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SECURING THE EUROPEAN UNION'S ELECTRONICS ECOSYSTEM

FROM JOHN W. MITCHELL

The strategic importance of the electronics sector cannot be overstated. Electronics are the backbone of modern innovation, driving advancements in aerospace, defence, healthcare, renewable energy, and more. As industries worldwide continue to integrate digital technologies, the demand for sophisticated electronic components will only intensify. For the EU to maintain its competitive edge and ensure industrial resilience, it must develop a self-sufficient and robust electronics manufacturing base.

The landscape of electronics manufacturing is evolving rapidly, and the EU finds itself at a critical juncture. The data presented in this report paints a stark picture of the EU's declining presence in the global electronics manufacturing arena. This decline is alarming, not only because of the economic implications but also due to the strategic vulnerabilities it exposes. The growing gap between domestic production and demand not only threatens the EU's industrial autonomy but also its ability to innovate and lead in next-generation technologies.

The EU's reliance on non-EU electronics is a critical vulnerability. Over the past two decades, the EU's share of global PCB production has plummeted from 13.8% to a mere 2.2%. This significant drop highlights a broader issue of dependency on non-EU suppliers, which is projected to worsen by 2035 if decisive actions are not taken. Looking ahead, the EU's share in electronics systems is expected to dip further, from 22% in 2022 to 20.8% in 2035. Such trends underscore the urgency for a strategic response to bolster the EU's competitiveness and resilience in this vital sector.

To counter these trends, the EU must maintain and enhance its global market share in electronics manufacturing. The EU's ambition to secure a 20% share of global semiconductor production by 2030 is commendable, yet it must be complemented with robust targets for advanced packaging and IC substrates. Currently, the EU holds just 2% and 1.3% of these markets, respectively. Without targeted policies and investments, these shares are poised to drop further, underscoring the need for immediate and concerted efforts to revitalise these critical areas.

The EU's strategic initiatives, such as the Chips Act, mark significant steps towards strengthening the region's semiconductor capabilities. However, a narrow focus on semiconductors alone is insufficient to ensure the region's technology leadership. A holistic approach that boosts PCB fabrication and electronic assembly capacities is essential. These segments are foundational to the production of electronic systems and play a crucial role in the broader electronics ecosystem.

Enhancing the EU's electronics manufacturing capabilities is not just about economic gains; it is about ensuring technological sovereignty, reducing dependency on non-EU suppliers, and fostering innovation across various sectors.

The future of the EU's electronics manufacturing base hinges on the actions taken today. By strategically investing in and supporting the growth of this sector, the EU can secure its position as a global leader in technology and innovation. This report serves as a clarion call for policymakers, industry leaders, and stakeholders to come together and chart a path forward that ensures the EU's industrial resilience, economic prosperity, regional security, and technological sovereignty.

As we move towards 2035, the goal is clear: to create a vibrant and self-sufficient electronics manufacturing ecosystem that not only meets domestic demand but also competes on the global stage. The challenges are significant, but so are the opportunities. With strategic foresight and collaborative effort, the EU can reclaim its leadership in the electronics manufacturing industry and pave the way for a prosperous future.

John W. Mitchell | IPC President & CEO

IPC

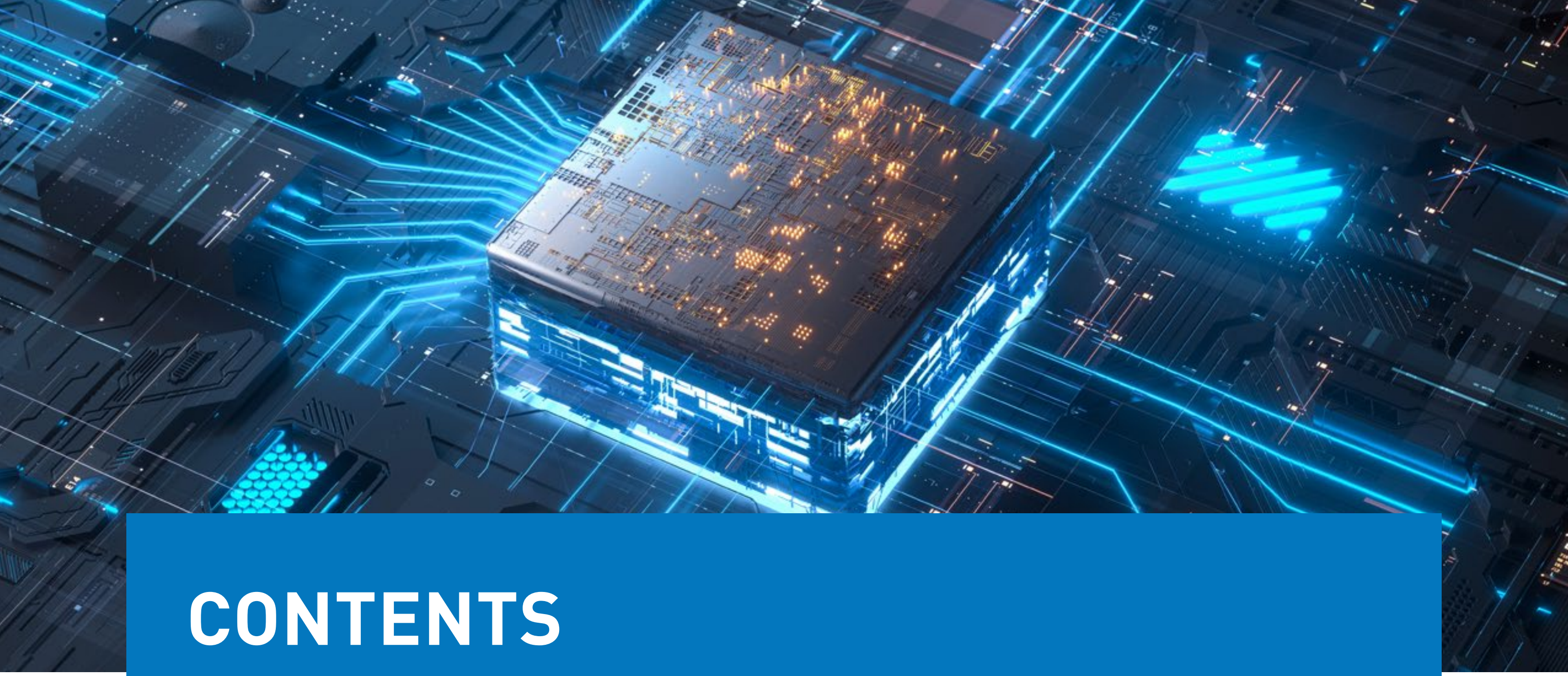
IPC is a non-profit, member-driven organisation and leading source for industry standards, training, industry intelligence and public policy advocacy. IPC is the global association that helps OEMs, EMS, PCB manufacturers and suppliers build electronics better. IPC is dedicated to furthering the competitive excellence of its more than 3,200 member companies, including more than 500 in Europe. They represent all facets of the electronics industry, including design, printed board manufacturing, electronics assembly, advanced packaging and testing. While the membership includes many multinational companies, the majority are small and medium-sized enterprises. In support of its mission, IPC works collaboratively with the electronics industry to develop technical standards and workforce credentialing programmes, in addition to a policy agenda that aims to cultivate a favourable environment for manufacturing, research and development and environmental stewardship. **www.ipc.org**

DECISION

Founded in 1991, DECISION is an independent strategy consulting firm renowned for its expertise in strategic analyses and studies across three highly innovative sectors: Electronic Components & Systems, Aerospace – Defence & Security, and Industry 4.0 & Electrics. Thanks to its core team of economists and its international network of industrial experts, DECISION has become a recognised European authority in market research within the electronics field. The firm produces regular market figures, analyses, and forecasts for Europe and other world regions, alongside in-depth analyses of major trends and key players. DECISION provides comprehensive studies and strategic consulting services to a diverse clientele, including industrial groups, innovative small and medium-sized enterprises, start-ups, financial institutions, investment funds, professional trade associations, national and local governments, and the European Commission. **www.decision.eu**

IN4MA

Weiss Engineering is a private unlimited company founded by Dieter G. Weiss in Germany 24 years ago. He has been working in the Electronics market for the last 46 years and worked with several associations on qualified market statistics for the PCB-industry, the PCBA-industry and the Hybrid-industry. 2015 he created and registered an own brand in4ma, which stands for information for manufacturers. Since that time his work focusses on the European EMS industry. He had a close colleague, Michael Gasch, who did similar work for the PCB-Industry in Europe and created the brand Data4PCB. Dieter worked with Michael closely together. In February of 2024 Michael was informed about a serious illness and transferred his files and work over to Dieter. Michael Gasch died on May 24, 2024. Dieter is continuing Michael's work now and has started to register the Data4PCB brand under his name now.



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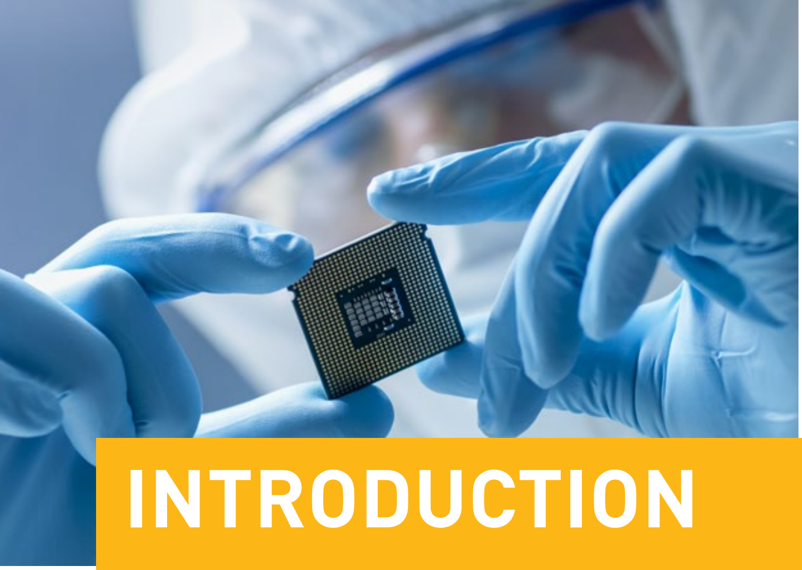
EXECUTIVE SUMMARY

This report highlights the current and future state of the EU's electronics manufacturing base across eight key sectors: aerospace and defence, automation, healthcare, mobility, renewable energy, security, and servers. These sectors are critical areas for expanding regional electronics production capabilities necessary to achieve key EU strategic priorities.

- **The EU's share of PCB production has fallen significantly in the last two decades and the EU's share of electronics manufacturing is slipping.**
  - Global PCB production has more than doubled since 2000. Over this same period, Europe's share of global PCB manufacturing fell from 13.8% to 2.2%.
- **The EU is highly dependent on non-EU countries, and these dependencies are expected to worsen by 2035 without a strategic response.**
  - Across eight strategic sectors, the overall share of electronics systems manufactured in the EU is projected to decline, falling from 16.7% in 2023 to 15% in 2035.
  - The EU's dependency on non-EU PCBs across eight strategic sectors is expected to increase from 82.5% in 2023 to 88.9% in 2035.
  - The EU's reliance on non-EU countries for key semiconductor assembly and testing, IC substrate fabrication, and advanced packaging is significant, with resiliency expected to further deteriorate by 2035.
- **The EU's production of electronic systems across eight strategic sectors is expected to lag global growth, posing a threat to the competitiveness and viability of EU OEM and EMS companies.**
  - The EU's production of electronic systems across eight strategic sectors is expected to grow by 52.5% between 2023 and 2035, but this growth rate is expected to lag the rest of the world, leading to a projected decline in the EU's market share from 16.7% to 15%.
  - Diminished market share threatens OEM, ODM, and EMS competitiveness as companies struggle to keep pace with technological advancements, cost efficiencies, and innovation, potentially leading to reduced economic growth within the EU.
  - To maintain its 2023 global market share of 16.7% in electronics systems, the EU must achieve an additional 16.8% growth over the next 12 years above its projected growth, resulting in a total electronics systems output in 2035 that is 11% higher than the current projection. This highlights the need for strategic

investments and comprehensive policies to enhance the EU's competitiveness.

- **Without a strategic response, the EU's ability to satisfy PCB demand through domestic production will be further diminished by 2035.**
  - In 2023, the EU produced €1,374 million PCBs against an estimated demand of €7,871 million, resulting in a production-to-demand ratio of just 17.5%.
  - By 2035, the EU's share of global electronics manufacturing is projected to decrease to 15%, with PCB production expected to grow by 4.9% to €1,441.3 million, but demand is projected to rise to €12,980.8 million, leading to a production-to-demand ratio of only 11.1%.
- **Targets for Advanced Packaging and IC Substrate production should mirror semiconductor goals in the EU.**
  - As of 2023, the EU's share of the global market for advanced packaging and IC substrates was 2% and 1.3%, respectively. Without strategic prioritisation, the risk exists that these shares could drop to 1.4% and 0.7% by 2035, emphasising the urgent necessity for targeted policies and investments to fortify these critical sectors.
  - Failure to strengthen Europe an IC substrate and packaging capabilities undermines the Chips Act and is likely to lengthen supply chains.
  - To support the EU's goal of achieving a 20% share of global semiconductor production by 2030, setting corresponding targets for advanced packaging and IC substrates is crucial. Such targets will ensure a robust supply chain and enhance the EU's competitiveness in the semiconductor industry.



INTRODUCTION

Today, electronics are ubiquitous. They are foundational in everything from personal devices and electric vehicles to wind turbines and industrial systems. These technologies are critical to nearly every aspect of modern life, making a thriving electronics manufacturing sector crucial for the EU's industrial resilience, regional security, and technological advancement. As industries increasingly depend on electronics for innovation, the role of electronics manufacturers as key facilitators of Europe's digital and environmental transitions becomes more significant.

With the enactment of the Chips Act, the EU has made a strategic commitment to bolstering a key segment of the electronics sector.

While semiconductors are crucial, a narrow focus on them neglects other essential parts of the broader electronics ecosystem, such as printed circuit board (PCB) fabrication, electronic manufacturing services (EMS), and semiconductor packaging. Enhancing these industry segments is vital for developing a robust European electronics manufacturing ecosystem that supports industrial resilience, advances dual transitions, and fosters European innovation.

Electronics systems manufacturing involves a complex network of companies working together. This collaboration includes Original Equipment Manufacturers (OEMs), Original Design Manufacturers (ODMs), and EMS providers. OEMs develop and market products under their brand names, while ODMs design and manufacture products for other companies to rebrand and sell. EMS providers offer a range of services, including assembly, testing, and distribution, ensuring that electronic systems meet required specifications and standards. Additionally, PCB manufacturers and semiconductor manufacturers are crucial to this ecosystem. PCB manufacturers produce the essential boards that connect electronic components, and semiconductor manufacturers supply the integrated circuits and chips that drive system functionality. This synergistic combination of OEM, ODM, EMS, PCB, and semiconductor roles fosters innovation and efficiency, enabling the production of advanced and reliable electronic systems across diverse markets.

It is vital all these entities work together seamlessly, as the electronics manufacturing industry cannot thrive without the contribution of each part. OEMs rely on the designs, innovations and services of ODMs /EMS, and the manufacturing powers of EMS providers to bring their products to market. At the same time, the functionality and reliability of these products depend heavily on the quality of PCBs and semiconductors. A disruption or lack of collaboration in any segment can hinder the entire manufacturing process, leading to delays, increased costs, and reduced product quality. Furthermore, for a healthy electronics manufacturing sector, each of these segments must be robust and thriving individually. The symbiotic relationship among OEMs, ODMs, EMS providers, PCB manufacturers, and semiconductor manufacturers is essential for sustaining the growth and advancement of the electronics industry.

ANALYSIS OF STRATEGIC EU ELECTRONICS MARKETS

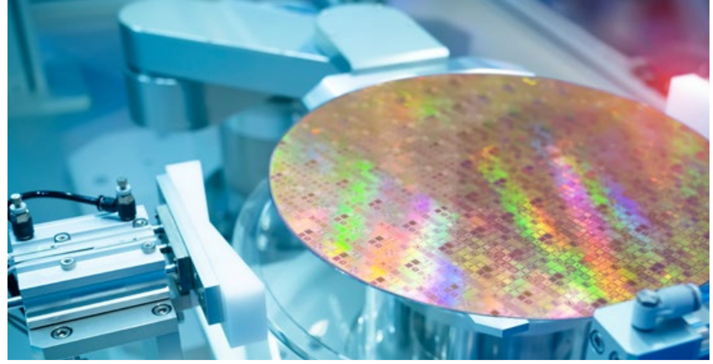
The EU has set its sights on becoming a major player in the global semiconductor industry, with the ambitious goal of doubling its current share to reach 20% of global chip production by 2030. This strategic shift is driven by the need for technological sovereignty and to fuel the digital and green transitions. To achieve this, the European Commission (EC) proposed and adopted the European Chips Act, a €43 billion initiative aimed at bolstering research, innovation, and production capabilities within the EU. This significant investment marks a pivotal moment in the EU's efforts to strengthen its semiconductor industry.

The Act seeks to attract leading global semiconductor manufacturers to establish and expand their operations within Europe, fostering technological innovation and industrial resilience. In Germany, the government has committed substantial resources to support semiconductor projects, including Intel's planned mega-factory in Magdeburg. This facility, set to be one of the most advanced semiconductor fabs in the world, represents a multi-billion-euro investment and is expected to significantly boost Europe's chip production capacity. Additionally, in France, STMicroelectronics and GlobalFoundries have announced a partnership to build a new semiconductor manufacturing plant in Crolles, further enhancing the region's production capabilities. Italy has also joined this wave of investments, with plans to support new semiconductor facilities and research centres aimed at developing next-generation technologies. These initiatives align with the broader EU strategy to reduce dependency on external sources and secure a stable supply of critical components for various industries.

However, focusing solely on semiconductors is not enough to ensure the EU's technological autonomy and supply chain resilience. A comprehensive strategy supporting the entire electronics ecosystem, from semiconductors to final assembly, is imperative. This holistic approach will address vulnerabilities in the supply chain and ensure that all critical components, not just chips, are produced within the EU. By fostering a robust electronics manufacturing industry, the EU can better withstand global disruptions and maintain a competitive edge. This means investing in areas such as PCBs, EMS, and advanced packaging. An integrated strategy will not only bolster the EU's industrial base but also drive the digital and green transitions, ensuring sustainable economic growth and technological leadership in the global market.

A holistic approach should start by focusing on sectors critical to the EU's green and digital transformation, or those crucial to global economic competitiveness and regional security. These sectors not only require sophisticated semiconductor technologies but also depend on a wide range of electronic components and systems. By targeting these high-impact areas, the EU can ensure that investments yield substantial returns in terms of innovation, sustainability, and economic growth. Moreover, fostering development in these sectors will help the EU achieve its ambitious climate goals and maintain its competitive edge in the global market. Supporting these strategic industries will drive demand for a diverse array of electronic products, thereby reinforcing the entire supply chain and enhancing resilience against future disruptions.

IPC has identified eight sectors as strategic to the EU's digital and green transitions and its key areas of economic competitiveness. These eight sectors include Aerospace & Defence, Automation (encompassing factory automation, home automation, and industrial robotics), healthcare, Mobility (including automotive, railways, and agriculture), Renewable Energies (covering solar systems,



wind turbines, and nuclear), Security, Servers (including servers, HPC, supercomputers, and dedicated terminals such as POS and ATM), and Telecommunications infrastructures. Combined, these eight segments accounted for 57% of global electronics production in 2023.[1]

For each of these eight strategic sectors, several common narratives emerge. First, without strategic policies, the overall share of electronics systems manufacturing in the EU is projected to decline by 2035. Second, the EU remains highly dependent internationally for critical inputs and processes, including PCBs, advanced packaging, and IC substrates. Third, without strategic interventions, these dependencies are expected to worsen by 2035.[2]

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY IN 8 STRATEGIC SECTORS

ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY (OEM/ODM/EMS)

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
16,6%	16,7%	16,6%	16,4%	16,1%	15,9%	15,7%	15,6%	15,5%	15,4%	15,3%	15,2%	15,1%	15,0%

PCB

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
3,1%	2,9%	2,8%	2,7%	2,5%	2,4%	2,3%	2,2%	2,1%	2,0%	1,9%	1,8%	1,7%	1,7%

ADVANCED PACKAGING

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
2,0%	2,0%	1,9%	1,7%	1,6%	2,4%	2,3%	2,1%	2,0%	1,8%	1,7%	1,6%	1,5%	1,4%

IC SUBSTRATE

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
1,0%	1,3%	1,5%	1,7%	1,6%	1,4%	1,3%	1,2%	1,1%	1.,0%	0,9%	0,9%	0,8%	0,7%

THE FOLLOWING IS AN ANALYSIS OF EACH OF THESE EIGHT STRATEGIC SECTORS.

AEROSPACE & DEFENCE

The aerospace and defence industries encompass intricate supply chains, extending from small parts and components to complete assemblies like aircraft and ships. The defence sector is primarily driven by global threats and military spending, whereas the civil aerospace industry is influenced by business factors such as air travel demand and international trade. Despite their interconnected nature, the supply chains for defence and civil aerospace follow distinct paths shaped by unique market forces. Both industries depend on complex supply chains involving raw materials to finished goods. However, each industry has specific growth drivers that uniquely influence their requirements for electronic systems.

Global demand for aerospace and defence electronic systems is projected to grow at an average annual rate of 5% from 2022 to 2035, surpassing the overall growth rate of the electronics industry.[3] The EU's aerospace and defence electronics systems market is expected to experience a 4.5% average annual growth rate through 2035, lagging slightly behind the global average. While the Ukraine conflict has spurred increased European military spending, a portion of these funds may benefit non-European defence companies that can provide readily available solutions. In 2023, the global market for electronic aerospace and defence systems was estimated at €130.4 billion, with approximately 30% attributed to aerospace systems and 70% to defence systems.

