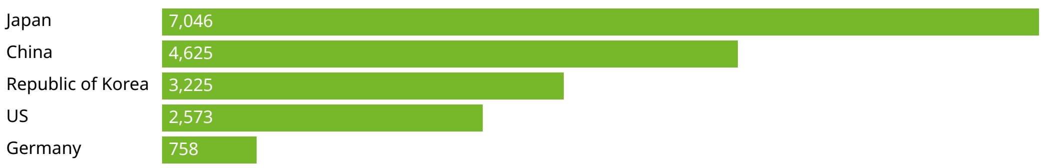


Source: WIPO, based on patent data from EconSight/IFI Claims, October 2024.

On a country level, most of the solid state battery patent families were published from inventors from Japan (more than 7000 patent families between 2000 and 2023). Japan is responsible for almost 40% of all solid state battery patent families published within that time period.

Most solid-state battery patent families, over 7,000, were published by inventors from Japan between 2000 and 2023, accounting for nearly 40% of all patent families in this field during that period.

Figure A50 Patent family publications in solid-state batteries, 2000–2023



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

Solid state batteries: patent examples

Patent activities in the field of solid-state batteries have surged in the last decade, reflecting the intense research and development efforts by companies and academic institutions. Leading companies in the automotive and battery industries, such as Toyota, BMW (e.g. Solid Power), and QuantumScape, are at the forefront of patent filings, focusing on various aspects of solid-state technology from material innovations to manufacturing processes. For instance, Toyota plans to showcase its solid-state battery technology in a prototype vehicle by the mid-2020s, emphasizing advancements in range and safety.[9] QuantumScape reported significant progress in scaling up its solid-state battery technology, with successful testing of multilayer battery

9 Toyota Europe (2023). Toyota's advanced battery technology roadmap. Available at: https://newsroom.toyota.eu/toyotas-advanced-battery-technology-roadmap.

cells.[10] Furthermore, companies like BMW started collaborations and investments to strengthen innovation activities, targeting commercialization by the end of this decade.[11]

Toyota's patent (WO2011142150A1) outlines a solid-state battery technology featuring an ionic conductor with a spinel structure, represented by the formula (AxM1−xyMy′)Al2O4(AxM1−xyMy′)Al2O4, where "A" is a monovalent metal like lithium, "M" is a divalent metal such as magnesium or zinc, and "M'" is aluminum. This conductor is used in various layers of the battery, including the cathode, anode, and solid electrolyte layers, with specific materials like LiMn2O4LiMn2O4 for the cathode and Li4Ti5O12Li4Ti5O12 for the anode. The design aims to improve battery performance and stability by optimizing the conductor's composition and integration.

FIG. 1

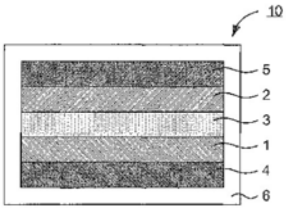
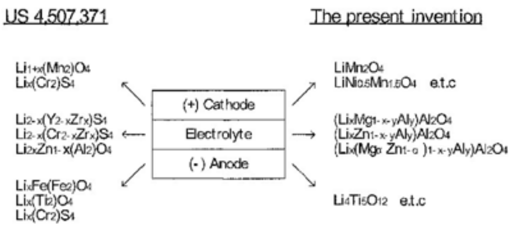


FIG. 2



Source: WO2011142150A1.

The use of a spinel structure ionic conductor, specifically tailored with lithium, magnesium, zinc, and aluminum, can enhance the ionic conductivity and stability of the battery. By incorporating these materials into the cathode, anode, and solid electrolyte layers, the design addresses key challenges in solid-state battery development, such as improving energy density, safety, and longevity. If successfully implemented, this could lead to more efficient, durable, and commercially viable solid-state batteries.