Aerospace and defence electronic systems are frequently designed near their final assembly locations and in 2023, the EU accounted for 23% of the global production of electronic systems in these sectors. In 2023, the EU produced an estimated €28.7 billion of aerospace and defence electronic systems, with approximately 35% attributed to aerospace systems and 65% to defence systems.

DEFENCE

World military expenditure increased for the ninth consecutive year in 2023, reaching a total of €2.21 trillion. The 6.8% rise in 2023 marked the steepest year-on-year increase since 2009, pushing global spending to a record level.[4] Military spending in Europe totalled $588 billion in 2023, reflecting a 16% increase from 2022 and a 62% rise since 2014.[5] The ongoing war between Russia and Ukraine has significantly boosted military expenditures for both countries and triggered a widespread surge in defence spending across Europe.

In 2022, Germany announced a 100-billion-euro defence plan,[6] while France and several other European nations also increased their military budgets. In 2023, Poland's military spending soared to $31.6 billion, representing a 75% increase from the previous year—the largest annual rise among European countries. This marked a 181% increase in Poland's military expenditure since 2014.[7] This upward trend is expected to continue over the next decade, with most NATO member countries in Europe planning to elevate their defence budgets to 2% of GDP. Additionally, defence electronics production in the EU grew 4.4% in 2023, following a 5.9% increase in 2022.

CIVIL AEROSPACE

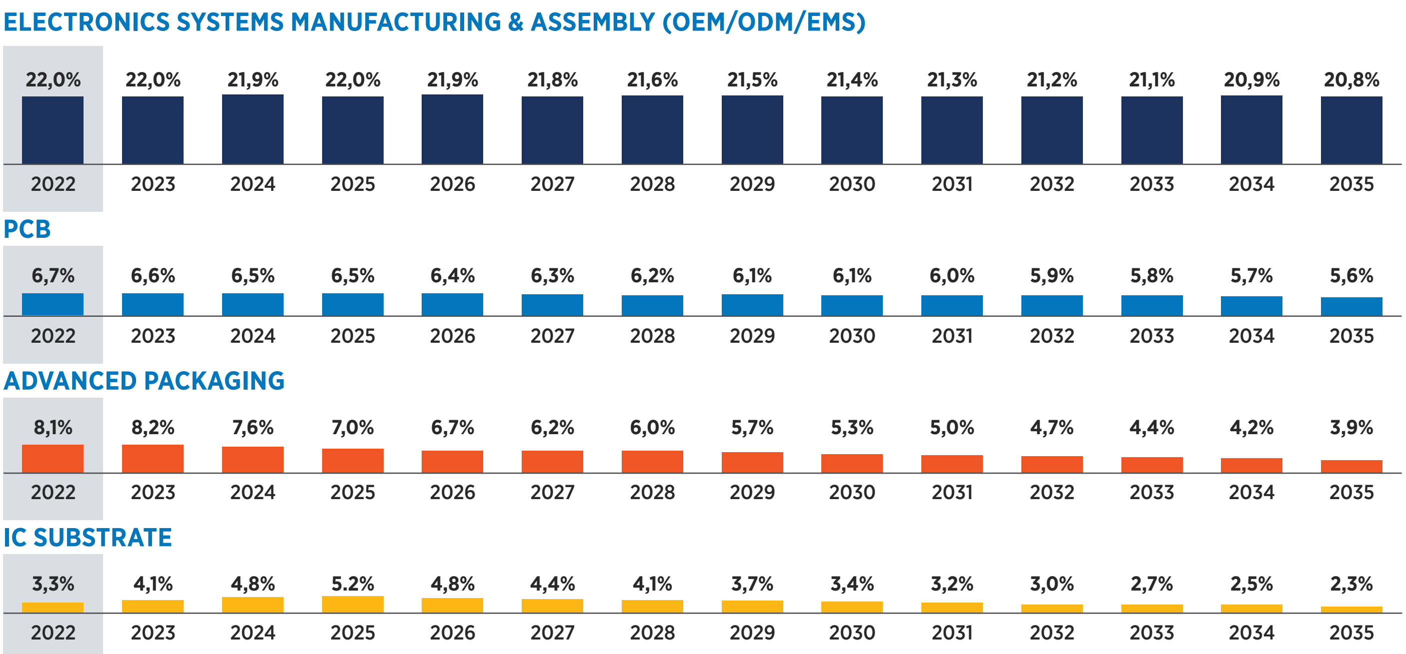
The civil aerospace industry experienced a faster-than-anticipated recovery following the pandemic. This resurgence was driven by pent-up travel demand, accelerated vaccination rollouts, and increased confidence in air travel safety measures. Consequently, airlines and related sectors swiftly adapted to meet the renewed passenger demand. By the end of 2023, Airbus reported a backlog of 8,598 aircraft,[8] while Boeing's backlog included over 5,600 commercial aeroplanes.[9] The production of electronics for civil aerospace systems closely followed the overall industry recovery, increasing by 17.7% in 2022 after a significant 30.6% rise in 2021. This growth brought global output to €10.5 billion in 2022.

The rise of "more-electric" aircraft, such as the Boeing 787 and Airbus A350, is driving a substantial increase in the value of electronic systems per plane. This trend supports robust growth in the global market for civil aircraft electronics, with projections indicating a 7.8% annual increase from 2022 to 2027, followed by a steady pace of 6.6% annually through 2035. By 2035, the market is expected to reach a projected value of €23.9 billion. The EU's production of electronic systems for civil aircraft is expected to mirror this global trend, with an average annual increase of 6.2% through 2035, reaching €8 billion by that year.

STRATEGIC DEPENDENCIES IN AEROSPACE & DEFENCE

While the aerospace and defence electronics value chain in the EU is notably resilient, it encounters significant vulnerabilities in its supply chain due to dependence on other countries for critical components such as PCBs, advanced packaging, and IC substrates. The EU's production of these categories is three to four times smaller than its production share of electronic systems. Despite manufacturing 22% of the global electronic systems used in this sector in 2023, the EU only produces around 6.6% of the world's aerospace and defence PCBs, 8.2% of advanced packaging applications, and 4.1% of total IC substrates for this sector. This disparity forces the EU to rely heavily on imports to fulfil the demands of its sophisticated defence and aerospace electronics systems. Furthermore, these production shares are anticipated to decline through 2035 as production capacities grow more rapidly outside the EU.

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: **AEROSPACE & DEFENCE**



AUTOMATION

Automation plays a crucial role in the functional structure of both factory and residential entities, bridging the gap between sensors and actuators on one side, and Supervisory Control and Data Acquisition (SCADA) systems and enterprise management (ERP) systems on the other. In essence, automation serves as the connective tissue that ensures efficient and effective operations by facilitating the seamless integration and coordination of various components within a system. The market for automation equipment, therefore, occupies a strategic position, encompassing technologies that enhance productivity, optimise resource utilisation, and improve overall system reliability. By interfacing with sensors to gather data and actuators to execute actions, while simultaneously interacting with SCADA and ERP systems for oversight and strategic management, automation enables entities to achieve higher levels of performance and operational excellence.

As a leader in automation technology, the EU leverages its strong industrial base and advanced research capabilities to maintain its competitive edge. The region's focus on automation extends beyond traditional manufacturing to encompass smart cities, energy management, and sustainable development. By investing in cutting-edge automation solutions, the EU enhances productivity, reduces operational costs, and minimises environmental impact. This commitment to automation not only strengthens the internal market but also positions the EU as a global leader in high-tech industries, fostering economic growth and job creation.

From 2016 to 2022, the global automation segment grew at an annual rate of 5.5%, fueled by significant advancements in robotics and home and building automation. EU countries are performing well compared to other regions. Although the EU has a relatively lower market share in the robotics segment, it is considered a leading region in factory automation and home and building automation. Leading companies such as Siemens, Schneider, ABB, and Bosch hold more than 25% global market share in each of these sub-segments. From 2016 to 2022, automation production in the EU grew at an annual rate of 6.3%, outpacing the global growth rate. This growth was supported by high demand in end-markets like energy, chemicals and automotive. In 2023, the worldwide production of automation electronics systems reached €286.3 billion. EU production was just under €60 billion, accounting for nearly 21% of the global total.

FACTORY AUTOMATION

The factory automation market[10] reached €140 billion in 2022, driven by technological advancements such as machine learning integration and continuous sensor upgrades. The market grew at an annual rate of 3.9% from 2016 to 2022, despite a 10% downturn in 2020 due to the pandemic, which underscored the need for automation to mitigate future disruptions.

INDUSTRIAL ROBOTS

Robotics consists of two main sub-segments: industrial robotics and service robotics, with the former representing nearly all current robotics applications. Industrial robots are reprogrammable, multipurpose manipulators used in factories, while service robots perform tasks for humans or equipment in non-industrial settings. In 2022, the industrial robotics market was valued at €47 billion. Despite a slight downturn in 2020 due to COVID-19, the market has shown consistent growth and is expected to continue growing at an average annual rate of 6.8% from 2022 to 2035, driven by increasing demand from North America and Asia, particularly China and Japan. Technological trends like Industry 4.0, IoT (Internet of Things) integration, and AI, along with societal trends such as workforce shortages in developed economies, are expected to sustain long-term demand. The European market, however, is expected to grow at a slower pace. In the EU, robotics production grew at an annual rate of 4.6% from 2016 to 2022 and is projected to maintain this growth rate through 2035.

HOME & BUILDING AUTOMATION

Automation systems in residential and commercial buildings enhance comfort, energy efficiency, and security by enabling communication between sensors, actuators, controllers, and man/machine interfaces via bus-type networks. These systems manage lighting, smoke and fire alarms, building

access, and other security systems. Initially driven by the quest for increased comfort, the market for Home & Building Automation is now primarily driven by energy efficiency, security, and the "smart building" and "smart home" paradigms.

The Home Automation market has grown since the early 2010s due to cheaper wireless security systems, IoT, and connected devices. Building Automation manages various functions in professional and collective residential buildings, converging towards the "intelligent building" with control over electrical energy, lighting, HVAC systems, and security functions. Overall, the home and building automation market was valued at €78 billion in 2022.

OUTLOOK FOR AUTOMATION ELECTRONICS

The global automation segment is projected to grow at an annual rate of 5% from 2022 to 2035, driven by investments in the automotive industry, but also electronics and semiconductors with the impact of various Chip Acts and advancements in AI. The Home & Building Automation sub-segment, which accounted for 34% of the total automation segment in 2022, is expected to grow faster than others, increasing its share to 38% by 2035. In the EU, the automation segment is expected to grow at an annual rate of 4.9% over the same period. Despite exceeding global production growth between 2016 and 2022, the EU's future growth trajectory is expected to converge with the global average by 2035. This shift is driven by a market focus on Asia and the increasing prominence of the Chinese electronics ecosystem.

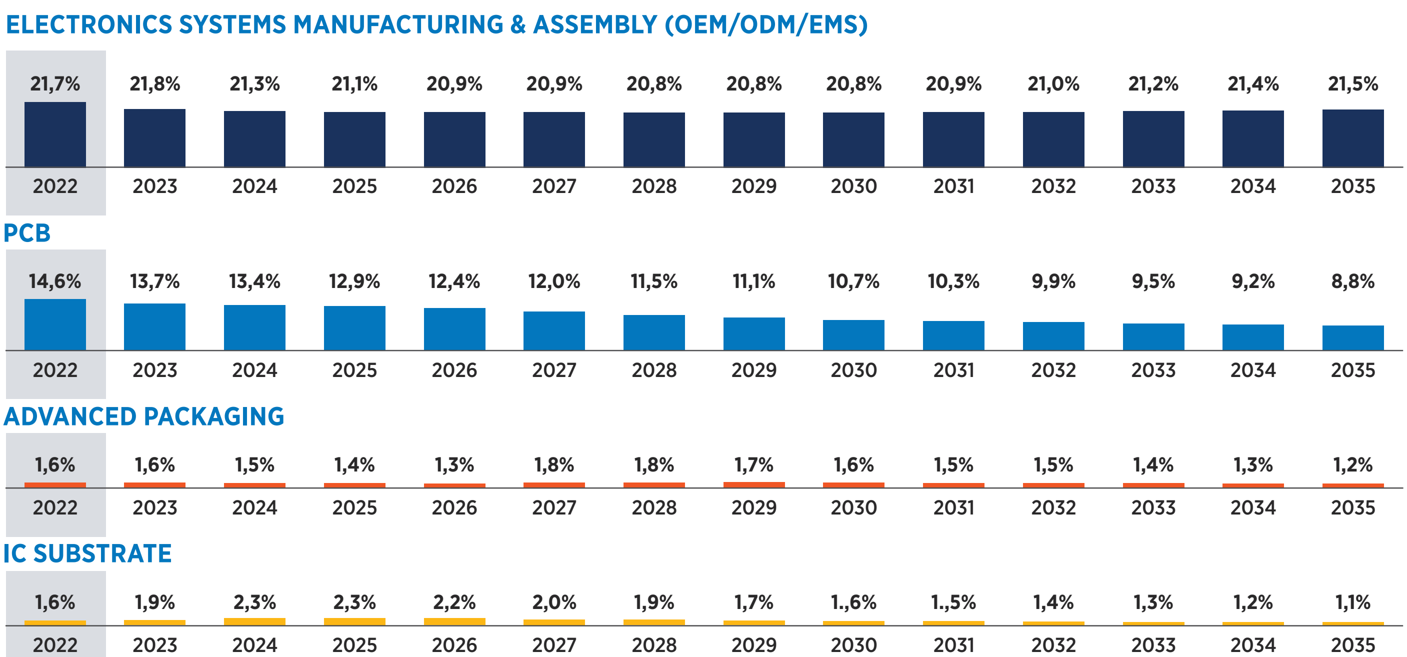
Growth in factory automation will be driven by investments in the EV sector, both in battery and vehicle manufacturing, due to their high automation levels. However, the primary driver will be the Home & Building Automation sub-segment, influenced by the EU's aim for highly energy-efficient, decarbonised building stock by 2050. This goal is supported by key measures such as the European Green Deal, the Energy Performance of Buildings Directive (EPBD), and the Energy Efficiency Directive. These measures include:

- Revised EPBD: Focuses on increasing the renovation rate of poorly performing buildings and supports the digitalization of energy systems.
- Financial Support and Incentives: Provides targeted financing and investment to fight energy poverty and support vulnerable consumers.
- Technological Requirements: Mandates the introduction of building automation and control systems, as well as room-level temperature regulation devices.

STRATEGIC DEPENDENCIES IN AUTOMATION

The EU's automation sector faces strategic dependencies due to its reliance on other countries for PCBs, advanced packaging, and IC substrates. While the EU accounted for just under 21% of the world's electronic systems production in 2023, its share in the production of PCBs (13.7%), advanced packaging (1.6%), and IC substrates (1.9%) was significantly lower. These discrepancies highlight key vulnerabilities in the supply chain, as the EU must import these critical components to support its automation industry. By 2035, the EU's production shares are projected to decline, reaching 20.7% for electronic systems, 8.8% for PCBs, 1.2% for advanced packaging, and 1.1% for IC substrates. This increasing dependency on external sources underscores the urgent need for strategic initiatives to bolster the EU's self-sufficiency in these essential areas.

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: **AUTOMATION**



HEALTHCARE

In 2022, the global market for electronic healthcare systems was valued at €65.6 billion. The U.S. leads this market, holding a 38% share and accounting for 34% of global production. The EU ranks second with a 30% market share and 16.4% of total production. Following the EU, China holds a 10% market share and contributes 22% of global production, driven by its rapidly expanding domestic market and significant manufacturing capabilities. Japan occupies the fourth position with a 10% market share and an 8% share of production. Other Asian countries collectively account for 4% of the market and 13% of production. Non-EU European countries, primarily Switzerland and the United Kingdom, contribute 5% to the market share and 4.5% to production.

The healthcare market is comprised of five main segments. Imaging systems, valued at over €18 billion in 2022, include X-ray radiography, ultrasounds, CT scanners, MRI, and nuclear medicine, critical for diagnostics, and driven by advancements in ultrasound and fusion-imaging technologies. Cardiac Rhythm Management (CRM), essential for managing heart conditions, includes defibrillators and pacemakers, with Medtronic leading the market, particularly in the widespread adoption of Cardiac Resynchronization Therapy Defibrillators (CRT-D). The hearing aids market, approaching €10 billion, is led by European companies like Amplifon and Oticon. Home-care medical devices, nearing €11 billion, stand out as the primary business-to-consumer segment, driven by disease prevention and personalised health trends, including blood pressure monitors, oximeters, digital thermometers, glucose monitoring devices, and telemedicine tools, with oximeters in high demand due to COVID-19. Lastly, other diagnostic and therapy systems, valued at €10.5 billion, include body function monitoring, patient vital sign monitoring, surgical equipment, and therapeutic equipment, with prominent manufacturers like Medtronic and Philips.[11]

TECHNICAL INNOVATION DRIVING NEW MARKETS IN HEALTHCARE ELECTRONICS

The healthcare electronics industry is rapidly evolving to meet new demands, driven by significant technical innovations. This sector is seeing the development of miniaturised diagnostic and healthcare solutions, including advanced hearing aids, glycaemia testers, blood pressure monitors, and oximeters. Moreover, innovative devices such as pill cameras, contactless power charging systems, and advanced pacemakers/defibrillators are becoming increasingly prevalent. Additionally, embedded chemical testers and other cutting-edge technologies are making significant strides. These innovations are fundamentally transforming the landscape of healthcare electronics by enabling more precise diagnostics, effective treatments, and improved patient outcomes.

Significant innovations are occurring both at the macro and micro levels. At the higher end, the integration of artificial intelligence (AI) and big data is revolutionising applications ranging from diagnostics to drug development. On the individual level, there is a proliferation of devices such as home care tools, wearables, implants, and ingestible devices. Key growth areas include 3D medical imaging technology for MRI and CT applications, computer-assisted and robot-aided surgery to enhance precision and reduce post-operative complications, and telemedicine for remote diagnosis and follow-up care at home. Additionally, the miniaturisation and widespread deployment of implants, such as stents, insulin pumps, and neuromodulators, are driving market expansion. The convergence of these technologies with big data and cloud computing is expected to further accelerate growth, although this will also raise concerns about patient confidentiality and risk management. As the population ages and the rate of equipment adoption in developing countries increases, the healthcare electronics market is poised for substantial growth, despite potential challenges posed by global energy shortages.

GROWTH PROSPECTS & FORECASTS

Over the past decade, the healthcare electronics sector has expanded at a pace similar to the overall electronics industry. While this sector enjoys strong growth drivers, its progress is somewhat constrained by its dependence on public and social security expenditures, which are often resistant to innovation and stagnating in many Western countries. According to the OECD, the growth of healthcare electronics systems has slightly surpassed both total health expenditure and GDP growth, a trend projected to continue globally.

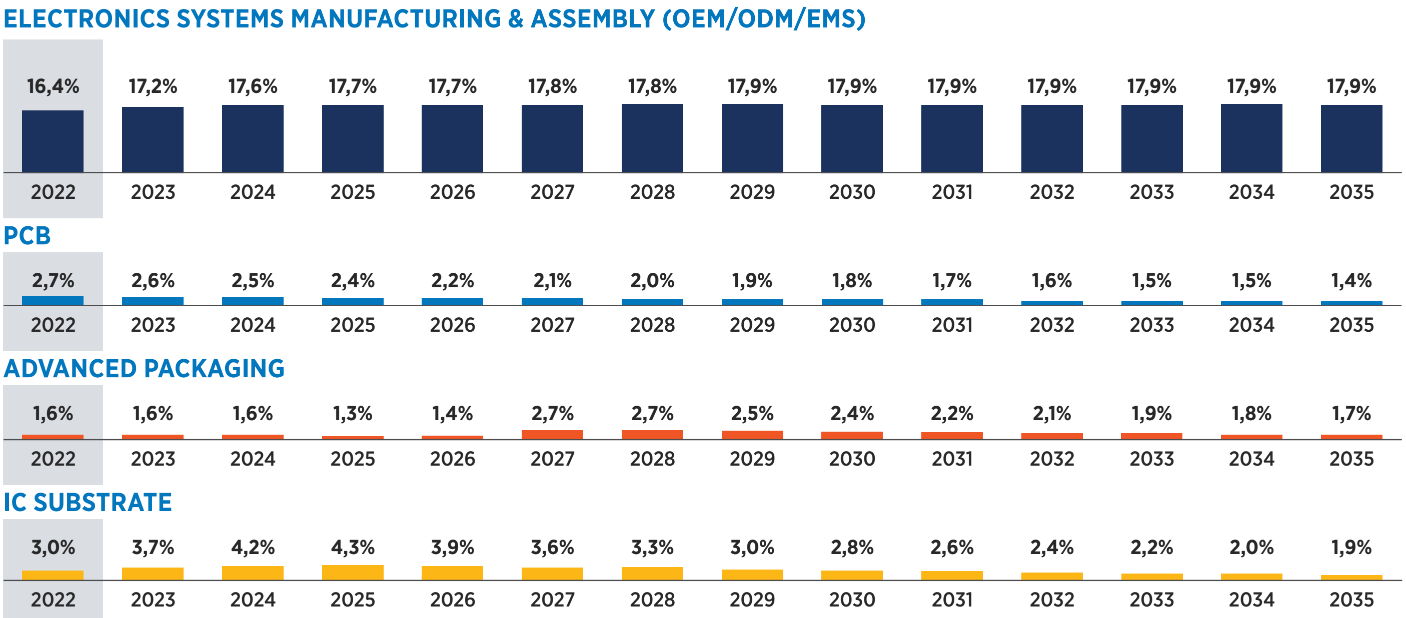
From 2017 to 2022, the global healthcare electronics industry experienced an annual growth rate of 3.4%. Future projections suggest an annual growth rate of 5.2% from 2023 to 2035. In 2023, the EU accounted for 17.2% of global healthcare electronics production, totalling €12.7 billion. The region's production grew at an annual rate of 5.1% from 2017 to 2022, outpacing global growth. Looking forward, the EU healthcare segment is expected to grow at an annual rate of 5.6% until 2035, exceeding overall global growth rates. Among the eight critical sectors, healthcare is the only one projected to gain market share.

STRATEGIC DEPENDENCIES IN HEALTHCARE

The EU's healthcare electronics sector faces significant strategic dependencies due to its reliance on other countries for PCBs, advanced packaging, and IC substrates. While the EU produced a substantial share of the world's healthcare electronic systems, accounting for 17.2% of total production in 2023, its output of PCBs (2.6%), advanced packaging (1.6%), and IC substrates (3.7%) was notably lower. These gaps create vulnerabilities in the supply chain, as the EU must import these critical components to support its healthcare electronics industry.

By 2035, the EU's production shares for electronic systems are projected to remain relatively stable at around 17.9%. However, the share for PCBs is expected to decline to 1.4%, for advanced packaging to 1.7%, and for IC substrates to 1.9%. This indicates an increasing dependency on external sources as global production outside the EU rises more rapidly. Addressing these weaknesses through strategic initiatives to bolster domestic production capabilities is crucial for enhancing the resilience and sustainability of the EU's healthcare electronics sector.

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: HEALTHCARE



MOBILITY

The mobility sector, encompassing automotive, rail, and agricultural machinery, is a dynamic and rapidly evolving industry. The sector has experienced robust growth over the past decade, driven by advancements in electric vehicles, increased integration of electronics, and the push for green mobility solutions. This evolution has not only enhanced vehicle performance and efficiency but also significantly reduced environmental impact. Emerging technologies such as autonomous driving and IoT connectivity are further revolutionising the landscape, making transportation safer and more efficient. As a result, companies within this sector are investing heavily in R&D to stay competitive and meet the growing demand for innovative mobility solutions.

AUTOMOTIVE

The global market for automotive electronics systems is €272 billion. The EU leads the automotive electronics market, controlling 27% of the global market and 20.5% of total global production. Globally, other key regions include China, Japan, and North America. China, with 22% of global production and 15%

market share, is rapidly growing due to its focus on electric vehicles. Japan holds 24% of the global market and 12% of production while North America represents 21.5% of the global market and 16% of production. South Korea also plays a significant role. Additionally, South Asian countries host substantial automotive electronics production facilities, often outsourced from Japan, the EU, and the US.

Over the past decade, the automotive electronics sector has grown significantly, outpacing the overall electronics industry. From 2012 to 2019, it grew at an annual rate of 6.2%, compared to the broader industry's 4.6%. Key factors driving this growth include robust industry growth and increased electronics integration. The Chinese market for cars, for example, has experienced tremendous growth and now commands a third of the global market. Increased Electronics Integration includes:

- Advanced Driving Assistance Systems (ADAS): Constituting 15% of in-car electronics, with levels 0-2 systems common and premium cars adopting level 3 systems.

- Infotainment/Smart Cockpit: Representing 30% of in-car electronics, including dashboards, GPS, live traffic, onboard diagnostics, screens, and entertainment systems.

- Connectivity: Telematic Control Units (TCU) enable connected car applications, essential for ADAS levels 4-5 and infotainment, though only 2% of in-car electronics' value.

- Powertrain & Chassis: Accounting for 40% of in-car electronics, driven by enhancements in thermal vehicle performance and the rise of battery management systems for electric vehicles.

- E/E Architectures: Centralising a car's Electronic Control Units (ECU) networks through Central Car Units (CCU) and Domain Control Units (DCU).

Despite global growth of 6.2% per year from 2012 to 2019, the EU's automotive electronics production lagged, growing at only 3.1% annually. However, the auto industry experienced a robust recovery in 2022 and 2023, with car production increasing at an annual rate of 7.8% and automotive electronics growing at an impressive 16.4% annually. The industry is expected to continue its upward trajectory, driven primarily by the burgeoning Asian market, especially China.

In contrast, the outlook for EU production is less optimistic. The European automotive market, which declined by 1.2% annually from 2012 to 2019, is expected to continue shrinking, reaching only two-thirds of its 2012 size by 2035, with fewer than 11 million new cars sold annually. European automakers face rising competition from US and Chinese manufacturers, with the EU's automotive trade balance decreasing by 2.5% per year since 2015. The EU aims for a nearly complete BEV (Battery Electric Vehicle) market by 2035, driven by new CO_2 emission reduction targets. However, the surge of US and Chinese manufacturers in the EU BEV market poses a significant challenge for domestic producers, with Chinese manufacturers' market share rising from 2% in 2019 to 28% in 2023. If this trend continues, US and Chinese manufacturers could capture 50% of the EU BEV market by 2025-2026, negatively impacting EU automotive production. EU automotive production is forecasted to decline by 1.9% annually through 2035, with automotive electronics growing only 0.6% annually from 2023 to 2035. Consequently, the EU's share of global automotive electronics production is expected to fall from 20% in 2023 to just 14.4% by 2035.

RAIL

Rolling stock and rail control (i.e. signalling) are the primary components of rail industry electronics. The global railway market declined during the pandemic but recovered in 2021 and 2022 despite the negative effects of Russia's war on Ukraine. In recent years, operational track increased by about 39,000 km, mainly in mainline and high-speed tracks, bringing the total global track infrastructure to over 1.7 million km. Most new tracks have been put in service in the Asia Pacific region, with significant developments in China and India. Investments in infrastructure and rail control have been substantial in both Asia Pacific and Europe, driven by political efforts to promote green mobility solutions. In Europe, initiatives like the European Green Deal are boosting demand for rail systems and associated electronics, especially alternative propulsion systems such as hydrogen- and battery-powered trains.

The market is also being driven by increased digitalization. In Europe, digital technologies such as the European Rail Traffic Management System (ERTMS), Communications-based Train Control (CBTC), predictive maintenance, Digital Automatic Coupling (DAC), 5G applications for rail, and advancements in passenger information, ticketing, and cybersecurity are increasing the use of electronics in the rail sector.

The electronic production for railway systems reached €4.5 billion in 2022 and is expected to grow at an annual rate of 3.7% until 2035. In Europe, production reached €1.6 billion in 2022 and is projected to grow to €2.6 billion by 2035, maintaining a steady growth rate of 3.7%. Consequently, Europe's share of global production will remain steady at 36%.

AGRICULTURAL MACHINERY

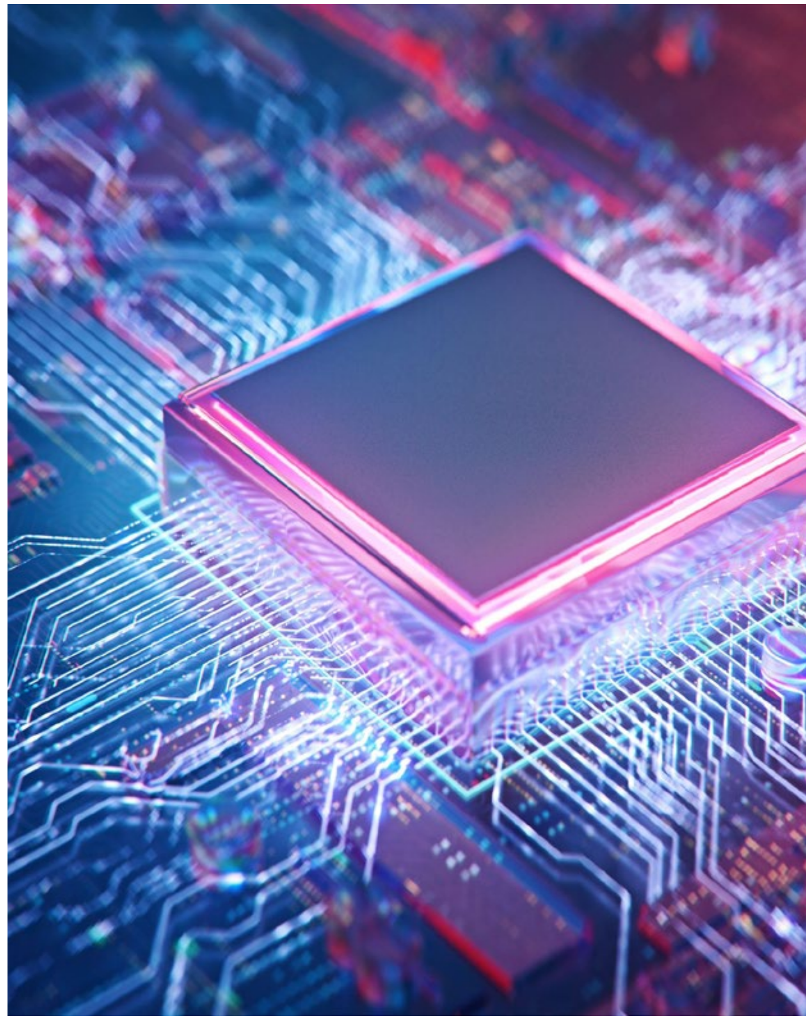
The agricultural machinery market accelerated strongly in 2021 and 2022, driven by increasing needs and farm mechanisation in countries like India, China, Brazil, and Indonesia. In North America and Europe, the electronic content of agricultural machinery is particularly high and continues to grow with the development of precision farming.

After a decline of 3.2% in 2020, electronic equipment production for agricultural machinery surged by 23.3% in 2021 and 16.4% in 2022, reaching €6.2 billion. European production decreased by only 0.6% in 2020 and then grew by 17.8% in 2021 and 9.4% in

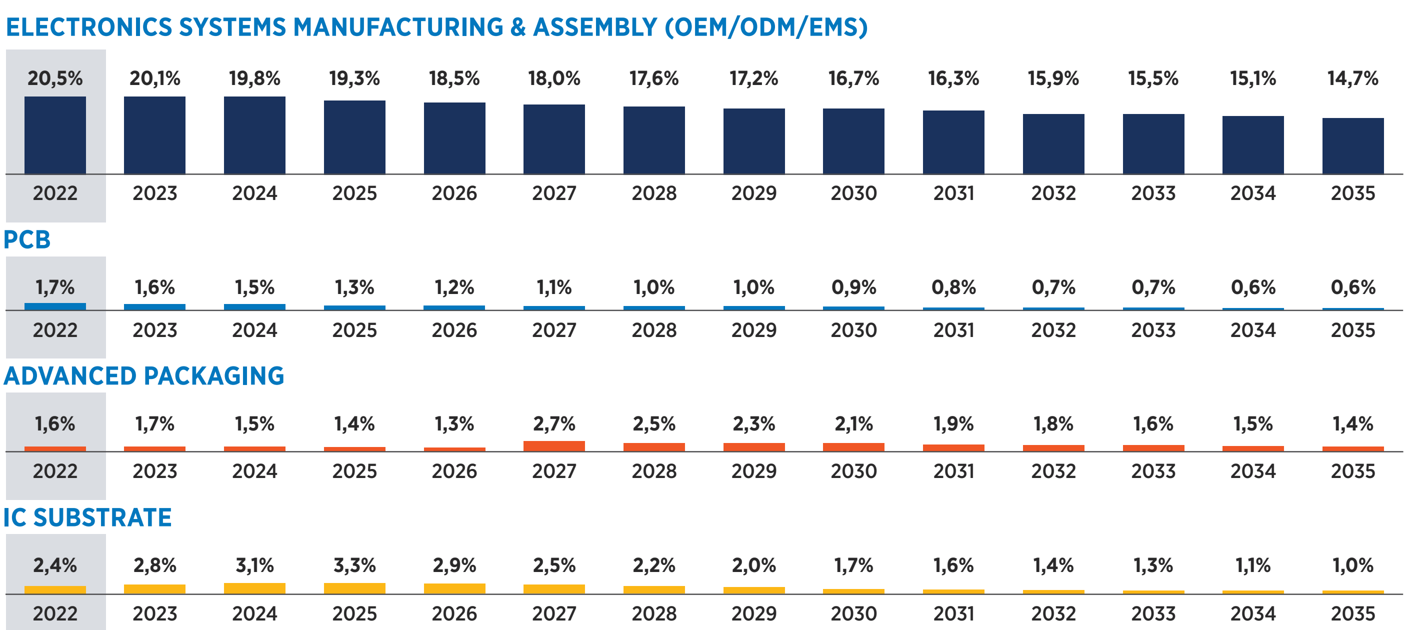
2022, reaching €1.3 billion in 2022. From 2022 to 2035, worldwide production is forecast to grow at an average annual rate of 5.8%, while European production is expected to grow at 4.9% annually.

STRATEGIC DEPENDENCIES IN MOBILITY

The EU's mobility sector faces significant strategic dependencies due to its reliance on other countries for PCBs, advanced packaging, and IC substrates. While the EU produces a considerable share of the world's mobility electronic systems, accounting for 20.1% in 2023, its production of PCBs (1.6%), advanced packaging (1.6%), and IC substrates (2.8%) is notably lower. These gaps create vulnerabilities in the supply chain, as the EU must import these critical components to support its mobility industry. By 2035, the EU's production shares are projected to decline further to 14.7% for electronic systems, 0.6% for PCBs, 1.4% for advanced packaging, and 1.0% for IC substrates, underscoring an increasing dependency on external sources as global production outside the EU rises more rapidly.



EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: MOBILITY



RENEWABLE ENERGIES

The renewable energy sector includes three distinct industries: solar panels, wind turbines, and nuclear power. Each of these has its distinct supply chains. Growth for the renewable energy sector is driven by government policies and private demand, with a new market for nuclear Small Modular Reactors (SMRs) emerging.[12]

Investment in the energy transition has surged globally, driven by policies such as the US Inflation Reduction Act and the EU's REPowerEU programme. These initiatives aim to accelerate the shift from fossil fuels to renewable energy in power generation, transport, and industry, setting ambitious targets for renewables.

Energy agencies predict that renewable energy, particularly wind and solar, will lead to electricity demand growth. The International Energy Agency forecasts renewables will account for 98% of the 2,518 TWh of new electricity generation from 2022 to 2025.[13] The Global Wind Energy Council expects an 8% annual increase in wind capacity from 2023 to 2027, including 130 GW offshore.[14] China will lead onshore wind with 300 GW, followed by Europe with nearly 100 GW, and offshore wind

is projected to grow by 19% annually.
In 2022, global production of renewable energy electronics reached €23.6 billion, with solar panels (€21.2 billion) leading the way, followed by wind turbines (€1.4 billion) and nuclear systems (€1 billion). This sector is projected to be the fastest-growing among the eight critical electronics sectors analysed. Demand for these components is expected to surge 14% annually between 2022 and 2027 (10.6% from 2022 to 2035).

Solar panel production is forecast to experience the most significant growth, with a projected annual increase of 14.6% until 2027 and 11% until 2035. Wind turbine electronics are anticipated to grow at a steady pace of 12% annually until 2027 and 9% until 2035. Nuclear electronics are expected to see more modest but consistent growth, with projections of 1.3% and 2.3% annual increases, respectively.

The EU's renewable energy electronics industry also shows promise. In 2022, the EU produced €1.2 billion worth of these electronics, with solar panels leading the way at €510 million.

Wind turbines (€40 million) and nuclear systems (€280 million) also contributed significantly. Mirroring the global trend, the EU market is expected to experience strong growth, with an anticipated 18% annual increase until 2027 and a steady 10% annual growth rate through 2035. Notably, EU solar panel production is forecast to grow 28% annually until 2027 and 14% until 2035. Wind turbine electronics in the EU are expected to see a 10% and 7% annual growth rate, while nuclear systems will likely maintain a modest but stable increase of 0.8% and 1.8% annually.

SOLAR PANELS

In 2022, solar electronic systems made up 90% of global renewable energy electronics production. Solar systems use crystalline silicon (c-Si) or thin-film solar cells, and a complete photovoltaic (PV) system includes solar cells, panels, and inverters to convert DC to AC. Solar panels and inverters account for only 25% of a PV system's cost, with the rest covering batteries, charge controllers, transportation, installation, and maintenance.

While Europe led in solar panel installation initially, production has largely shifted to Asia, especially China. In 2021, China accounted for 33% of global installed solar capacity, bolstered by substantial government investments. Top solar panel manufacturers are mostly Chinese, with exceptions like Canadian Solar, Hanwha, and First Solar. The EU lacks significant solar panel manufacturers but excels in solar inverter production with companies like SMA Solar Technology, Power Electronics, Schneider Electric, and ABB. In 2022, 60% of EU PV electronics manufacturing was inverters, while solar panels made up one-third.

Global demand for solar electronics is expected to surge, driven by political initiatives, resource depletion, and external factors like the Ukraine-Russia war. Global demand for solar electronic systems is projected to grow 14.6% annually from 2022 to 2027 and 8.7% from 2027 to 2035.

Europe's solar panel production has declined due to higher energy costs and lower investment compared to China. In 2022, the EU's share of global solar panel production was 1.2%. However, the EU aims to boost production through initiatives like the EU Solar PV Industry Alliance, expecting 28% annual growth until 2027. From 2028 to 2035, growth is projected to slow to 6.3% annually.

WIND TURBINES

In 2022, wind turbine electronic systems made up 6% of global renewable energy electronics production. These systems include:

- Electrical and Control Panel: Monitors and adjusts turbine operations based on weather, controlling pitch and yaw motors, the hydraulic brake, and the generator's electromagnetic field.
- Variable Frequency Drive (VFD): Adjusts current frequency from the generator to the grid.
- Uninterruptible Power Supply (UPS): Ensures reliable power for transmission and distribution applications.

- Power Converters: Some turbines need AC/DC converters with electronic components.
- Remote Monitoring Platform: Centralizes and analyses turbine data for real-time control.

In 2022, the global wind turbine market was €124 billion, with installation costs at €2.4 million per turbine. Electronics systems, costing €27,000 on average, represent less than 10% of total production costs.

The EU's market position is shaped by the end market, turbine producers, and electronics systems manufacturers. China led with 48% of global installations and 53% market share for turbine manufacturers. Chinese firms like Huawei and Kehua Group lead electronics systems production, accounting for 34% of global output. The EU followed with 22% of installations and 34% market share for turbine manufacturers, including Vestas and Siemens Gamesa. EU companies also dominate electronics systems, representing 31% of global production.

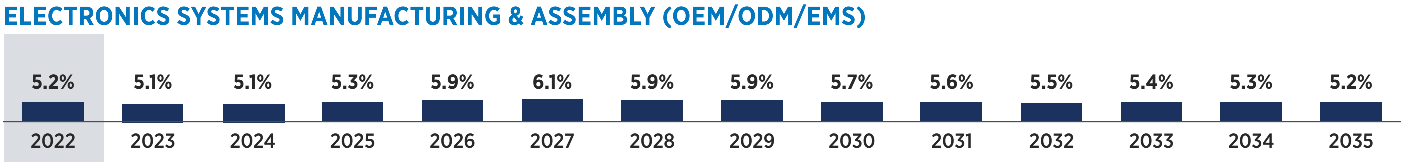
The US, with 19% of installations and 11% market share, is led by General Electric. US firms account for 16% of global electronics systems production. India is developing its manufacturing ecosystem, and Japan, though strong in electronics systems, has a small wind energy market.

From 2012 to 2022, the EU's share of global wind turbine electronics production fell from 37% to 32%, averaging a 1.6% annual decline. EU companies, despite their long-standing leadership, face intense competition from the US, Japan, and China, with China becoming the main growth driver. China's production share overtook the EU's in 2018.

Between 2022 and 2035, the global market is expected to grow 9% annually. However, the EU's production share is likely to continue declining due to Chinese competition. The EU's wind turbine electronics production is projected to grow 7% annually, remaining one of the EU's fastest-growing production segments.