QuantumScape's patent US10439251B1 focuses on lithium-stuffed garnet materials suitable for use as electrolytes and catholytes in solid-state battery applications. The core invention involves garnet compositions, including those doped with alumina, which enhance the ionic conductivity and stability of the battery. The patent also describes the creation of lithium-stuffed garnet thin films with fine grains, which are integral for improving battery performance. Additionally, it outlines methods for manufacturing these garnet materials and preparing dense, thin free-standing membranes (less than 50 micrometers) for use in various battery components.

10 Volkswagen Group (2024). PowerCo confirms results: QuantumScape's solid-state cell passes first endurance test. Available at: www.volkswagen-group.com/en/press-releases/powerco-confirms-results-quantumscapes-solid-state-cell-passes-first-endurance-test-18031.

11 BMW Group (2021). BMW Group strengthens leadership position in battery technology with investment in solid-state innovator Solid Power. Available at: www.press.bmwgroup.com/global/article/detail/T0331495EN/bmw-group-strengthens-leadership-position-in-battery-technology-with-investment-in-solid-state-innovator-solid-power?language=en.

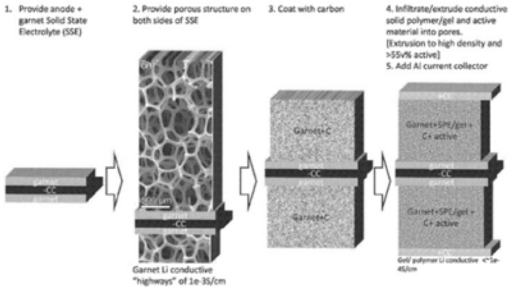


Figure 25

Source: US10439251B1.

The patent further details innovative sintering techniques, such as field-assisted sintering (FAST), to optimize the fabrication of solid-state energy storage devices and their components. This technology aims to advance solid-state batteries by improving their performance, stability, and manufacturability.

While spinel materials offer high thermal stability, good electrical conductivity, and cost-effectiveness, garnet materials provide high ionic conductivity, chemical stability, and resistance to dendrite formation. These distinct advantages make both types of materials essential for the development of advanced solid-state batteries, each contributing to different aspects of battery performance and safety.

The adoption of solid-state battery technology in land transportation is influenced by evolving regulations and standards aimed at promoting safety, performance, and environmental sustainability. Organizations like the International Electrotechnical Commission (IEC) and the Society of Automotive Engineers (SAE) are working on developing standards specific to solid-state batteries, addressing testing protocols, safety requirements, and performance benchmarks to ensure their reliable integration into commercial and passenger vehicles.[12] [13]

12 Intertek (2024). IEC 62133: Safety testing for lithium ion batteries. Available at: www.intertek.com/batteries/iec-62133.
13 SAE (2021). Measuring properties of li-ion battery electrolyte, J3042_202101. Society of Automobile Engineers. Available at: www.sae.org/standards/content/j3042_202101.

Emerging technology in detail: platooning

Platooning represents a significant advancement in land transportation technology, enabling multiple vehicles to travel closely together at high speeds, controlled by automated driving systems and vehicle-to-vehicle (V2V) communication. This technology involves forming a convoy of vehicles, typically trucks, where the lead vehicle is manually driven, and the following vehicles are autonomously controlled to maintain close distances and synchronized movements (Balador et al., 2022).[1] The vehicles communicate with each other through wireless technologies to ensure coordinated acceleration, braking, and steering.

Platooning is particularly relevant for both freight and passenger vehicles due to its potential to enhance efficiency, safety, and reduce operational costs. In freight transport, platooning allows trucks to travel in closely spaced formations, reducing aerodynamic drag and, consequently, fuel consumption. Studies have shown that platooning can lead to fuel savings of up to 10% for trailing vehicles and 5% for the lead vehicle, translating into significant cost reductions for logistics companies (NACFE, 2018).[2] For passenger vehicles, platooning can improve traffic flow, reduce congestion, and enhance road safety by minimizing human error and enabling more predictable vehicle behavior (Mushtaq et al., 2021).[3]