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: **RENEWABLE ENERGIES**

ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY (OEM/ODM/EMS)



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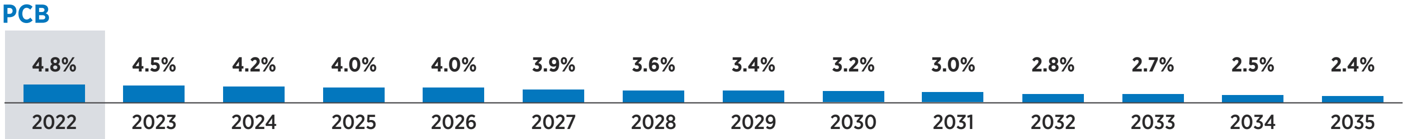
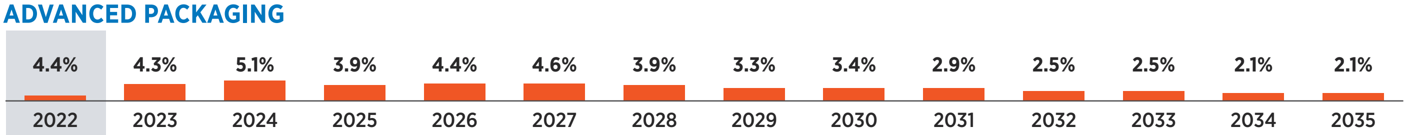


ADVANCED PACKAGING



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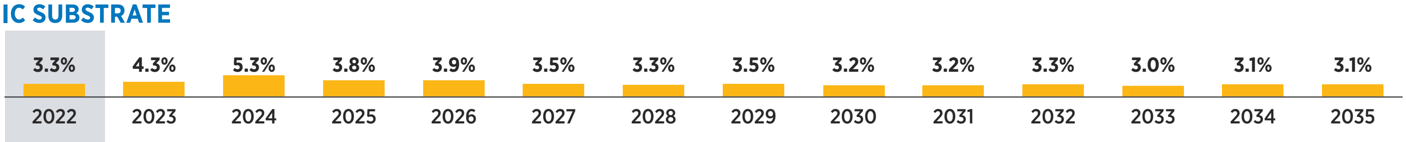


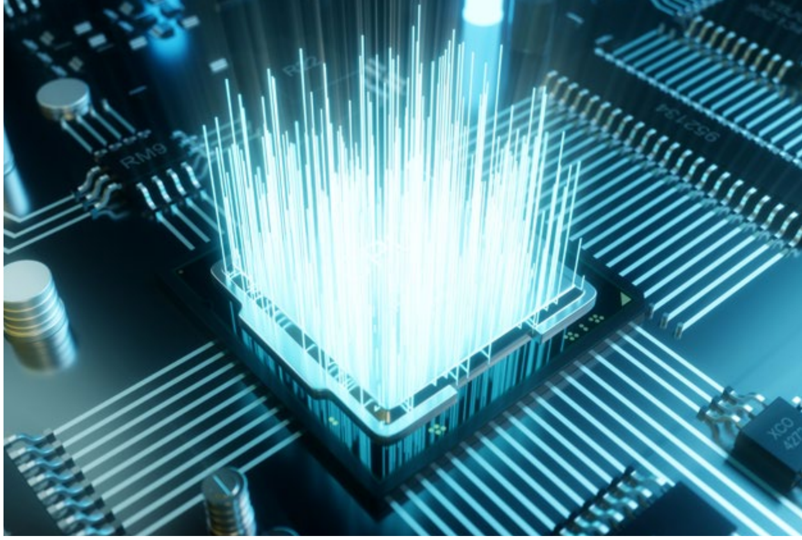
NUCLEAR

Nuclear power plants rely on instrumentation and control (I&C) systems, including sensors, control devices, computers, and relays, to ensure proper functioning and safety.[15] In 2022, nuclear electronic systems made up 4% of global renewable energy electronics production. The EU led this sector, producing 28% of global nuclear I&C systems, with major players like Areva NP, Siemens, Schneider Electric, and Atos. Chinese suppliers, growing rapidly, held a 19% market share, followed by North American and Japanese suppliers at 17%, and Russian suppliers at 12%. Non-EU European countries, including the UK, Switzerland, and Ukraine, accounted for 10% of production, while the rest of the world held 14%.

STRATEGIC DEPENDENCIES IN RENEWABLE ENERGY ELECTRONICS

The EU's renewable energy electronics sector faces significant strategic dependencies due to its reliance on other countries for PCBs, advanced packaging, and IC substrates. In 2023, the EU produced 5.1% of the world's renewable energy electronic systems, but domestic production of PCBs for this sector accounted for just 4.5% of the global total. Similarly, the EU produced only 4.3% of the world's advanced packaging needs and 4.3% of the world's IC substrates. Although these figures are higher than other sectors, strategic vulnerabilities remain in the supply chain. The EU must import critical components to support its renewable energy industry.

By 2035, the EU's production share for electronic systems is projected to remain stable at 5.2% of the global market. However, the share for PCBs is expected to decline to 2.4%, for advanced packaging to 2.1%, and for IC substrates to 3.0%. This trend highlights a continued dependency on external sources as global production outside the EU rises more rapidly. Addressing these weaknesses through strategic initiatives to bolster domestic

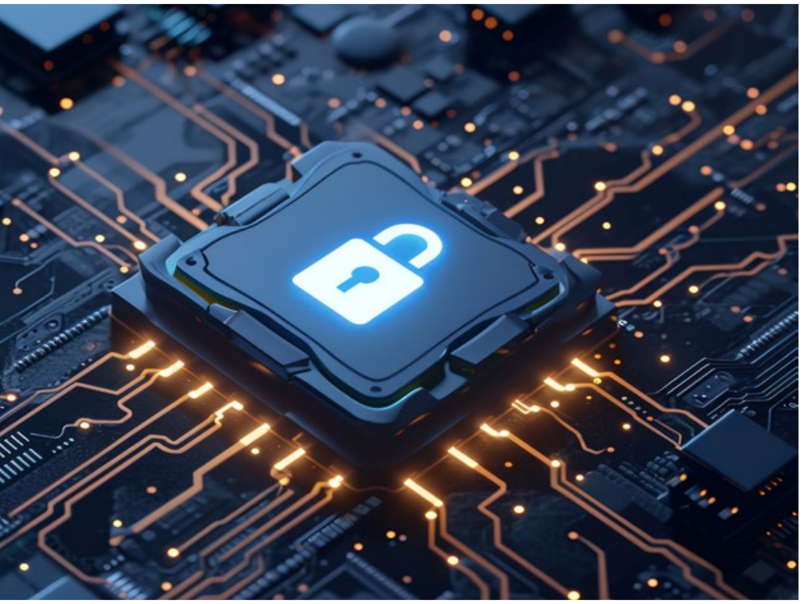


production capabilities is crucial for enhancing the resilience and sustainability of the EU's renewable energy electronics sector.

SECURITY

Following the September 11, 2001 attacks, "Homeland Security" emerged as a high-potential market in developed regions facing terrorist threats and necessitating new protection measures. Over the next decade, continuous investment and market consolidation, spearheaded by the USA and its Department of Homeland Security, laid the groundwork for a burgeoning security market. By the early 2010s, these efforts began to bear fruit, turning the security sector into a significant growth driver for major electronic equipment suppliers worldwide. For the past 20 years, this sector has seen substantial expansion, driven by the ongoing demand for advanced security solutions in response to evolving threats.

The security market encompasses both traditional and emerging segments. Traditional markets include products like fire alarms and electronic safes, which are primarily driven by the private sector and characterised by low-cost, high-volume devices. These markets often integrate with other sectors such as home and building automation. On the other hand, emerging security markets cater to new demands for protection against external threats like natural disasters, terrorism, and organised crime. These markets involve diverse applications such as airport security and civil protection, heavily relying on electronic devices for sensing, processing, and communication. Unlike traditional security markets, these emerging segments are predominantly funded by public investment and public/private partnerships.



The security sector is served by a diverse range of suppliers, from large defence system integrators to niche equipment providers. Defence integrators dominate a significant share of the security market due to their advanced system integration capabilities. However, evolving threats have created new market needs, offering opportunities for new entrants, including environmental and energy service companies. These new players can leverage their expertise in sustainability and infrastructure protection to meet emerging security demands, thereby diversifying and enhancing the overall security landscape.

The four major segments of the security market include:

- **BORDER CONTROL:**
  - Border management & immigration checkpoints: Technologies for people and goods scanning, biometrics, ID, and RFID
  - Border surveillance, land and sea (including ports): Surveillance technologies/sensors, perimeter security, C3I system
- **CIVIL & CITIZENS PROTECTION:**
  - First responders (firefighters, police, medical emergency): Emergency preparedness and response capabilities (including search and rescue, disaster response capabilities, communications, training)
  - Anti-CBRNE threats: Equipment and systems for detection and decontamination
  - Fight against crime, violence, and terrorism/law enforcement: Data mining/fusion/analysis, intelligence, and data management & sharing
- **CYBER SECURITY:**
  - IT network and database security
  - C3I (Command, Control, Communication, Intelligence)
  - Electronic identification and authentication
- **CRITICAL INFRASTRUCTURE PROTECTION:**
  - Aviation security including airports (people and goods/freight)
  - Ground/mass public transport security
  - Other infrastructures including energy, supply chain and container security, food, water, agricultural, banking, and finance infrastructures

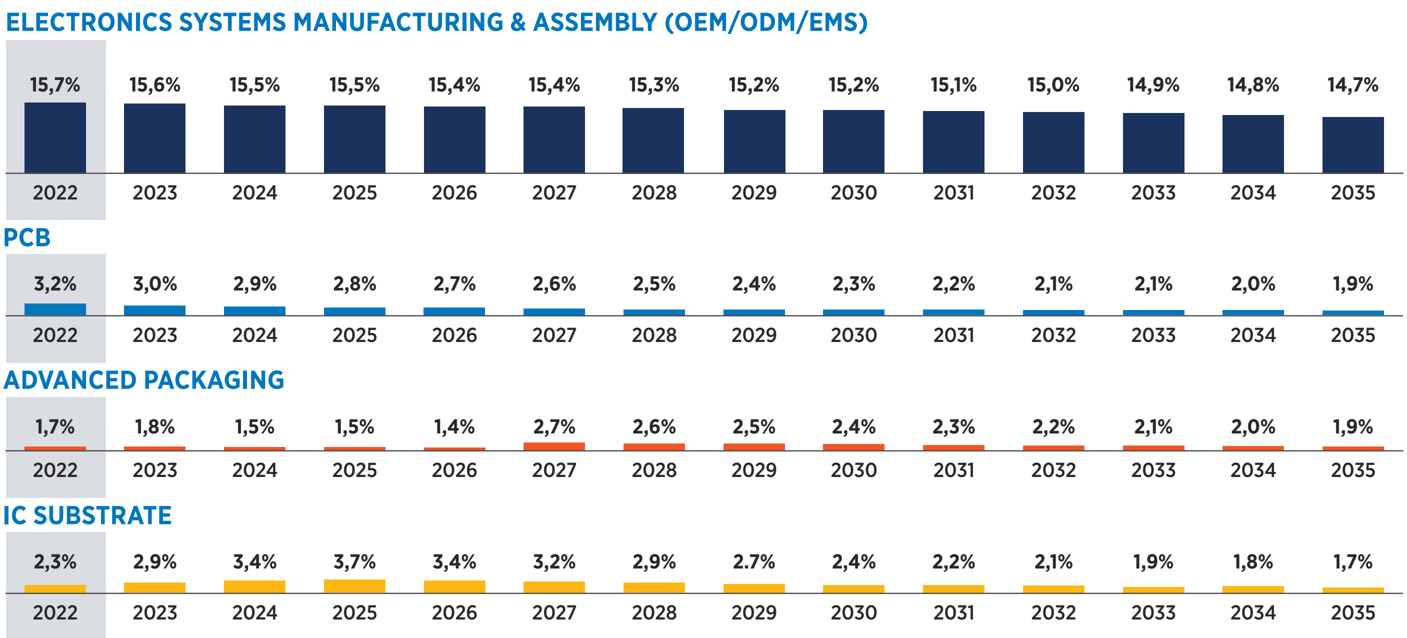
The security electronics manufacturing market was valued at €45 billion in 2023 and is projected to grow at an annual rate of 4.8%, reaching €78.8 billion by 2035. The most dynamic segments are expected to be cybersecurity and critical infrastructure protection, while other segments will grow slightly below the overall trend. This growth is driven by the development of international standards and ongoing geopolitical instability. Unlike the global electronics market, the security market is less cyclical due to long-term programmes and investment patterns. Despite a weaker domestic market, European security suppliers are finding growth opportunities abroad, particularly in the U.S. and Asia. In 2023, European production of security electronic systems accounted for 15.6% of global demand, valued at €7 billion. European production is expected to grow at an annual rate of 4.3% through 2035, slightly below the global trend. As the market evolves to address new security threats and regulatory changes, new European leaders may emerge in sectors like environment, energy, and transport, capitalising on their expertise and innovation to capture a larger share of the global market.

STRATEGIC DEPENDENCIES IN THE SECURITY ELECTRONICS MARKET

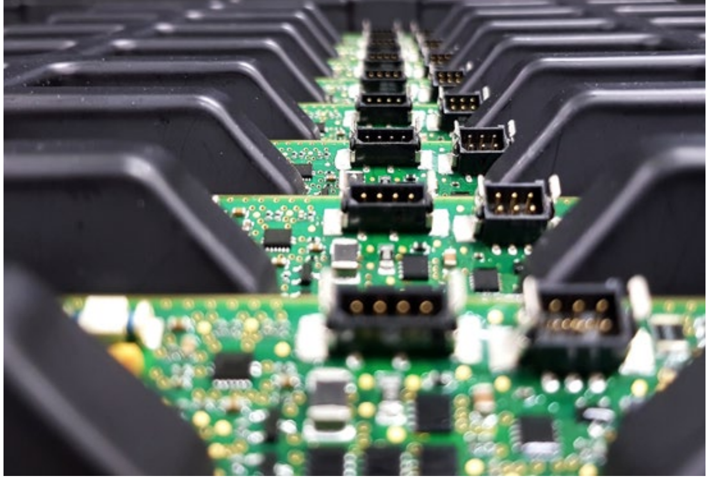
The EU's security electronics sector faces significant strategic dependencies due to its reliance on other countries for EMS, PCBs, advanced packaging, and IC substrates. While the EU produces a substantial share of the world's security electronic systems, accounting for 15.6% in 2024, its production of PCBs (3%), advanced packaging (1.8%), and IC substrates (2.9%) is notably lower. These gaps create vulnerabilities in the supply chain, as the EU must import these critical components to support its security electronics industry.

By 2035, the EU's production share is projected to decline to 14.7% for electronic systems, 1.9% for PCBs, 1.9% for advanced packaging, and 1.7% for IC substrates. This highlights an increasing dependency on external sources as global production outside the EU rises more rapidly. Addressing these weaknesses through strategic initiatives to bolster domestic production capabilities is crucial for enhancing the resilience and sustainability of the EU's security electronics sector.

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: SECURITY



SERVERS



The server sector encompasses traditional servers (middle and low range), High-Performance Computing (HPC), and dedicated terminals such as Point of Sale (POS) systems and Automatic Teller Machines (ATMs). Traditional servers and dedicated terminals are mainly driven by private industries, including large companies and SMEs. HPC includes supercomputers and high-end technical servers, which are expensive and highly powerful machines used for specialised purposes like R&D, cybersecurity, and meteorology. Customers for HPC are typically Research and Technology Organizations (RTOs), government bodies, and large corporations.

From 2017 to 2022, servers demonstrated the fastest worldwide growth among electronic systems, driven by the swift expansion of cloud computing and the widespread adoption of AI and big data use cases in both business-to-consumer (B2C) and business-to-business (B2B) industries. In 2023, the server market declined 5% as companies reduced IT spending, leading to a decrease in unit sales, although selling prices remained on an upward trend. However, despite this downturn, the server market is expected to regain momentum, likely driven by continued growth in cloud computing, big data, AI, and advancements in generative AI technologies.

Driving factors for the server industry include:

- **Generative AI:** The rising field of generative AI drives demand for high-computing capacities, requiring advanced server technologies to support the extensive computational needs of these models.

- **5G/6G Technologies and Edge Computing:** Advances in 5G/6G and edge computing are significant growth drivers for server suppliers. These technologies attract new clients from the telecom industry and embedded industries such as automotive, Industry 4.0, and healthcare. The server market for edge computing in embedded industries is expected to grow at an annual rate of 18% from 2021 to 2027.

- **Quantum Computing and Supercomputers:** The development of quantum computing increases investment in post-quantum cryptography, requiring supercomputers. The potential for quantum computing to break current encryption standards accelerates these investments.

- **Semiconductor Industry Innovations:** Innovations in the semiconductor industry, such as Nvidia's latest GPUs optimised for machine learning, drive advancements in server equipment, enhancing the capacity to handle complex AI algorithms.

Global server demand is projected to grow 4.1% annually from 2022 to 2027 and 5.3% from 2022 to 2035, exceeding the overall electronics industry. The 2023 downturn will affect 2024 demand, shifting focus from traditional server applications to AI applications. Increased AI computing needs will drive 8.5% production growth in 2025 and 2026.

In 2022, the EU accounted for over 14% of global server market demand but only 7.4% of global production, with most low and mid-range servers made in China and continued outsourcing in the EU. From 2017 to 2022, the global server market grew 7.5% annually, while EU production fell 2.1% annually. EU production is projected to stagnate in the coming years., However, investments in advanced semiconductors, such as Intel's facility in Germany, are anticipated to boost future

EU production. Overall, server production in the EU is expected to grow 3.8% annually through 2035.

FOCUS ON HPC

HPC is a critical driver of scientific, economic, and technological advancement. HPC enables the processing of vast amounts of data at unprecedented speeds, facilitating breakthroughs in fields like climate modelling, medical research, materials science and artificial intelligence. Countries are investing in HPC to enhance their research capabilities, solve complex problems, and remain competitive in the global economy. Moreover, HPC can accelerate innovation across various industries, leading to new products, services, and business models that drive economic growth and improve the quality of life for citizens. Prioritising HPC development ensures a nation is at the forefront of technological progress and can effectively address future challenges. The global HPC hardware market was €14.6 billion in 2022, comprising supercomputers and high-end technical servers. Globally, the HPC market is expected to grow at 6.5% annually between 2022 and 2035.

STRATEGIC DEPENDENCIES IN THE SERVER MARKET

The EU's server electronics sector faces significant strategic dependencies due to its reliance on other countries for EMS, PCBs, advanced packaging, and IC substrates. While the EU accounts for 7.5% of global server electronic systems, its production of PCBs (0.1%), advanced packaging (1.6%), and IC substrates (0.5%) is notably lower. These gaps create vulnerabilities in the supply chain, as the EU must import these critical components to support its server electronics industry.
By 2035, the EU's production share is projected to decline to 5.7% for electronic systems, 0.0% for PCBs, 1.1% for advanced packaging, and 0.4% for IC substrates. This highlights an increasing dependency on external sources as global production outside the EU rises more rapidly.

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: SERVERS

ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY (OEM/ODM/EMS)

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
7,4%	7,5%	7,4%	6,8%	6,3%	5,9%	5,7%	5,6%	5,6%	5,6%	5,6%	5,7%	5,7%	5,7%

PCB

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%

ADVANCED PACKAGING

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
1,6%	1,7%	1,5%	1,4%	1,3%	2,1%	2,0%	1,8%	1,7%	1,6%	1,4%	1,3%	1,2%	1,1%

IC SUBSTRATE

2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0,5%	0,7%	0,8%	1,0%	0,9%	0,9%	0,8%	0,7%	0,6%	0,6%	0,5%	0,5%	0,5%	0,4%

TELECOMMUNICATIONS INFRASTRUCTURE

Telecommunications infrastructure is the backbone of modern society, driving collaboration, economic activity, technological advancements, and social interactions. Its ongoing development is essential for a connected, globally integrated world. Modern communication technology merges voice communications from the traditional telecom industry with digital data from the data network industry. Telecom infrastructures encompass fixed landlines, mobile networks, and private IT networks, all interlinked.

Telecom networks serve both large-scale carriers offering fixed and mobile services, and private companies needing customised networks. Historically separate, enterprise networks (e.g., Cisco, Juniper) and carrier technologies (e.g., Ericsson, Nokia, Huawei) are now converging, especially with the rise of mobile communications and 5G.

The telecom market has evolved with increasing user demands for mobility, performance, and flexibility. Carriers are adopting Network Functions Virtualization (NFV) and Software Defined Networking (SDN) to transform and support 5G and IoT. Digital transformation boosts data transfer rates, influencing network construction. Telecom companies must balance requirements like data size, speed, security, and power consumption, especially with the rise of cloud computing and big data. Energy efficiency is also a growing consideration.

In 2022, global telecommunication infrastructure grew 6.5%, reaching €198.4 billion, driven by high demand for connectivity. Carrier networks rebounded with 4.2% growth, totalling €126.4 billion, while enterprise and private networks surged 10.7%, amounting to €72 billion. This growth underscores the increasing need for robust and expansive network solutions across both public and private sectors.

Despite economic challenges, global telecom carriers maintained stable investments, fueled by persistent demand for services. The expansion of 5G was pivotal, with over 500 carriers in more than 150 countries investing in 5G by year-end, and the number of 5G commercial terminals rising by 67% to 1,431 models. Wireline networks continue to transition from copper to optical wires to meet increasing bandwidth demands from 5G. Carriers worked to upgrade networks and conversions to meet escalating demand for this bandwidth.

In 2022, China led the way with a 7.5% increase in telecom infrastructure production, totalling €96.6 billion, thanks to advancements in 5G and optical networks. Europe's production rose by 2.1% to €12.3 billion, with Nokia and Ericsson remaining significant players despite Huawei's dominance.

The telecommunications market is growing due to increased demand from mobile communications, smartphone evolution (4G and 5G), cloud-based communications, IoT, and connected vehicles. By 2035, 5G will be fully adopted, with 6G arriving around 2032-2033. Global telecom infrastructure equipment production is set to grow 3.3% annually until 2027, reaching €233.6 billion. Carrier networks will grow 2.8% per year, while enterprise infrastructure will expand 4.3% annually.

The carrier market will benefit from continued 5G adoption, with only 20% of radio base stations upgraded to 5G mid-band by the end of 2022. 5G deployment in India around 2025 will further boost production, despite declining investments in LTE and 3G/4G. Fixed wireless access, fibre, IP routing, and optical networks will grow moderately due to high-speed access demand and competition-driven price impacts.

The enterprise telecommunication segment, driven by COVID-19 and technological improvements, will outperform the overall telecom segment. Remote work solutions and cloud-based communications like UCaaS and CPaaS will drive growth, offering flexibility, scalability, and cost-effectiveness.

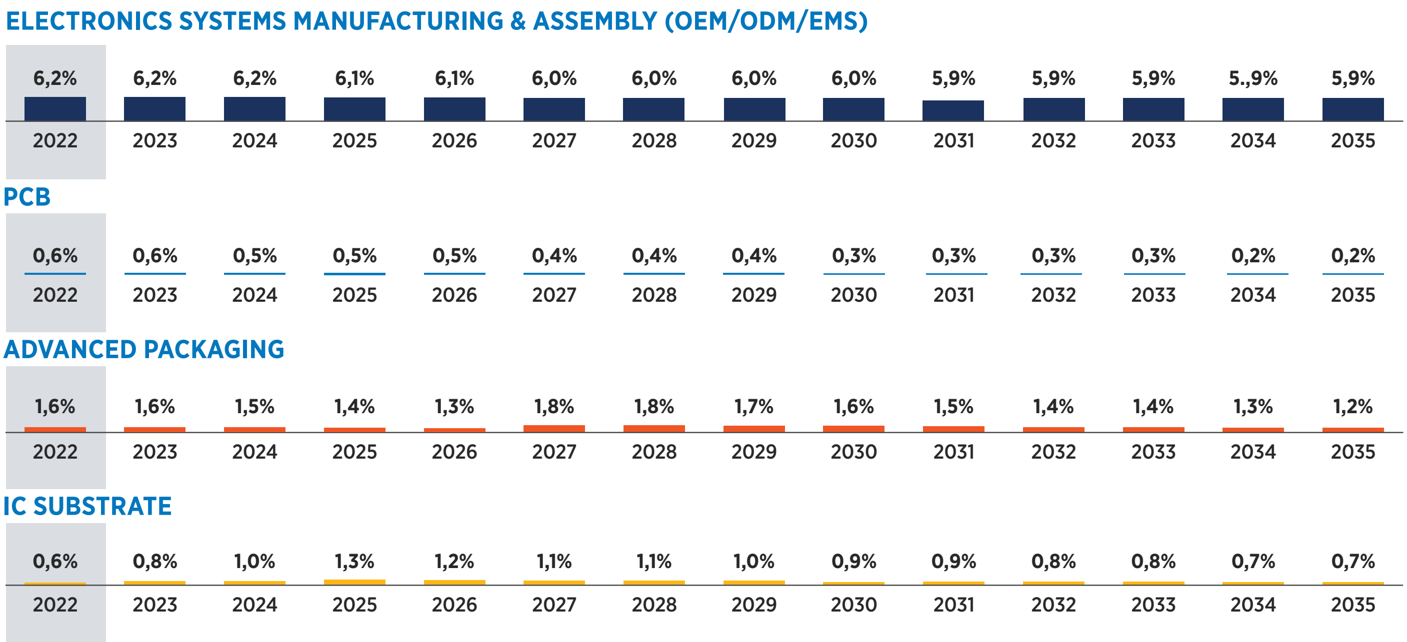
5G adoption will enhance enterprise telecommunications, supporting IoT and augmented reality. Industrial 5G use cases will emerge in sectors like manufacturing, logistics, seaports, airports, mining, utilities, smart agriculture, and smart cities. Edge computing will increase the need for efficient telecom solutions for low-latency applications in industrial IoT.

European telecom infrastructure equipment production is expected to grow 2.8% annually until 2027 and 2.7% until 2035, slightly below the global trend due to competition from China and Asia.

STRATEGIC DEPENDENCIES IN TELECOMMUNICATIONS EQUIPMENT

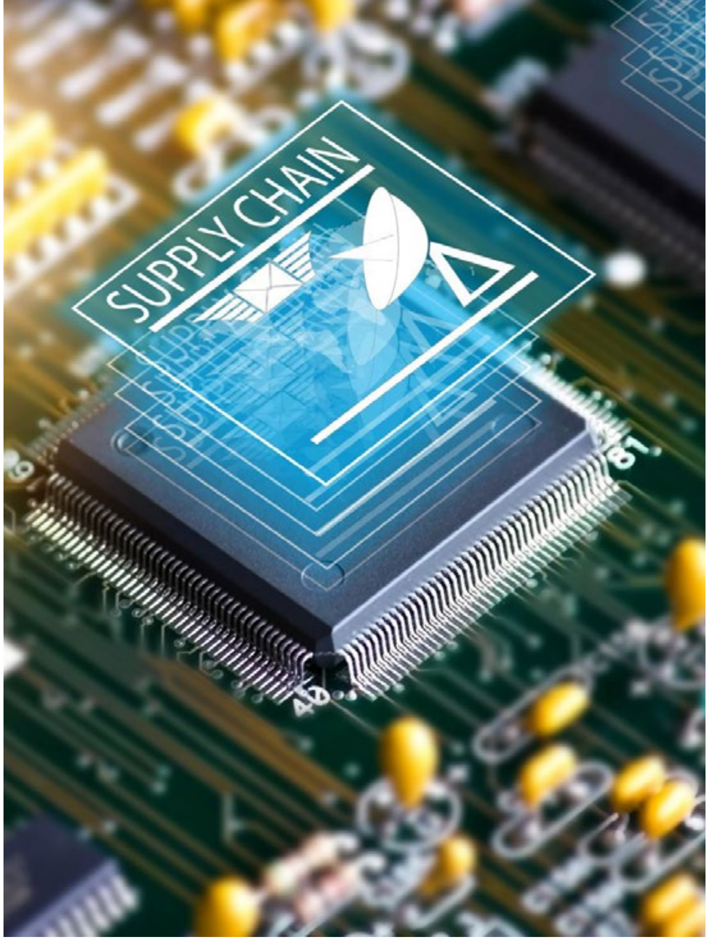
The EU's telecommunications equipment sector faces significant strategic dependencies due to its reliance on other countries for PCBs, advanced packaging, and IC substrates. In 2023, the EU produced only 6.2% of global telecommunications electronic systems and accounted for just 0.6% of total global PCB production for this sector. Additionally, the EU's share of global advanced packaging

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY: TELECOMMUNICATIONS INFRASTRUCTURE



was just 1.6%, and it contributed only 0.8% of global IC substrates. These substantial gaps create vulnerabilities in the supply chain, as the EU must import these critical components to sustain its telecommunications industry. Strengthening domestic production capabilities in these areas is crucial for reducing these dependencies and enhancing the resilience of the sector.

By 2035, the EU's production share is projected to decline to 5.9% for electronic systems, 0.2% for PCBs, 1.2% for advanced packaging, and 0.7% for IC substrates. This highlights an increasing dependency on external sources as global production outside the EU rises more rapidly. Addressing these weaknesses through strategic initiatives to bolster domestic production capabilities is crucial for enhancing the resilience and sustainability of the EU's telecommunications equipment sector.



ADDRESSING CRITICAL NEEDS FOR EU AUTONOMY

The EU's reliance on semiconductor production in Asia has long been a point of vulnerability for its technology sector. The disruptions caused by global supply chain issues have starkly highlighted the risks associated with this dependence. Recognizing this, the EU has set ambitious goals to bolster its semiconductor production, aiming to increase its share from 10% to 20%. While this target is a step in the right direction, it only addresses part of the problem. Semiconductors alone cannot sustain the technological ecosystem; they require an integrated and robust supply chain to function effectively.

A comprehensive solution requires support across the entire supply chain, from laminate manufacturing and PCB production to PCB assembly and semiconductor fabrication. Each of these components plays a critical role in the functionality of electronic systems. Without a cohesive strategy that encompasses all these elements for critical needs, the EU will continue to face challenges in achieving true technological independence. Building a resilient supply chain is essential for reducing reliance on external sources and ensuring the continuity of production, especially in times of global disruptions.

Enhancing local production capabilities will reduce the need to import electronics subsystems in critical sectors of the economy. Scaling up PCB manufacturing within the EU is crucial. PCBs are the backbone of electronic devices, and having a reliable domestic production capacity ensures that the EU can meet its demands without relying on non-EU suppliers.

Furthermore, expanding PCB assembly operations is vital for integrating semiconductors into functional electronic systems. This involves not just assembly but also testing and quality assurance to ensure that the final products meet high standards. Finally, while increasing semiconductor production is important, it must be part of a broader strategy that includes strengthening these other components of the supply chain. Only by addressing each link in the chain can the EU maintain technological autonomy and reduce its dependence on external sources.

The EU's goal of increasing its semiconductor production share is commendable but insufficient on its own. A holistic approach that supports the entire supply chain, from laminate manufacturing to PCB production and assembly, IC substrate, advanced packaging and equipment suppliers for PCB and PCBA manufacturers is necessary to build a robust and resilient electronics industry. By investing in these areas, the EU can enhance its technological independence and better withstand global supply chain disruptions.

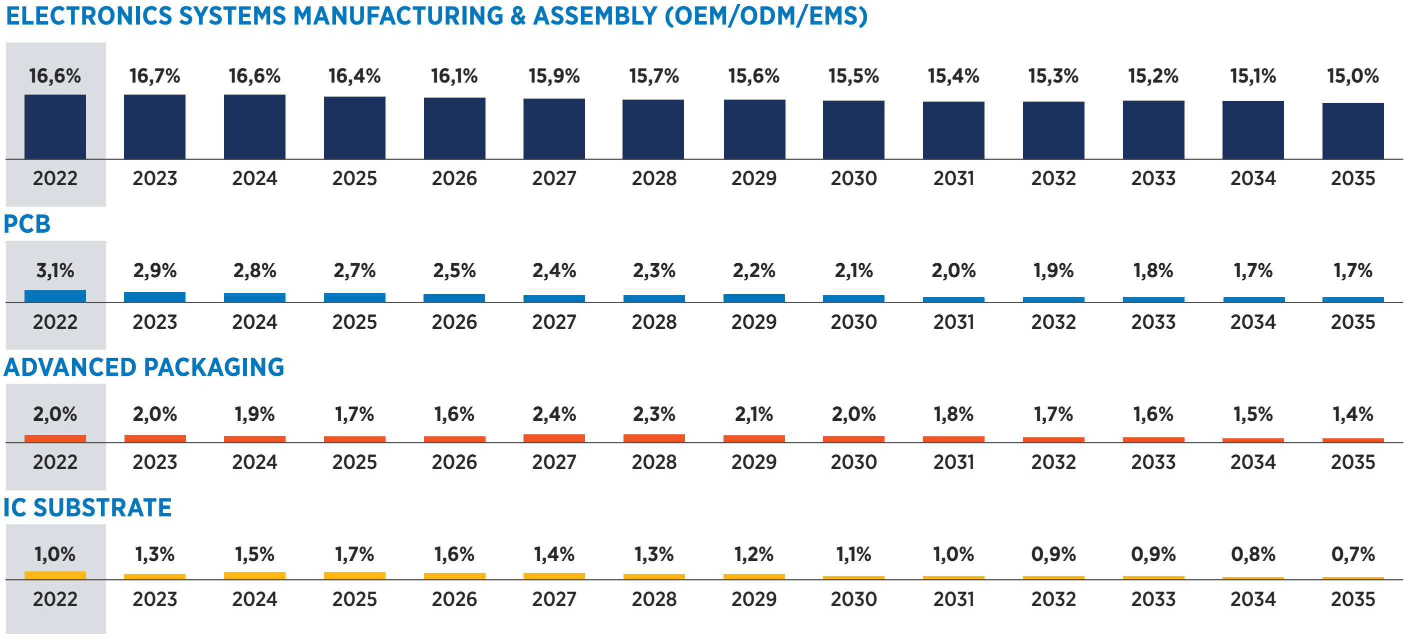
To mitigate these dependencies and enhance resiliency, the EU should support strategically critical electronics supply and manufacturing.

SETTING REASONABLE TARGETS FOR ELECTRONICS SYSTEMS IN THE EU

The EU's production of electronic systems across these 8 strategic sectors is anticipated to grow by 52.5% between 2023 and 2035. However, this growth rate lags behind that of other countries, leading the EU to cede market share to non-EU competitors. Globally, electronics systems in these eight strategic sectors are expected to increase by 70% over the same period. As a result, the EU's share of electronics systems in these sectors is projected to decline from 16.7% in 2023 to 15% by 2035.

At a minimum, the EU should establish a target to sustain its global share of electronics systems in these 8 strategic sectors at the 2023 level of 16.7%. Achieving this objective would require an additional 6.1% of electronics systems over the next 12 years, beyond current projections. Total electronics systems in 2035 would be 11% higher than current projections. This ambitious target underscores the necessity for comprehensive policies and strategic investments to bolster the EU's competitiveness in the global electronics market.

EU'S SHARE OF GLOBAL ELECTRONICS SYSTEMS MANUFACTURING & ASSEMBLY:
8 STRATEGIC SECTORS



SETTING REASONABLE TARGETS FOR PCB PRODUCTION IN THE EU

The EU holds a significant position in the global electronics manufacturing landscape, particularly within these eight strategic sectors, accounting for 16.7% of global production in 2023. However, the EU faces a substantial gap between its production and demand for PCBs. In 2023, the EU produced €1,374 million worth of PCBs, while its estimated demand was €7,871 million, resulting in a production-to-demand ratio of just 17.5%. This imbalance is particularly pronounced in sectors such as mobility and servers, HPC, and supercomputers, where the production-to-demand ratios are 8% and 2%, respectively.

Looking ahead to 2035, the EU's share of global electronics manufacturing is projected to decrease to 15%, despite overall growth in the region's electronics manufacturing production. While PCB production is expected to grow by nearly 4.9% to €1,441.3 million, this growth will not keep pace with the projected demand of €12,980.8 million, leading to a projected production-to-demand ratio of only 11%. With demand expected to grow by nearly 65% and PCB production to rise by less than 5%, sectors such as mobility,

	EU's Share of Global Electronics Manufacutring (2023)	EU's Production of PCBs (Mil of Euros, 2023)	EU's Demand for PCBs (Mil of Euros, 2023)	Ratio of EU Production to Demand 2023	EU's Projected Share of Global Electronics Manufacutring (2035)	EU's Projected Production of PCBs (Mil of Euros, 2035)	EU's Projected Demand for PCBs (Mil of Euros, 2035)	Projected Ratio of EU Production to Demand 2035	Required EU PCB Production in 2035 to Keep Ratio of Production to Demand at 2023 Levels	Required Growth Above Projection in 2035	Reasonable Targets for 2035 Ratio of PCB Production to Domestic Demand	Projected EU PCB Production in 2035 if Reasonable Targets are Achieved
AEROSPACE & DEFENCE	22.0%	€ 221	€ 736	30.1%	20.8%	€ 310.7	€ 1,144.2	27.2%	€ 344.4	11%	95%	€ 1,087.0
AUTOMATION	21.8%	€ 554	€ 878	63.1%	21.5%	€ 571.4	€ 1,393.0	41.0%	€ 878.5	54%	50%	€ 696.5
HEALTHCARE	17.2%	€ 181	€ 1,206	15.1%	17.9%	€ 228.5	€ 2,958.4	7.7%	€ 445.3	95%	25%	€ 739.6
MOBILITY	20.1%	€ 251	€ 3,193	7.9%	14.7%	€ 178.0	€ 4,543.0	3.9%	€ 357.1	101%	25%	€ 1,135.8
RENEWABLE ENERGIES	5.1%	€ 17	€ 19	86.9%	5.2%	€ 28.6	€ 63.0	45.4%	€ 54.7	91%	50%	€ 31.5
SECURITY	15.6%	€ 83	€ 429	19.4%	14.7%	€ 86.5	€ 672.3	12.9%	€ 130.8	51%	50%	€ 336.2
SERVERS, HPC & SUPERCOMPUTERS	7.5%	€ 3	€ 191	1.7%	5.7%	€ -	€ 300.8	0.0%	€ 5.1	N/A	25%	€ 75.2
TELECOMMUNICATIONS INFRASTRUCTURES	6.2%	€ 64	€ 693	9.2%	5.9%	€ 37.6	€ 950.4	4.0%	€ 87.2	132%	25%	€ 237.6
TOTAL	**16.7%**	**€ 1,374**	**€ 7,871**	**17.5%**	**15.0%**	**€ 1,441.3**	**€ 12,980.8**	**11.1%**	**€ 2,266.7**	**57%**	**33.4%**	**€ 4,339.3**
SHARE OF GLOBAL PCB PRODUCTION FOR 8 STRATEGIC SECTORS									**2.6%**			**5.0%**

where the demand for PCBs is expected to rise significantly to €4,543 million, will see a particularly stark drop in the production-to-demand ratio to less than 4%.

To maintain the current production-to-demand ratio of 17.5% in 2035, the EU would need to increase its PCB production to €2,266.7 million, representing a required growth of 57% above current projections. This ambitious target underscores the necessity for strategic intervention to boost domestic PCB production. For instance, the renewable energies sector would need a 91% increase in production to meet this target, highlighting the critical need for innovation and capacity expansion in this field.

Setting reasonable targets for 2035 across these eight strategic sectors would result in about one-third of demand being satisfied by domestic production. If these targets are met, the EU's PCB production would reach €4,369.3 million, helping to reduce import dependency and improve resilience. Achieving these targets would involve concerted efforts across various sectors, including automation, healthcare, and security, where the target ratios are 50%, 25%, and 50%, respectively. The result would be that 5% of global PCB production for these eight strategic sectors would be produced in the EU.

While the EU has a robust electronics manufacturing base, the PCB production sector faces significant challenges. Meeting the projected reasonable targets for 2035 will be crucial for enhancing the EU's self-sufficiency and competitiveness in the global electronics market.

SETTING REASONABLE TARGETS FOR ADVANCED PACKAGING & IC SUBSTRATE PRODUCTION IN THE EU

As of 2023, the EU's share of the global market for advanced packaging and IC substrates stood at 2% and 1.3%, respectively. However, projections indicate that if these areas are not strategically prioritised, the EU's share could drop to 1.4% for advanced packaging and 0.7% for IC substrates by 2035. This potential decline underscores the urgent need for targeted policies and investments to strengthen these critical sectors. Without strategic intervention, the EU risks increasing its dependency on external sources and losing its competitive edge in the semiconductor industry.

Setting reasonable targets for advanced packaging and IC substrate production in the EU is crucial for bolstering the region's semiconductor industry. As the EU strives to achieve a 20% share of global semiconductor production by 2030, it is essential to align the targets for related segments, such as advanced packaging and IC substrates, to support this overarching goal. Advanced packaging and IC substrates are integral components of the semiconductor supply chain, and their development is pivotal for ensuring the EU's competitiveness in the global market.

Advanced packaging technologies are essential for enhancing the performance and efficiency of semiconductor devices. These technologies allow for higher transistor density, improved power efficiency, and better heat dissipation, which are critical for the development of next-generation electronics. By setting a target to capture 20% of the global market share in advanced packaging, the EU can ensure a robust supply chain that supports its semiconductor ambitions.
IC substrates, which serve as the foundation

for semiconductor devices, play a critical role in the overall performance and reliability of these devices. The production of high-quality IC substrates is essential for advanced packaging technologies, as it directly impacts the performance of the final semiconductor products. To achieve the 20% semiconductor target, the EU must also aim for a corresponding 20% share in the IC substrate market. This alignment will ensure that the region has a comprehensive and integrated approach to developing the semiconductor ecosystem.

Semiconductor production, advanced packaging, and IC substrates are interconnected, and advancements in one area often drive progress in the others. For example, innovations in advanced packaging can lead to new requirements for IC substrates, while breakthroughs in semiconductor technology can spur the development of more sophisticated packaging solutions. Therefore, setting consistent targets across these categories will enable the EU to create a cohesive strategy that addresses the needs of the entire semiconductor value chain.

Establishing a 20% market share target for advanced packaging and IC substrates is vital for the EU's semiconductor strategy. These targets will ensure that the region is not only a leader in semiconductor production but also in the supporting technologies that are essential for the industry's growth. By aligning these goals, the EU can foster a resilient and competitive semiconductor ecosystem that meets the demands of the global market and drives technological innovation.

FROM SILICON-TO-SYSTEMS

Silicon to Systems encapsulates the entire lifecycle of electronic product development and manufacturing, from the initial design and fabrication of silicon chips to the integration of these chips and other components on PCBs. PCBs serve as the backbone for mounting various electronic components and, more importantly, facilitate electronic interconnection among components to deliver functionality.

PCBs populated with components are called electronic assemblies. Assemblies can constitute independent systems (e.g., a smartwatch), but are just as likely to be integrated as subsystems into even larger systems (e.g., an automobile, network server, or industrial machinery). Each step, from silicon chip to the assembled system, requires precise engineering and integration, ensuring that the final product performs reliably and as designed.

In electronics manufacturing, reliability is of paramount importance, and reliability is largely dictated by the integrity of the electronic interconnections. But, as semiconductor packages become more sophisticated, the PCB designs and electronic assembly required to support them also become more complex. In Europe, many firms do not have the resources to upgrade their facilities. The challenge is particularly acute in the PCB industry, where very few European fabricators can achieve what in Asia is considered the state of the practice.

The lack of a robust silicon-to-systems ecosystem undermines the region's digital and green transitions, as well as other key initiatives, but it also subjects Europe to potentially crippling supply chain disruptions by maintaining grossly imbalanced dependencies on non-EU suppliers. A silicon-to-systems perspective better reflects the interconnectedness and complexity of the electronics industry's supply chain, which is crucial for fostering collaboration, driving innovation, and ensuring the reliability and quality of electronic products.