Thus, the technological benefits of platooning include improved fuel efficiency, enhanced safety, and increased road capacity. By reducing aerodynamic drag, platooning significantly lowers fuel consumption and greenhouse gas emissions, contributing to more sustainable transportation practices. The synchronized movements of platooned vehicles reduce the likelihood of accidents caused by sudden braking or lane changes, enhancing overall road safety. Furthermore, platooning increases road capacity by allowing vehicles to travel closer together, potentially alleviating traffic congestion in urban areas (Mushtaq et al., 2021).[4]

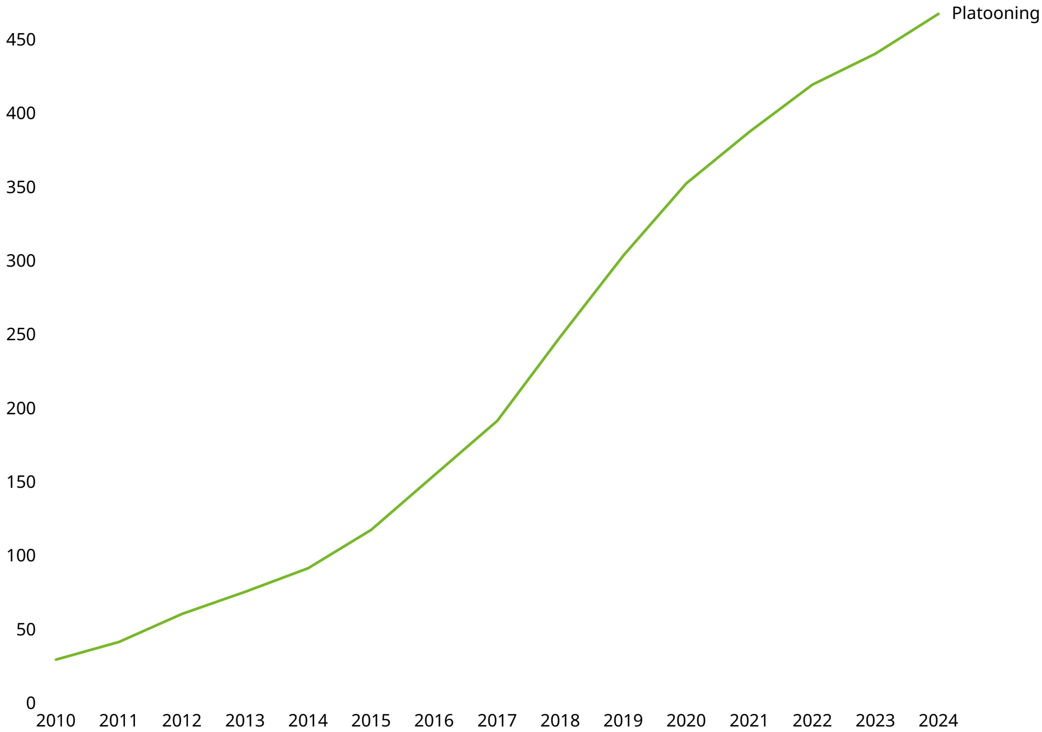
However, platooning also faces several challenges and limitations. These include the need for reliable V2V communication systems, regulatory and legal hurdles, and the requirement for consistent road infrastructure to support automated driving technologies (Ahangar et al., 2021).[5] Research is ongoing to address these issues, with a focus on improving the robustness of communication systems, developing appropriate legal frameworks, and ensuring that road infrastructure can support platooning operations (Lesch, 2021).[6]

1 Balador, A., A. Bazzi, U. Hernandez-Jayo, I. de la Iglesia and H. Ahmadvand (2022). A survey on vehicular communication for cooperative truck platooning application. Vehicular Communications, 35, 100460.
2 NACFE (2018). Confidence Report on Two-truck Platooning. North American Council for Freight Efficiency. Available at: https://nacfe.org/wp-content/uploads/2018/02/TE-Platooning-CR-FINAL-_0.pdf.
3 Mushtaq, A., I. U. Haq, W. U. Nabi, A. Khan and O. Shafiq (2021). Traffic flow management of autonomous vehicles using platooning and collision avoidance strategies. Electronics, 10(10), 1221.
4 Mushtaq, A., I. U. Haq, W. U. Nabi, A. Khan and O. Shafiq (2021). Traffic flow management of autonomous vehicles using platooning and collision avoidance strategies. Electronics, 10(10), 1221.
5 Ahangar, M. N., Q. Z. Ahmed, F. A. Khan and M. Hafeez (2021). A survey of autonomous vehicles: Enabling communication technologies and challenges. Sensors, 21(3), 706.
6 Lesch, V., M. Breitbach, M. Segata, C. Becker, S. Kounev and C. Krupitzer (2021). An overview on approaches for coordination of platoons. IEEE Transactions on Intelligent Transportation Systems, 23(8), 10049–10065.

Platooning: scientific publications

A significant rise in scientific research on platooning is seen, especially from 2018 onward, reflecting its growing recognition as a key technology for the future of land transportation.

Figure A51 Development of global scientific publications in platooning, 2010–2024

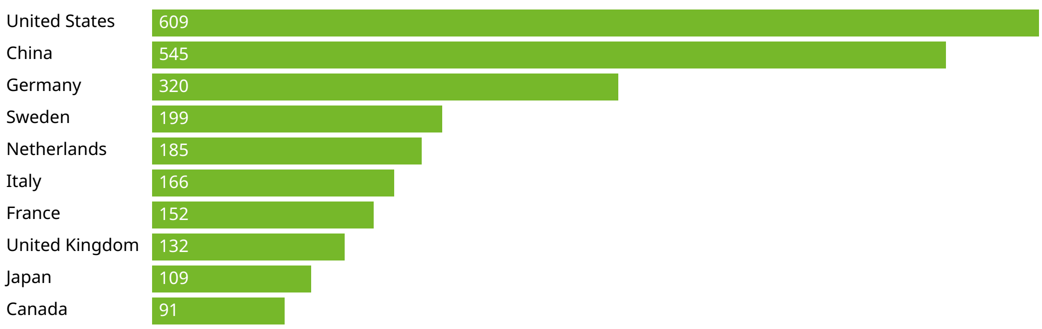


Source: WIPO, based on publication data from EconSight/Scopus, October 2024.

The visualization clearly indicates that scientific research on platooning has gained substantial momentum over the past decade, especially from 2018 onwards. The exponential growth in publications reflects the increasing recognition of platooning as a viable and beneficial technology for the future of land transportation. Continued research and development in this area are expected to further enhance the feasibility and implementation of platooning systems on a wider scale. Primary research topics in platooning have included advancements in V2V communication technologies, the development of robust control algorithms, and the assessment of platooning's impact on traffic dynamics and fuel efficiency. Researchers are also exploring the integration of platooning with other intelligent transportation systems (ITS) to create more cohesive and efficient road networks.

The leading countries in platooning research, with the United States, China, and Germany at the forefront of scientific publications in land transportation.

Figure A52 Origin countries for scientific publications in solid-state batteries



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

The visualization highlights the number of scientific publications related to platooning in land transportation, with the United States, China, and Germany leading the research efforts.

The United States leads in platooning research, with over 600 documents published. This significant output is driven by the country's robust research infrastructure, substantial funding, and active participation of major automotive and technology companies. The U.S. Department of Transportation (USDOT) has been a major proponent of autonomous vehicle research, including platooning.[7] Initiatives like the Automated Vehicle Research Program and the ITS (Intelligent Transportation Systems) Joint Program Office support research and development in vehicle automation and connectivity. Additionally, projects like the Federal Highway Administration’s (FHWA) Exploratory Advanced Research (EAR) Program focus on advancing platooning technologies. Private sector investments from companies such as Tesla, Uber, and Waymo also contribute significantly to the research landscape, exploring the commercial viability of platooning for freight and passenger transport. These combined efforts aim to enhance road safety, reduce fuel consumption, and improve traffic efficiency.