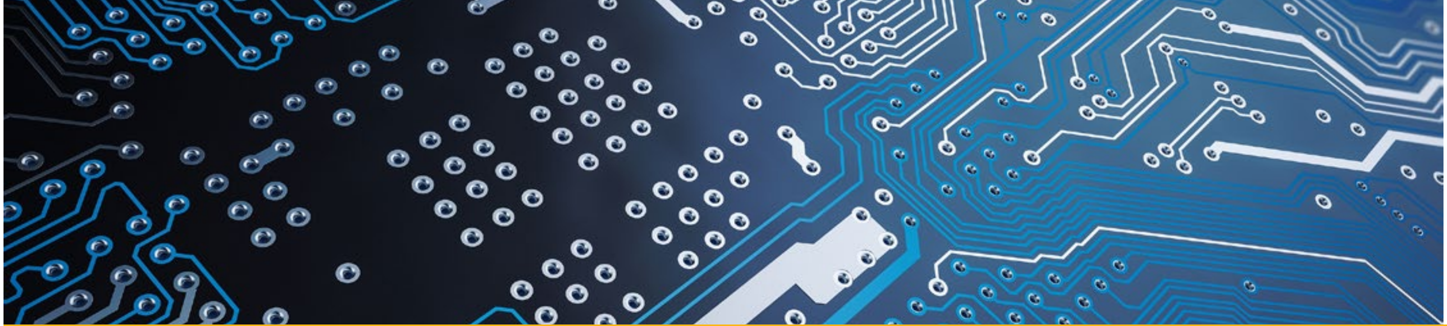
CONCLUSION

The analysis of Europe's electronics manufacturing sector reveals significant challenges and opportunities across eight strategic areas: aerospace and defence, automation, healthcare, mobility, renewable energy, security, servers, and telecommunications. Despite the EU's commitment to bolstering its electronics production capabilities, the region faces critical dependencies on non-EU countries for essential components like PCBs, advanced packaging, and IC substrates. These dependencies pose risks to the EU's industrial resilience and underscore the need for strategic initiatives to enhance domestic production capabilities.

The EU's share of global PCB production has drastically declined over the past two decades, and this trend is expected to continue unless there are targeted efforts to reverse it. By 2035, the EU's share of electronics systems in key sectors is projected to fall further, highlighting an urgent need for strategic investments. Without a robust response, the EU's ability to meet the growing demand for electronic systems, driven by advancements in technology and new market needs, will be compromised. Addressing these vulnerabilities is crucial for maintaining the EU's competitiveness and ensuring the stability of its supply chains.

Strategic initiatives must focus on increasing the EU's production of critical components. For example, achieving a 20% share of global semiconductor production by 2030 is a commendable goal, but it should be complemented by corresponding targets for advanced packaging and IC substrates. This comprehensive approach will ensure that the EU not only leads in semiconductor production but also secures the necessary infrastructure to support this industry. Investments in areas such as PCB manufacturing and electronic assembly are essential to reduce dependency on external sources and enhance the region's technological autonomy.

The EU's electronics manufacturing sector stands at a crossroads. While there are significant challenges, there are also substantial opportunities for growth and innovation. By adopting a holistic approach that supports the entire supply chain, from silicon to systems, the EU can build a robust and resilient electronics industry. Strategic investments, comprehensive policies, and a focus on critical sectors will enable the EU to enhance its competitiveness, ensure industrial resilience, and drive sustainable economic growth. Addressing these needs is essential for the EU to maintain its leadership in the global electronics market and achieve its digital and green transition goals.



ENDNOTES

1 For additional information on study methodology, see Appendix I.

2 See Appendix II for a review of electronics systems manufacturing in Europe.

3 The aerospace segment is expected to grow an average of 5.9% annually until 2027 and by 5.1% until 2035, while the defence sector is anticipated to increase by 4.7% and 4.9% during the same periods, respectively.

4 Stockholm International Peace Research Institute. (2024, April). Trends in world military expenditure, 2023 (SIPRI Fact Sheet). Retrieved from https://www.sipri.org/sites/default/files/2024-04/2404_fs_milex_2023.pdf

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6 Reuters. (2022, June 3). German lawmakers approve 100 billion euro military revamp. Retrieved from https://www.reuters.com/world/europe/german-lawmakers-approve-100-bln-euro-military-revamp-2022-06-03/

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8 Airbus. (2024, February). Airbus reports full-year (FY) 2023 results. Retrieved from https://www.airbus.com/en/newsroom/press-releases/2024-02-airbus-reports-full-year-fy-2023-results

9 Boeing. (2024, April). Boeing reports first quarter results. Retrieved from https://investors.boeing.com/investors/news/press-release-details/2024/Boeing-Reports-First-Quarter-Results/default.aspx

10 Excluding robotics.

11 Smartwatches are excluded from the healthcare electronics category by DECISION and are classified within the consumer audio and video segment. This is because smartwatches, though capable of some health monitoring functions, are primarily used for purposes beyond healthcare and are produced by companies mainly engaged in consumer electronics. The industrial landscape of smartwatches is distinctly different from professional healthcare equipment manufacturers. Furthermore, smartwatches lack the “critical” aspect defined by the EU, which is applicable to professional electronic healthcare systems, such as imaging systems.

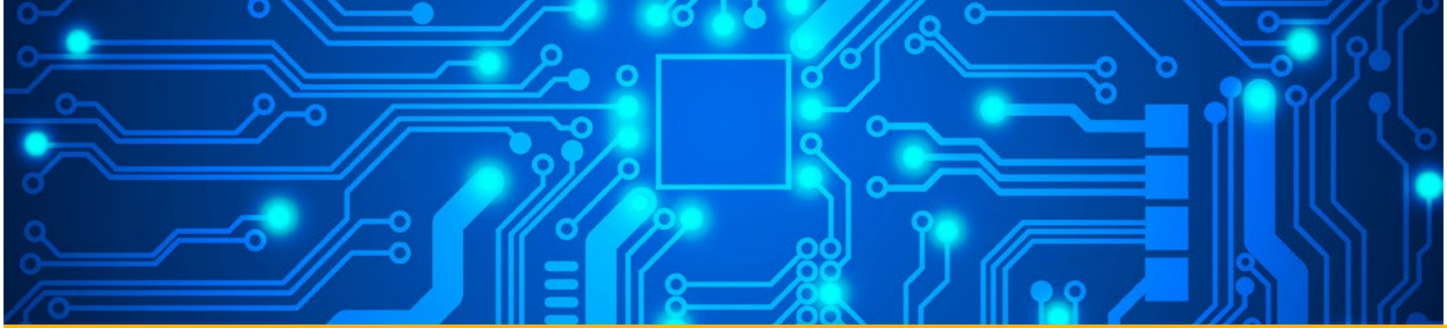
12 Notably, corporations like Microsoft are exploring SMRs for datacenter power.

13 International Energy Agency. (2023). Renewables 2023: Analysis and forecast to 2028.

14 Global Wind Energy Council. (2022). Global Wind Report 2022.

15 The nuclear industry consumes two types of electronics systems: Instrumentation & Control systems for nuclear plants, including associated sensors and IoT networks, but also NRBC detection electronic systems. However, NRBC detection electronic systems are considered as part of the Security electronics segment and are also used in other end-user industries such as air transport.

16 Gartner. (2023, December 4). Gartner forecasts worldwide semiconductor revenue to grow 17 percent in 2024. Retrieved from https://www.gartner.com/en/newsroom/press-releases/2023-12-04-gartner-forecasts-worldwide-semiconductor-revenue-to-grow-17-percent-in-2024



APPENDIX I: METHODOLOGY

The main goal of this study is to analyse and forecast the EU electronics manufacturing sector, focusing on electronics systems, PCB production, and the advanced packaging and IC substrate industries. The study aims to project industry data and identify potential gaps by 2035.

Data sources include baseline figures from In4ma and DECISION. In4ma provides historical data on the EU and World EMS and PCB industries for the period from 2012 to 2022, establishing a historical baseline for the analysis. DECISION offers baseline figures for 2022 on the EU and World advanced packaging and IC substrate industries, providing a current snapshot to support the forecasting process. Statistical and econometric models were used to project future trends in these industries up to 2035, incorporating various scenarios and assumptions to account for potential market changes and uncertainties.

After forecasting, a gap analysis compares the projected data against baseline figures, highlighting potential gaps and areas of concern or opportunity for stakeholders in the OEM industry. The study employs statistical analysis, econometric models, and scenario planning. Techniques like regression and time-series analysis help analyse historical data and project future trends. Econometric models consider economic, technological, and market factors, while scenario planning explores different future industry states and their implications.

The forecast models are validated through cross-validation with historical data to ensure accuracy and reliability. This thorough approach provides a detailed analysis and forecast of the EU electronics manufacturing sector, identifying strategic areas for development and addressing potential challenges by 2035.

APPENDIX II:
THE EUROPEAN MARKET FOR ELECTRONICS

European companies were once at the forefront of electronics manufacturing, dominating the market with their advanced production capabilities. However, intense competition from Asia and other regions has shifted European firms towards specialising in high-value, lower-volume production niches such as embedded systems used in medical technologies, industrial equipment, defence, space, aerospace, and automobiles. This pivot to specialised production has resulted in European manufacturers relinquishing much of the volume of manufacturing associated with products in several economic sectors to Asia. Europe's leadership decline has profound implications for the resilience of its supply chains and the autonomy of technology.

Embedded systems are a growing market as electronics increasingly become fundamental to all sectors of the economy, driving digital and green transitions across industries. For Europe, which aims to maintain global leadership in sectors such as clean energy, connected and autonomous mobility, Industry 4.0, and cybersecurity, it becomes strategically important to localise critical electronics manufacturing.

The volatility of global supply chains, exacerbated by trade conflicts, health crises, and natural disasters, highlights the need for resilient, regional supply chains. European companies are recognizing the importance of diversifying and regionalizing their supply chains to mitigate risks associated with global dependencies. This is especially true in sectors like defence and aerospace where data protection and security are paramount. However, the shift away from volume production has left European PCB manufacturers with insufficient resources to reinvest in their operations, technology, and equipment.

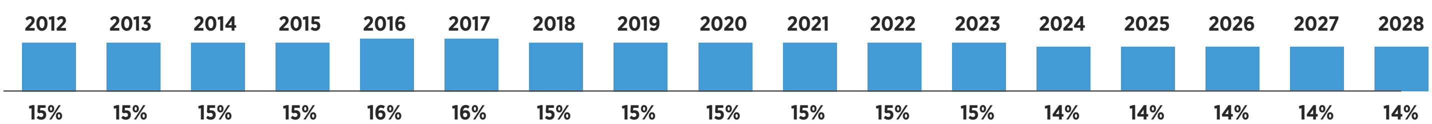
The adaptability and innovation that enabled many European companies to persist over the past two decades are unlikely to suffice in the coming years. Advances in semiconductor technology are imposing increasingly rigorous and costly demands on both PCB and EMS providers. Moreover, the steady global rise in demand for electronics, driven by overarching trends, risks bypassing Europe altogether as original equipment manufacturers (OEMs) turn to more capable, inexpensive, and expansive facilities in Asia. Without significant strategic changes, the European electronics industry will face constraints in capacity and innovation, longer lead times, and increased costs for electronics assemblies in all modules and systems, affecting semi-finished and final products across all industries.

ELECTRONICS SYSTEMS MANUFACTURING IN EUROPE

The EU is a significant economic powerhouse, contributing substantially to global GDP. The collective economic output of EU countries accounts for approximately 15% of the world's total GDP, making it one of the largest economic blocs globally. This substantial share reflects the EU's diverse and robust economic activities, ranging from advanced manufacturing and services to innovative technology sectors. Despite various challenges, including economic fluctuations and geopolitical tensions, the EU's integrated market and regulatory frameworks continue to foster economic stability and growth, reinforcing its critical role in the global economy.

While the EU's GDP is rising in absolute terms, its percentage of gross world product is expected to decrease over the next decade due to the rapid economic growth of emerging economies like China, India, and Brazil. In 2021, the EU's total GDP was around €14.5 trillion, representing approximately 15% of global trade in goods. The EU's share of world GDP at purchasing power parity (PPP) is expected to drop to around 9% by 2050, as China's and India's shares rise to 20% respectively.

EU SHARE OF GLOBAL GDP



SOURCE: IMF, WORLD ECONOMIC OUTLOOK, PURCHASING POWER PARITY

THE EMS MARKET IN EUROPE

The EMS market in the EU has evolved significantly over the past few decades. Initially, the EMS industry began as a support function for OEMs, providing basic assembly services. By the 1990s, the industry experienced rapid growth due to increased outsourcing by OEMs, driven by the need to reduce costs and focus on core competencies. This period saw the rise of prominent EMS providers such as Flextronics, Jabil, and Celestica, which established a strong presence in Europe through mergers, acquisitions, and the establishment of manufacturing facilities across the region.

In the 2000s, the EMS market in the EU continued to expand as technological advancements and globalisation fueled demand for more complex and high-value services. The adoption of advanced manufacturing technologies, such as surface-mount technology (SMT) and automated assembly lines, enabled EMS providers to offer a wider range of services, including design, testing, and logistics. The industry's growth was further supported by the increasing complexity of electronic products and the need for shorter product life cycles, which required flexible and scalable manufacturing solutions.

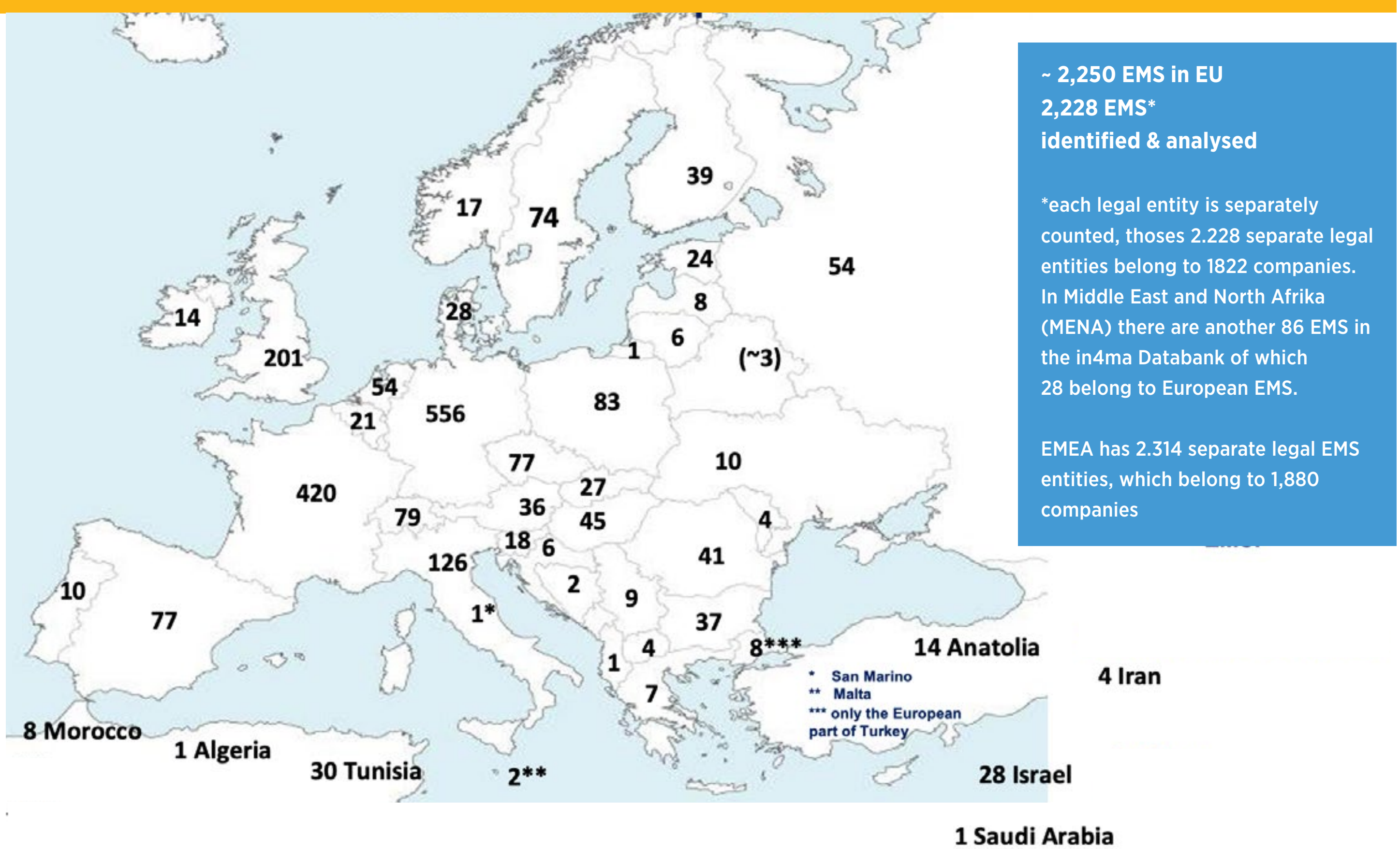
As of 2023, the EMS market in the EU is a critical component of the region's electronics manufacturing ecosystem. The market is characterised by a diverse range of services, from basic assembly to full product lifecycle management, including design, testing, engineering, fully assembly of the product (i.e. box-build), logistics, and after-market services. The EU's EMS industry is highly competitive and includes both global EMS giants and numerous small-to-medium enterprises (SMEs) that cater to niche markets and specialised applications.

The EU's EMS market is driven by several key sectors, including the eight sectors analysed by this research. The automotive sector, for example, has seen substantial growth due to the increasing integration of electronics in vehicles and the rise of electric and autonomous vehicles. Industrial electronics also represent a significant market segment, driven by the demand for automation and smart manufacturing solutions. Additionally, the medical electronics sector has grown, fueled by advancements in medical devices and diagnostic equipment.

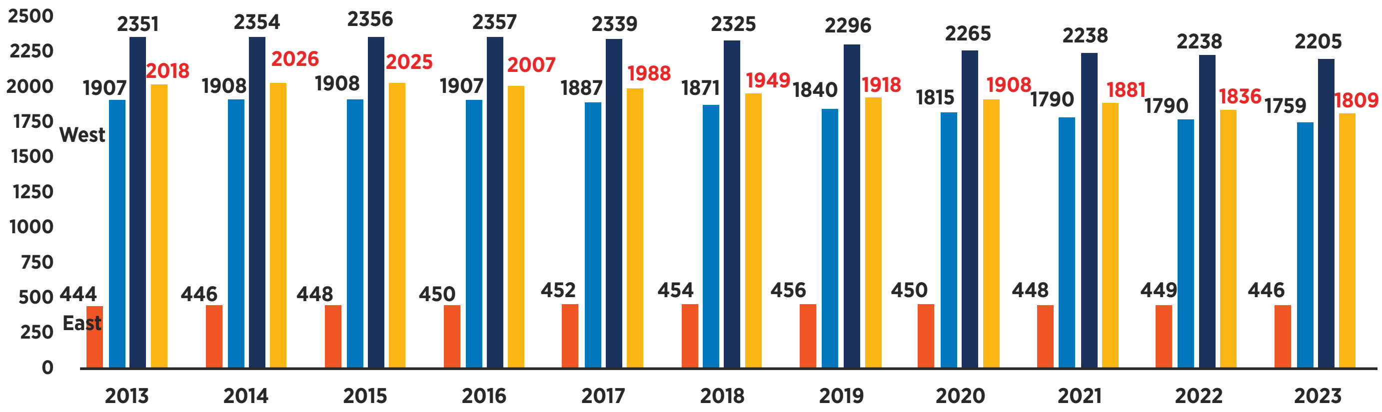
Despite its strengths, the EMS market in the EU faces several challenges. One of the primary issues is the increasing competition from low-cost manufacturing regions, particularly in Asia. Countries like China and Vietnam offer lower labour costs and have developed robust EMS capabilities, making them attractive alternatives for OEMs looking to reduce manufacturing costs. This has put pressure on EU-based EMS providers to continually innovate and improve efficiency to remain competitive.

Another significant challenge is the reliance on imported components and materials. The EU's EMS industry depends heavily on global supply chains for key electronic components, such as semiconductors and PCBs. Disruptions in these supply chains, as seen during the

NO. OF EMS IN EUROPE 2024



NO. OF EMS / ODM COMPANIES IN EUROPE 2013-2023



COVID-19 pandemic, can have significant impacts on production timelines and costs. Furthermore, stringent regulatory requirements and standards in the EU add complexity and cost to manufacturing processes, posing additional hurdles for EMS providers.
To address these challenges, the EU's EMS industry is focusing on several strategic initiatives. One key area is the adoption of Industry 4.0 technologies, including IoT, AI, and advanced robotics. These technologies enable greater automation, improve production efficiency, and allow for more flexible manufacturing processes. By leveraging these advancements, EMS providers can reduce costs, enhance product quality, and offer more value-added services to their clients.

Another strategic focus is on strengthening regional supply chains and reducing dependency on non-EU sources. The EU is investing in initiatives to bolster local component manufacturing, such as semiconductor production, through policies like the European Chips Act. Additionally, there is a growing emphasis on sustainability and environmentally friendly manufacturing practices. EMS providers in the EU are increasingly adopting green manufacturing processes and focusing on the recyclability and energy efficiency of their products.

The future of the EMS market in the EU looks promising, driven by ongoing technological advancements and strategic initiatives aimed at enhancing competitiveness and sustainability. The increasing complexity and integration of electronics across various sectors will continue to drive demand for EMS services. Additionally, the shift towards more sustainable and localised supply chains will create new opportunities for EU-based EMS providers.

As the EU continues to invest in advanced manufacturing technologies and strengthen its electronics ecosystem, the EMS market is expected to play a crucial role in supporting the region's digital and green transitions. By focusing on innovation, efficiency, and sustainability, the EU's EMS industry can maintain its competitive edge and contribute to the growth and resilience of the broader electronics manufacturing sector.