China ranks second in the number of publications, reflecting its strategic focus on intelligent transportation systems and substantial investments in automotive innovations. The Chinese government has outlined ambitious goals in its national strategies, such as the "Made in China 2025" plan, which emphasizes the development of smart and autonomous vehicles.[8] The Ministry of Industry and Information Technology (MIIT) and the Ministry of Transport (MOT) are actively involved in promoting research and development in this field. Significant funding is directed towards pilot projects and collaborative efforts between universities, research institutes, and industry players. Companies like Baidu, Huawei, and Tencent are heavily investing in autonomous driving and V2V communication technologies essential for platooning. These initiatives are part of China’s broader goal to become a global leader in autonomous and connected vehicle technologies.

Germany is the third most prolific country in terms of platooning research publications. Known for its strong automotive industry, Germany’s research efforts in platooning are driven by major automotive manufacturers like Daimler, BMW, and Volkswagen, as well as research institutions. The German government's "High-Tech Strategy 2025" includes autonomous driving as a key area of focus, promoting innovation through various funding programs (BMWK, 2024).[9] One notable initiative is the "Platooning on German Motorways" project, which involves extensive testing and development of platooning technologies on public roads. This project is supported by the Federal Ministry of Transport and Digital Infrastructure and aims to integrate platooning into existing traffic systems to enhance efficiency and safety. The collaboration between industry leaders and academic institutions ensures that Germany remains at the forefront of platooning research and development.

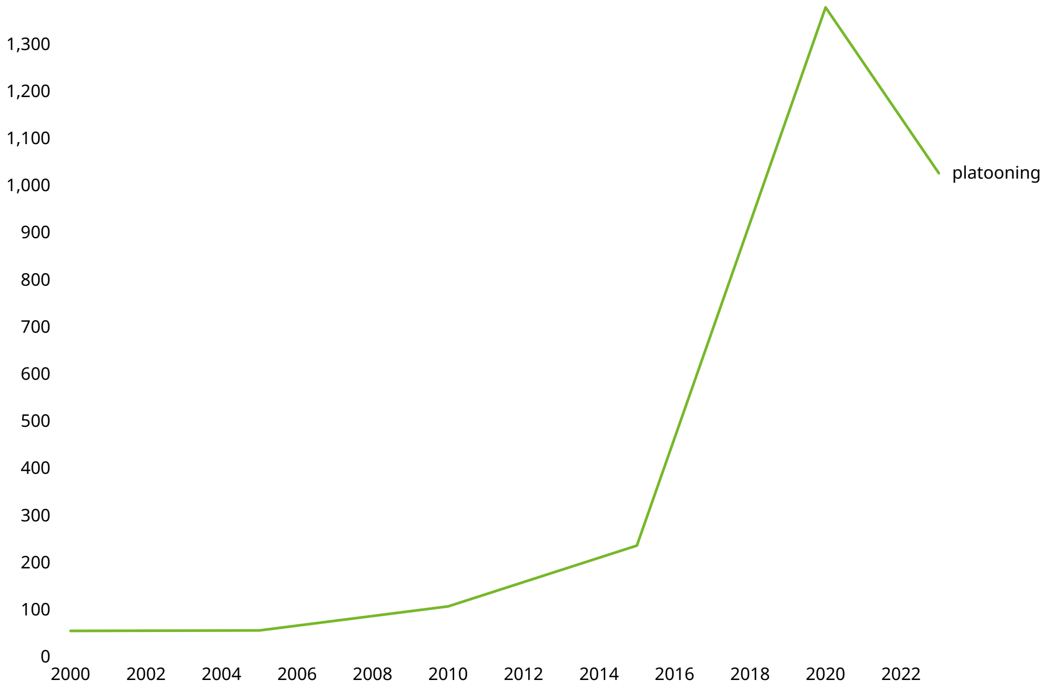
Platooning: patent data

Patent activities related to platooning have been increasing, reflecting the growing interest and investment in this technology. Major automotive and technology companies are actively filing patents for various aspects of platooning, including V2V communication protocols, control systems, and safety mechanisms. Between 2014 and 2023, the number of published patent families per year has increased from 166 to 1024. However, patent family publications have declined in the most recent years after reaching a peak of 1376 in 2020.