THE PCB MARKET IN EUROPE

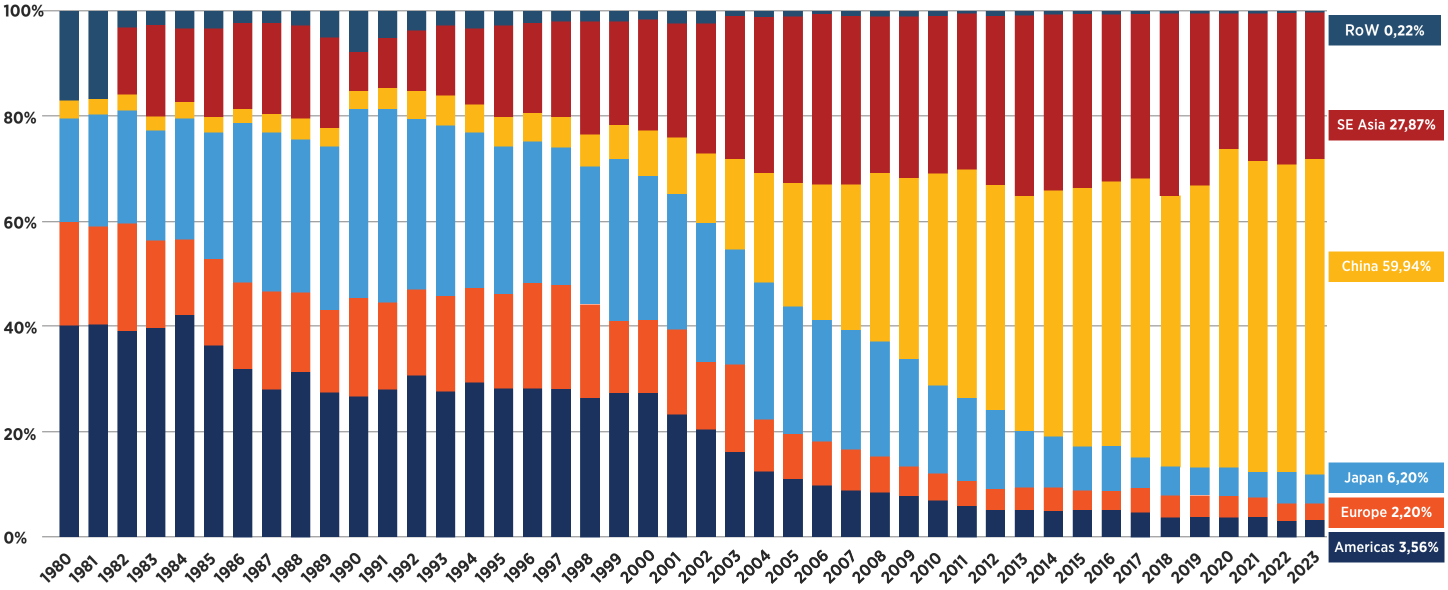
Historically, the PCB production landscape was geographically diverse, with multiple regions contributing significantly to total global output. However, over the last three decades, a clear trend emerged with Asia's, and in particular China's, growing dominance in PCB manufacturing. In the 1980s, North America and Europe were both significant players in the PCB industry. In 1980 for example, China produced only about 2% of global PCB production, while Europe produced nearly 20% and the Americas, which was primarily the U.S., produced 40%.

As we moved into the 1990s, there was a gradual shift in global production. By 1995, Asia had increased its share of global production to over 50%, up from less than 35% in 1980. By 1999, Europe's share of global production had fallen to under 14% and production in the Americas was down to 27.4%. During this time China's share of production increased 300%, but was still just 6.7% of the total.

The next major inflection point followed the early 2000s recessions in Europe and the U.S.. These recessions coincided with China joining the World Trade Organization (WTO) in 2001. Over the next decade, the PCB landscape would dramatically transform, with Asian countries, particularly China, escalating their production capacities at an unprecedented rate. This shift is attributed to several factors, including lower labour costs, advancements in manufacturing technologies, and strong government support for electronics manufacturing sectors in these regions. European and North American shares in global PCB production began to decline as companies moved their manufacturing bases to Asia to capitalise on these advantages. This period marks a significant pivot towards European shares reflects the broader deindustrialization trends in these regions concerning low-margin electronic manufacturing, coupled with the increasing complexity and demand of PCBs that have made localised production less competitive against Asian efficiencies. Today, Europe and U.S. PCB production focuses on high mix, low volume.

WORLD PCB PRODUCTION 2023

90.090 MILLION USD (EST)



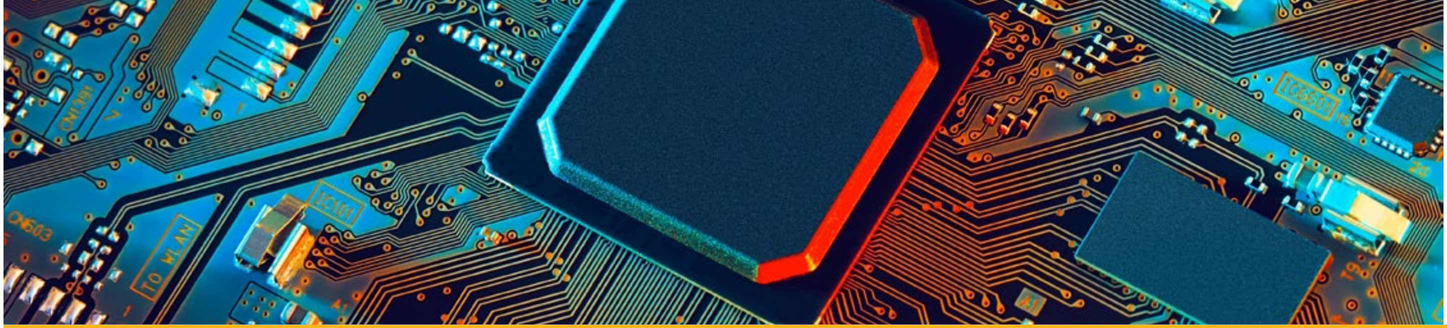
China becoming the epicentre of PCB manufacturing. China would surpass Japan as the global PCB leader in 2006. By 2009, China produced over a third of the PCB market.

China would continue to consolidate global PCB production through the 2010s, driven by continued cost-effectiveness and massive scaling of operations. Today, China produces nearly 60% of the PCB market and Asia production outside of China represents another third of global production. The Americas and Europe production shares have dwindled to just 3.5% and 2.2% respectively. The significant drop in North American and

China consolidated global PCB production through the 2010s, driven by cost-effectiveness and massive scaling of operations. Today, China produces nearly 60% of the global PCB market, with other Asian countries contributing another third. The Americas and Europe now account for only 3.5% and 2.2% of global production, respectively. This decline in North American and European shares reflects broader deindustrialization trends in these regions, particularly in low-margin electronic manufacturing. The increasing complexity and demand for PCBs have made localised production less competitive compared to Asian efficiencies.

As a result of these shifts over the last three decades, Europe and the U.S. now primarily focus on high-mix, low-volume PCB production. This strategy emphasises producing a diverse range of PCB types in smaller quantities, allowing manufacturers to cater to specialised and niche markets that require customised and innovative solutions, or that need PCBs quickly for applications like rapid prototyping. Unlike high-volume production, which aims to minimise costs through economies of scale, high-mix, low-volume production prioritises flexibility and the ability to respond to unique customer needs rapidly. This approach leverages advanced technologies and skilled labour to deliver high-quality, tailored products. Consequently, these regions lack the capacity and, in some instances, the capabilities to meet the entire market's electronics manufacturing needs.

Asia, particularly China, dominates the PCB manufacturing landscape with approximately 1,350 factories, followed by Taiwan with around 120 and Japan with 200. This significant concentration in Asia underscores the region's pivotal role in the global electronics supply chain. In contrast, Europe has a relatively modest PCB production capacity with only around 170 factories. This limited capacity highlights the region's dependency on imports to meet its electronic manufacturing needs, which poses a strategic vulnerability. Moreover, of the roughly 170 factories in Europe, a third of them produce under €2M a year and 75% produce less than 10 million a year. Because small manufacturers invest less in new technologies, the ability to use the newest technologies to drive productivity or produce cutting-edge technologies is further limited. Of the 139 largest PCB manufacturers, only a small fraction belongs to European and American companies, with the majority being owned by Chinese, Taiwanese, and Japanese entities. This ownership distribution further emphasises the strategic reliance of Western countries on Asian production capabilities.



APPENDIX III:
IC SUBSTRATE MARKET IN EUROPE

IC substrates are essential components of substrate-based IC packages that connect integrated circuit (IC) chips with PCBs. They consist of a conductive network of traces and vias that facilitate this connectivity. IC substrates perform multiple critical functions: they support and safeguard the circuit, aid in heat dissipation, and are key to distributing signals and power. These substrates are pivotal in driving miniaturisation in PCB manufacturing and share many process similarities with semiconductor manufacturing.

Technological advancements in Ball Grid Array (BGA) and Chip Scale Package (CSP), among other integrated circuits packages, have spurred significant growth in the IC substrate industry. As a result, IC substrates have evolved into a sophisticated form of PCB, experiencing a surge in popularity and use, particularly in telecommunications, consumer electronics, and servers. The increasing demand for smaller, faster, and more efficient electronic devices has driven innovation in IC substrate technology, making them indispensable in modern electronics manufacturing.

IC substrates are categorised based on several criteria. First, by package type, including BGA, CSP, Single Chip Package (SCP), and Multi-Chip Modules (MCM), each tailored for specific packaging needs. Secondly, by material, including rigid substrates made from resins like epoxy, BT, or ABF, flexible substrates composed of PI or PE resin, and ceramic substrates made from materials such as alumina, aluminium nitride, or silicon carbide. Thirdly, by interconnect technologies, including wire bonding, Tape Automated Bonding (TAB), and FC bonding.

These substrates are primarily used in lightweight, high-performance electronics like smartphones, laptops, and tablets. They also find applications in sectors such as telecommunications and automotive. The versatility and critical role of IC substrates in these applications underscore their importance in the electronics supply chain.

The production of IC substrates, especially those based on BGA architecture, poses unique challenges. They require greater precision than standard PCBs due to differences in material design, equipment selection, and post-processing methods. Key manufacturing aspects include managing substrate thinness and deformation risk, microvia manufacturing, advanced patterning, copper plating, solder mask fabrication, and surface treatment. Additionally, the production of IC substrates demands specialised testing equipment and skilled engineers to ensure the substrates meet stringent performance and reliability standards.

Overall, IC substrates are a critical component in the advancement of electronics technology, enabling the production of smaller, faster, and more efficient devices. Their role in the connectivity and functionality of ICs and PCBs makes them indispensable in the modern electronics landscape. As technology continues to evolve, the importance and complexity of IC substrates are expected to grow, driving further innovation and development in this crucial area of electronics manufacturing.

INDUSTRIAL LANDSCAPE

Asia dominates the IC substrate industry, with Taiwan producing approximately 29% of the global market. This is followed by South Korea, which accounts for 24.4%, and Japan, contributing 21.5%. The leading companies in this industry are Taiwan-based Unimicron, which holds a 17% market share, Japan's Ibiden with 12%, and South Korea's Samsung Electro-Mechanics with 10.3%. These companies primarily supply IC substrates to the computing and telecommunications markets, reflecting the high demand for advanced electronics in these sectors.

In Europe, AT&S stands as the largest IC substrate manufacturer, capturing a 5% share of the global market. Ranked as the ninth-largest IC substrate company worldwide, AT&S specialises in substrates (Organic), which are predominantly used for high-end chips like CPUs and GPUs. This specialisation aligns AT&S closely with the computing sector, making it the fifth-largest supplier in this market segment, following industry leaders Unimicron, Ibiden, Samsung Electro-Mechanics, and Shinko.

Meanwhile, in China, there is a growing emphasis on products like FC CSP, FC BGA, and WB BGA/CSP. This trend is supported by an expansion in production capacity and technological advancements among local manufacturers, particularly in the field of High-Density Interconnect (HDI) products. Chinese companies are increasingly focusing on enhancing their technological capabilities to compete with established players in the global market, indicating a strategic move towards higher-value and more complex IC substrate production.

MAIN APPLICATIONS

Currently, the telecommunication, personal computer, and server markets are the primary applications for IC substrates. The automotive industry is expected to significantly increase its use of IC substrates throughout the 2020s as vehicle manufacturers incorporate more advanced electronics and computing capabilities. This shift is driven by the need to support applications such as Advanced Driver Assistance Systems (ADAS), infotainment systems, and sophisticated electronic/electrical (E/E) architectures, including central car units. In the global market, the customer base for IC substrates is diverse, including major PC, communication, and server chip manufacturers like Intel, AMD, and NVIDIA, along with packaging and testing plants. This diversity reflects IC substrates' broad applicability and critical importance across various high-tech industries.

MARKET DYNAMICS

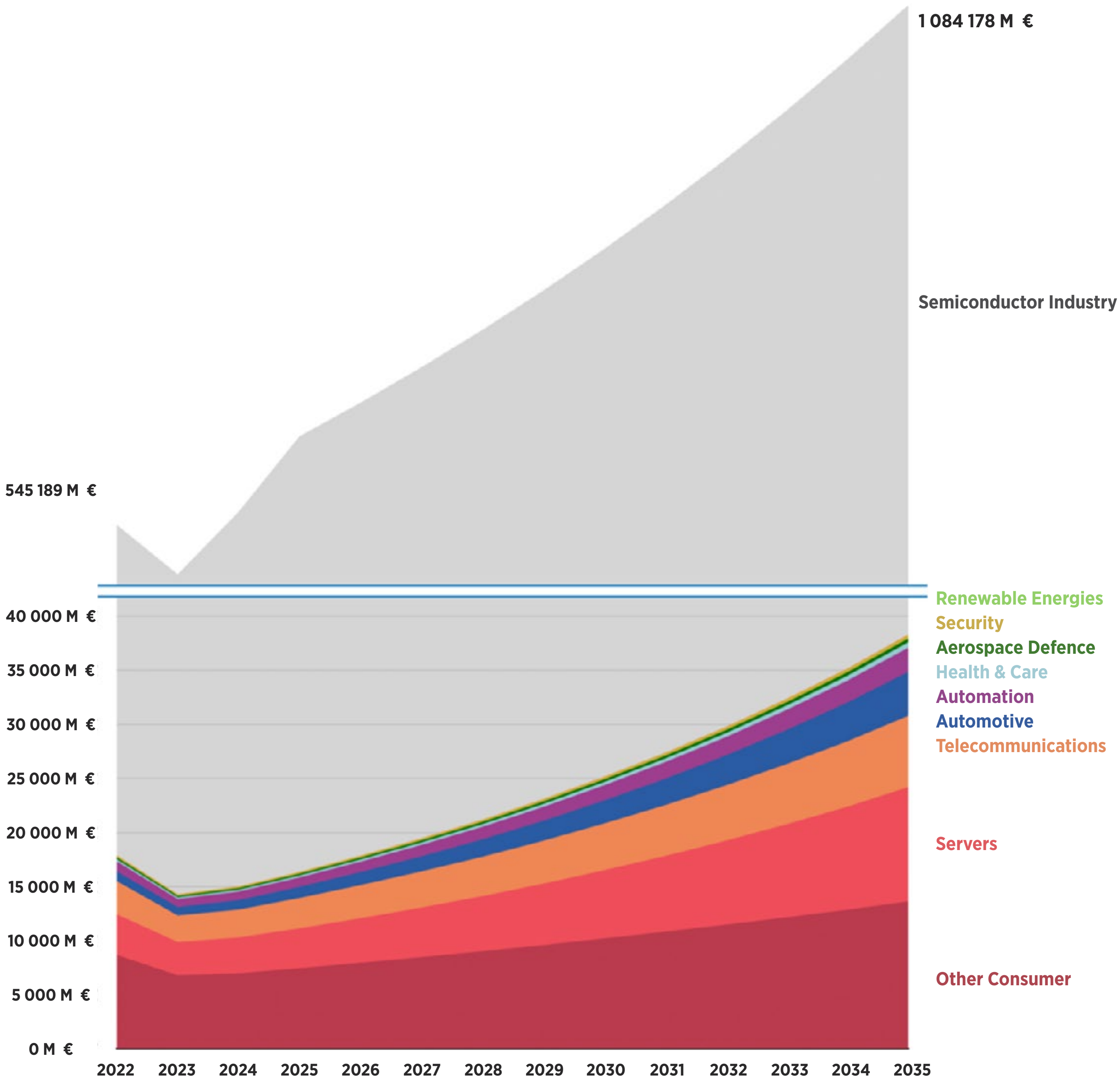
With the increasing demand for computing power, chip manufacturers have sought solutions to enhance chip performance, a need effectively met by IC substrates. The growth in relevant end markets, coupled with the surging computing requirements, has propelled the IC substrate market to expand, registering an average annual growth rate of 20% for the 2018-2022 period. IC substrates have become integral to advancing semiconductor technology, offering improved connectivity, heat dissipation, and miniaturisation, which are crucial for modern high-performance electronics.

However, 2023 witnessed a downturn in the IC substrate market, a consequence of declines observed in both the server and PC markets. The server market faced decreased sales, particularly affecting the memory and consumer segments, and this trend is expected to persist into 2024. This downturn was further exacerbated by a reduction in enterprise IT spending, as major cloud service providers announced decreases in capital expenditures and delays in new investments. Similarly, the PC market faced challenges, entering an inventory adjustment period with excess channel inventory as a primary concern. Despite the end of the pandemic-induced boom, the total volume of PC sales in 2022 remained significantly higher than pre-pandemic levels of 2019, indicating that the slowdown might be a temporary adjustment rather than a long-term decline.

Despite these challenges in 2023, the future of the IC substrate market looks promising. Considering current trends in computing and the approaching limits of Moore's law, IC substrates present a viable alternative for addressing the increasing demand for computing power. For instance, according to Gartner, the integration of AI techniques into data centre applications will result in more than 20% of new servers including workload accelerators.[16] As such, the IC substrate market is expected to grow at an annual rate of 6% from 2022 to 2035, following the growth in the markets it supplies, including servers, PCs, telecommunications, and automotive. This anticipated growth underscores the critical role of IC substrates in enabling the next generation of computing technologies and applications.

When examining the end-application mix for IC substrates, the consumer, mobile, PC, telecommunication, and server markets accounted for a combined share of 89% in 2022. The remaining segments, including automotive, automation, renewable energies, healthcare, aerospace and defence, and security, represented 11% of the market. However, this end-application mix is expected to shift by 2035, with the primary consumer categories projected to account for 83%, while the other segments are anticipated to grow to 17%. This shift reflects the increasing adoption of advanced electronics in a wider range of industries, particularly as automotive and industrial applications continue to integrate more sophisticated electronic systems.

GLOBAL IC SUBSTRATE MARKET 2022-2035 BY APPLICATION



EU production is approximately 0.7% of world production. Within the EU, there are less than 1000 employees focused on IC substrates, producing an estimated €120 million in 2022.

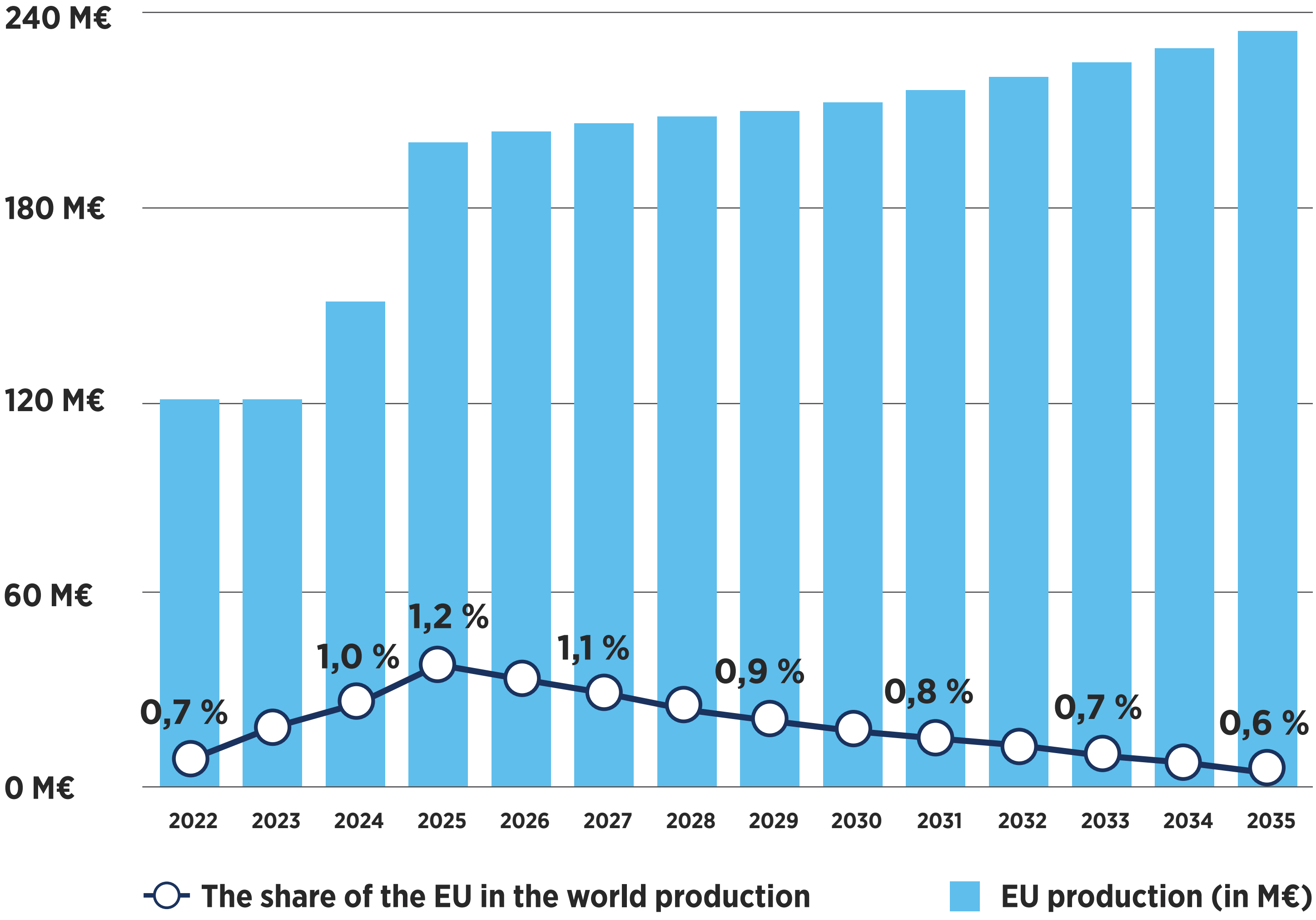
SUBSTRATE FACILITIES IN THE EU

COMPANY	LOCATION	TYPE OF SUBSTRATES	DETAILS OF THE PRODUCTS
AT&S	Leoben, Austria	Advanced substrates	Advanced substrates (AB and substrates for modules)
SCHWEIZER	Schramberg, Germany	Advanced substrates	Substrates for embedded die, substrates for Power
WÜRTH ELEKTRONIK	Germany	Advanced substrates	Substrates for embedded die
KSG GROUP	Gornsdorf, Germany	Legacy substrates	
SOMACIS	Italy	Legacy substrates	
MICRO SYSTEMS ENGINEERING GMBH	Berg, Germany	Legacy substrates	Ceramic substrates (LTCC and thick film)
SERMA MICROELECTRONICS	Perigny, France	Legacy substrates	Ceramic substrates (thick and thin film) and some organic substrates
SELMIC OY	Turku, Finland	Legacy substrates	Ceramic substrates (thick film, LTCC)

The majority of substrate manufacturing facilities in the EU are focused on producing ceramic substrates, which are primarily used in industrial electronics. AT&S stands out as the only manufacturer in the region producing advanced substrates, such as ABF substrates, which are predominantly used in PCs high performance computing, and data servers. This specialisation positions AT&S as a key player in the EU's advanced substrate market, highlighting the limited scope of advanced substrate production within the region.