7 USDOT (2022). USDOT automated vehicles activities. U.S. Department of Transportation (USDOT). Available at: www.transportation.gov/AV.
8 State Council China (2016). Made in China 2025. Available at: http://english.www.gov.cn/2016special/madeinchina2025.
9 BMWK (2024). Strengthening vehicle manufacturers and component suppliers for the future. Federal Ministry for Economic Affairs and Climate Action. Available at: www.bmwk.de/KOPA35C/automotive-industry-of-the-future.html.

Between 2014 and 2023, the number of published patent families annually rose from 166 to 1024, though there has been a decline in recent years following a peak of 1376 in 2020.

Figure A53 Development of global patent family publications in platooning, 2000–2023



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

On a country level, the US is the top research country in terms of published platooning patent families (3074 patent families between 2000 and 2023). Japan, Germany and China are other leading research countries in the field.

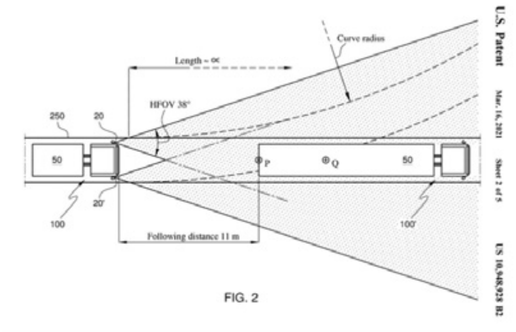
The US leads in platooning patent families with 3074 published between 2000 and 2023, followed by Japan, Germany, and China as other key research countries in the field.

Figure A54 Patent family publications in platooning, 2000–2023

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

Platooning: patent examples

A recent development from DAF (US10948928B2) relates to a method for autonomously guiding motor vehicles in a platooning formation, using steering and headway controllers coupled with lateral and front distance control systems. It involves dual lane side detectors, which could be 2D or 3D laser scanners or integrated cameras in modified side mirrors, providing image data to maintain vehicle alignment and proximity to the leading vehicle. Additionally, these systems are capable of complex tasks such as arbitrating between lateral distance, a pre-set forward look-ahead point, and data from other sensors such as radar for comprehensive vehicle steering and navigation control.



Source: US10948928B2.

Another recent invention from GM (US2023316914A1) provides further insights on how platooning can be considered in the future. The invention outlines a method for providing platooning information via a multi-focal plane augmented reality (AR) display in a host vehicle. It involves receiving data from multiple remote vehicles in a platoon, including their locations, trajectories, and headways. The method determines if the platoon is within a set distance from the host vehicle and then transmits a command to the AR display to show a virtual image that represents a platooning action. This innovative approach leverages augmented reality to improve safety and efficiency in vehicular platooning.

Recent developments in platooning include several pilot projects and real-world trials. For instance, in Europe, the EU-funded ENSEMBLE project aims to demonstrate multi-brand truck platooning on public roads, highlighting the interoperability of platooning technologies across different manufacturers (Cordis, 2023). [10]

Despite these advancements, the practical implementation and commercialization of platooning have faced challenges. Issues such as the need for reliable V2V communication, regulatory and legal hurdles, and the requirement for consistent infrastructure have slowed down widespread adoption. Moreover, recent setbacks and the shifting focus of some companies have led to concerns about the viability of platooning in the near term.

10 CORDIS (2023). ENabling SafE Multi-Brand pLatooning for Europe. European Commission: Community Research and Development Information Service (CORDIS). Available at: https://cordis.europa.eu/project/id/769115.

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, so including them can dilute the focus on more substantial technological advancements.

Patent indicators

Patent application

To obtain a patent, an application must be filed in the appropriate IP office 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 that 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

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

the Cooperative Patent Classification (CPC) in order to harmonize the patent classifications systems between the two offices.

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 provides an in-depth examination of the technological landscape within the domain of land transportation.