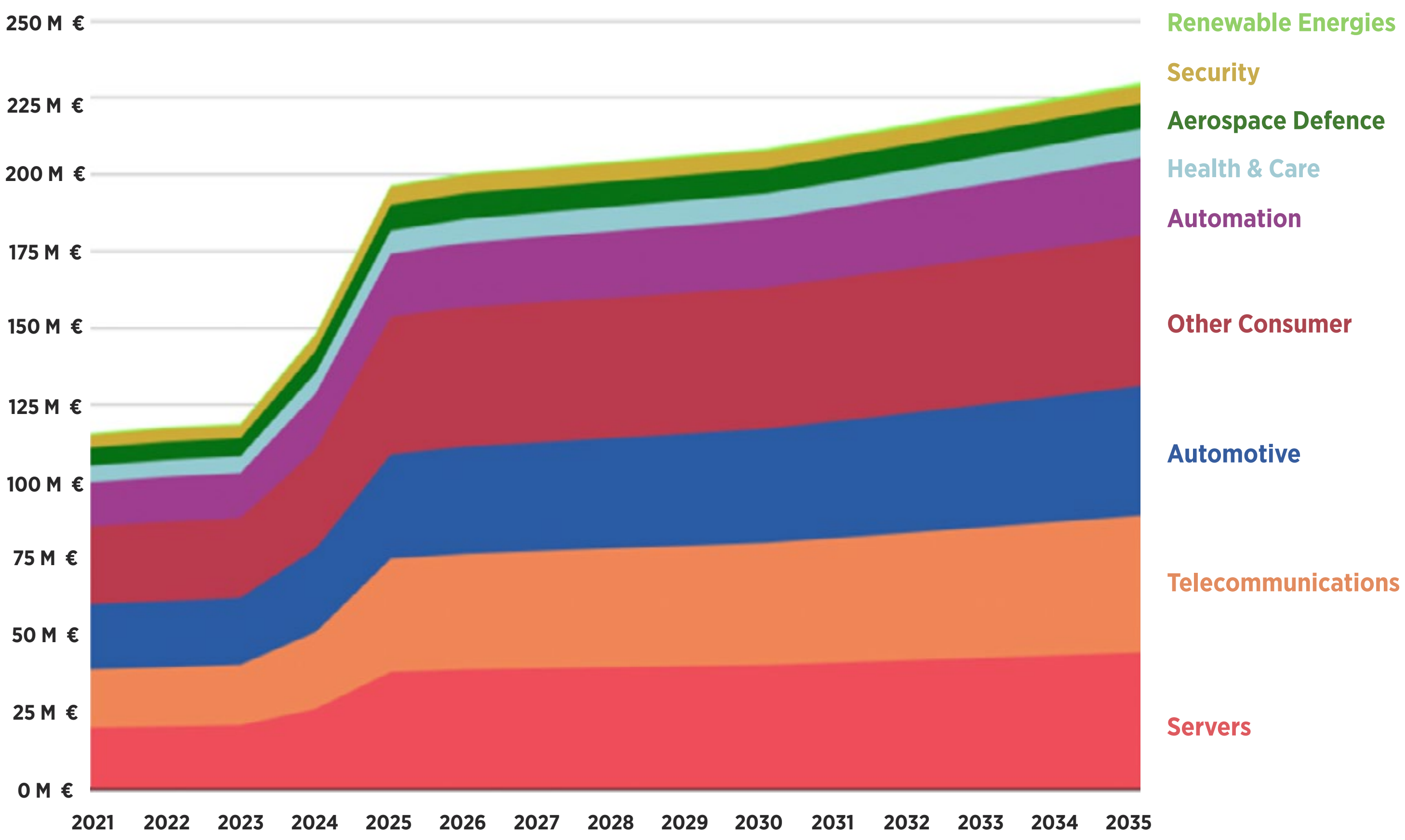
EU production of IC substrates is expected to see a slight increase in 2024 due to the current investment by AT&S in a new production line in Leoben, Austria. This Facility together with its R&D center (research and production centre for advanced packaging and IC substrates) is expected to employ up to 700-800 people and will boost the region's production capacity, particularly in the high-tech sector, such as AI chips and HPC. This capacity is unique in the Western world. However, even with this new production line, the EU's share of global IC substrate production is projected to barely exceed 1% from 2024 to 2028. As substantial investment projects in other regions, particularly in Asia, continue to advance, the EU's share of global production is expected to steadily decline in the latter half of the 2020s through 2035, as the growth rate in the EU will be outpaced by the global market.

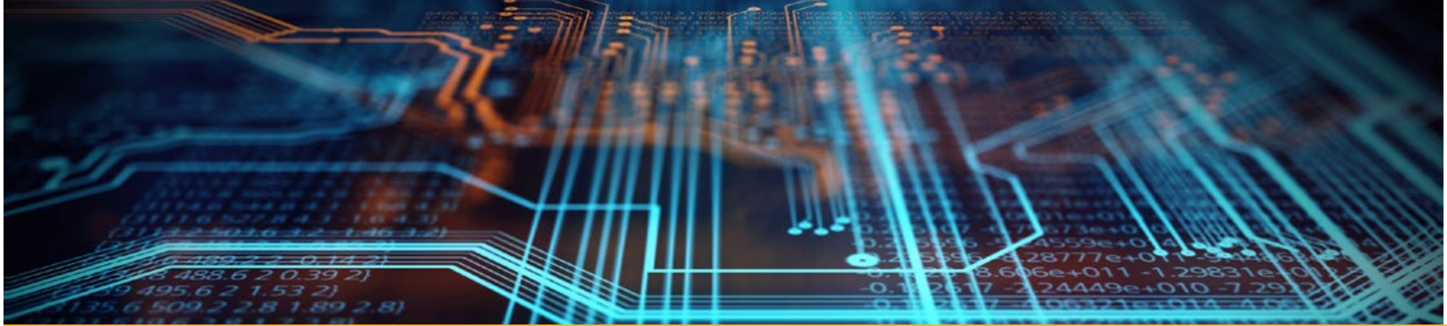
THE SHARE OF THE EU PRODUCTION IN THE WORLD POPULATION



From 2022 to 2035, IC substrate production in the EU is anticipated to grow at 5.3% annually. In terms of application mix, the consumer, telecommunication, and server markets currently account for 53% of the EU's production, while industrial segments account for the remaining 47%. This distribution is expected to remain relatively stable through 2035, with a slight shift in favour of consumer and telecommunication markets, driven by the production increase from the AT&S Leoben investment, which will primarily serve the PC, server, and telecommunication markets.

THE EU IC SUBSTRATE PRODUCTION 2022-2035 BY APPLICATION





APPENDIX IV: ADVANCED PACKAGING MARKET IN EUROPE

The semiconductor industry began around 1947 with the invention of the point-contact transistor, followed by the junction transistor in 1948. This marked the beginning of semiconductor technology, which saw exponential growth in semiconductor packaging technologies. The first semiconductor package was invented in 1965, and until the 1990s, most packages included the Dual Inline Package (DIP), the Quad Flat Package (QFP), and the Small Outline Package (SOP). In the 1990s, more advanced packages such as Ball Grid Arrays (BGAs) and Quad Flat No-leads (QFNs) emerged. The 2000s saw the advent of Chip Scale Package (CSP) and System-in-Package (SiP) technologies, with wafer-level packaging becoming mainstream towards the end of the decade.

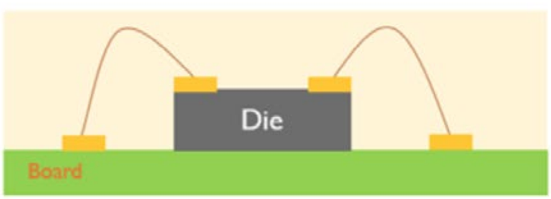
In 2007, Freescale (now part of NXP) invented the first Fan Out packaging, known as Redistributed Chip Packaging (RCP), which remains in use today.
In 2008, Infineon introduced the embedded Wafer-Level Ball grid array (eWLB) technology, which has been widely licensed to non-European Outsourced Semiconductor Assembly and Test (OSATs) companies. Although the first Fan-Out technologies were developed in the EU, they were quickly adopted by Asian and US OSATs. The latest innovations in Fan Out packaging now come from Asian countries, with companies like TSMC, SEMCO, PTI, JCET, and ASE leading the innovation process. Stacking technologies such as 2.5D and 3D gained traction in the 2010s, driven by the need for higher performance, greater bandwidth, and lower power consumption.

The first 2.5D structure was introduced by Xilinx in 2011, and Samsung launched the first 3D stacked DRAM memory in 2014 using silicon via (TSV) interconnections. TSV technology has enabled devices like High Bandwidth Memory (HBM) and the 2.5D structure based on silicon interposers. Embedded die technology began its development in 1968 with General Electric, but the first product only hit the market in 2010. Since then, several companies, including European firms like AT&S, Schweizer, and Würth Elektronik, as well as non-European substrate makers and OSATs, have entered this field.

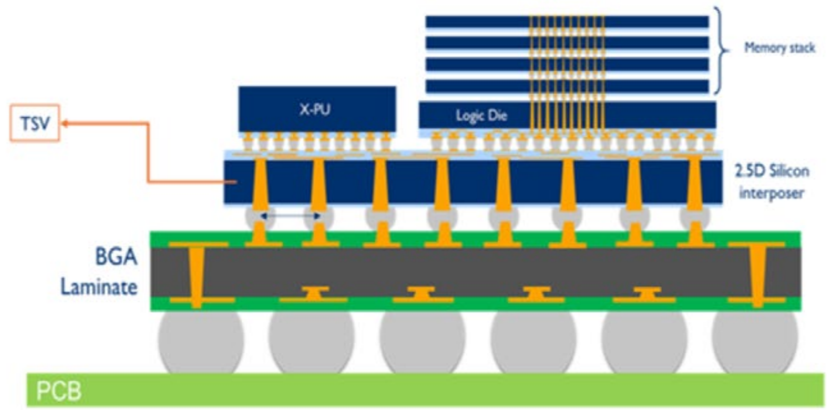
Historically, semiconductor packaging was a simple interconnection between a die and a substrate, with limited added value to the final product. However, with the evolution of semiconductor technology and the increasing complexity of dies, packaging has transformed into a functionality that enhances die performance and reliability. Modern packaging designs aim to improve integration and, in some advanced cases, serve as enablers for new advanced hardware, with multiple function dies gathered in the same package. This evolution highlights the critical role of packaging in the semiconductor industry, extending beyond mere interconnection to become a vital component of electronic devices' overall performance and functionality.

BASIC WIRE BOND INTERCONNECTION VS. ADVANCED FUNCTIONAL PACKAGE

BASIC WIRE BOND PACKAGE



ADVANCED 2.5D STRUCTURE



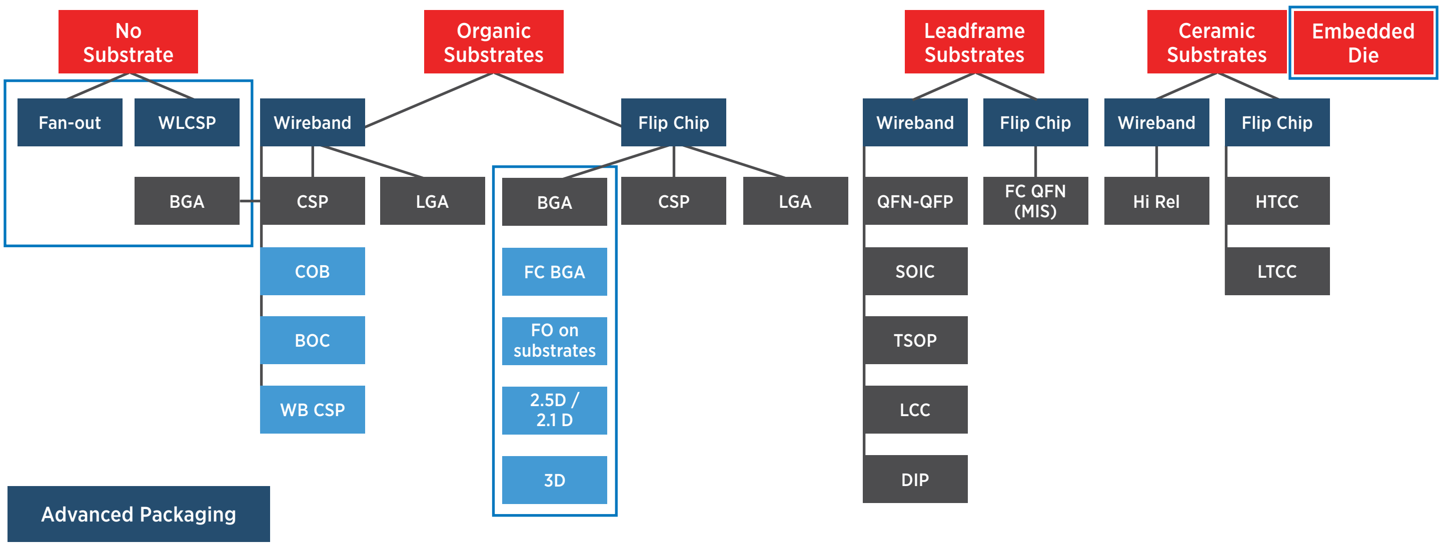
EVOLUTION OF SEMICONDUCTOR PACKAGING: FROM LEGACY TO ADVANCED TECHNOLOGIES

Semiconductor packaging technologies are essential building blocks for integrating electronic dies and systems, primarily functioning to connect a chip to a substrate or a board. The packaging industry has evolved significantly to meet the varying demands of the electronics sector. In the early stages of the semiconductor industry, each die was individually packaged. Over time, the trend shifted towards integrating multiple dies into a single package to enhance performance, reduce footprint, and lower power consumption. This evolution has led to the emergence of two distinct packaging families: legacy packaging and advanced packaging.

Legacy packaging technologies, such as Dual Inline Package (DIP), Quad Flat Package (QFP), and Ball Grid Array (BGA) have been fundamental in the semiconductor industry for decades. These technologies were designed to meet the requirements of earlier semiconductor nodes, focusing on cost-effectiveness and reliability. As the industry progressed, the need for more sophisticated packaging solutions became evident, particularly as the technology nodes continued to scale down following Moore's Law. However, reaching the 12 nm technology node marked a turning point where the complexity and cost of further scaling became prohibitive for most players in the industry.

This turning point led to the emergence of advanced packaging technologies as a solution to the slowdown of Moore's Law. Advanced packaging includes techniques like System-in-Package (SiP) solutions in Chip Scale, BGA formats, Fan in and fan out wafer level packaging, 2.5D stacking with interposers, 3D packaging with chip stacked and chip on wafer level integration, Heterogeneous Integration with hybrid bonding interconnect and Panel based packaging solutions. These technologies enable the integration of multiple dies with different functions into a single package, significantly improving performance, reducing power consumption, and minimising the overall footprint. Advanced packaging has become crucial for maintaining the pace of innovation in the semiconductor industry, especially as the cost and complexity of traditional scaling continue to rise.

Today, semiconductor packaging can be categorised into two families: legacy packaging and advanced packaging. Legacy packaging continues to play a vital role in applications where cost and simplicity are paramount. In contrast, advanced packaging is increasingly essential for high-performance applications, including computing, telecommunications, and automotive sectors. The continued development and adoption of advanced packaging technologies are expected to drive the future of the semiconductor industry, ensuring that it can meet the growing demands for more powerful, efficient, and compact electronic systems.



ADVANCED PACKAGING TECHNOLOGIES

FAN-OUT (FO) PACKAGING

Fan-Out (FO) packaging is a technology where the interconnections are extended outward from the die's surface, allowing bump sizes to be independent of the die's surface area. Popular FO packages do not use any substrate, making them thinner than substrate-based packages. In FO packaging, dies are flipped and placed on a Re-Distribution Layer (RDL) and then embedded in an epoxy/polymer mould. Substrate-free FO uses semiconductor tools, enabling line/space dimensions down to 1/1µm. Substrate-based FO technologies, which utilise PCB manufacturing processes, have lower line/space resolution.

The first FO technology, known as embedded Wafer-Level Ball grid array (eWLB), was invented in Europe, though most innovation in FO now comes from Asia. This technology is popular in the consumer mobile market and automotive sector and is increasingly being used in High-Performance Computing (HPC) and 5G/6G applications. FO technology became more accessible around 2007-2008, with companies like Freescale (now NXP) and Infineon leading the way. Infineon's eWLB technology, developed and commercialised by Infineon and licensed to OSATs, is one of the most widely used FO technologies. Newer FO technologies, such as TSMC's integrated FO on substrate (info-oS), have been developed for more complex applications, with major advancements coming from Taiwanese and South Korean companies like ASE, Samsung, and PTI.

FLIP CHIP BASED PACKAGING

Flip chip (FC) packaging was developed to achieve higher I/O counts, better reliability, and improved performance by replacing wire bonding interconnections with bump interconnections. This technology is widely used in application processors for mobile and HPC devices and is increasingly being incorporated into automotive ADAS computing units. FC CSP packages are utilised for smaller devices in mobile applications, such as PA and PMIC.

Flip chip technology, which uses ball interconnections beneath the die, marked a significant evolution from traditional wire bonding. Developed before the 1990s, it matured in the late 1990s after addressing challenges related to creating reliable interconnections with smaller balls and tighter spacing. Flip chip interconnections allow for higher I/O counts and reduced device footprints, eliminating the need for wire bonding. Initially, FC CSP packages were preferred over FC BGA due to their ability to reduce semiconductor die size. However, with increasing performance and die complexity demands in the early 2010s, FC BGA packaging became more suitable for applications requiring high I/O counts and larger package sizes. FC BGA packaging is now in mass production, driven by demand from HPC and automotive ADAS computing units, as well as ongoing needs in mobile and data centres.

STACKING TECHNOLOGIES

Stacking technologies, such as 2.5D and 3D stacking, are considered promising solutions to the slowdown of Moore's law, supported by various semiconductor players. The initial stacking technology, Through-Silicon Via (TSV), and the emerging hybrid bonding are widely used. Stacking technologies are popular in HPC, stacked memory, and CMOS Image Sensor (CIS) markets.

2.5D STACKING

Research on 2.5D stacking began well before its adoption by Xilinx in 2011. The

2.5D structure includes an interposer layer, typically a bulk silicon substrate with TSV. Early volumes were low until AMD used this technology for their Fiji GPU in 2015, followed by adoption by Xilinx, Intel, and Nvidia. This led to mass production, with more players like Broadcom, Fujitsu, and Google adopting the technology for HPC and data centre hardware. Current R&D focuses on developing simpler and cheaper alternatives to the bulky silicon interposer, with European research centres like CEA Leti, IMEC, and Fraunhofer contributing to these advancements. However, most innovation in 2.5D structures comes from Asia, particularly from TSMC, UMC, ASE, and US companies like Intel and AMKOR.

3D STACKING (TSV & PATTERNED HYBRID BONDING)

3D stacking using TSV interconnections was pioneered by AMD in the early 2000s. One of the first products using TSV was a DRAM memory module from Micron in 2011. Other memory specialists, such as SK Hynix and Samsung, entered the stacked memory market in 2014 with their proprietary DRAM modules using TSV. SK Hynix's release of the first High Bandwidth Memory (HBM) in 2015, used in AMD's Radeon R9 Fury X GPU, marked a significant milestone. Samsung followed with a 3D RDIMM and later with HBM2 used in Nvidia's Tesla P100 GPU.

In 2016, TSV technology was introduced in smartphone CMOS Image Sensors (CIS) by Sony for the iPhone 7+, followed by Samsung's hybrid bonding interconnection in the Galaxy S7. Sony continued to innovate with a three-layer stacked image sensor in 2017. Hybrid bonding is expected to gain more market share from TSV in the future, particularly in image sensors. The continuous development in stacking technologies is driven by the need for higher performance and efficiency in advanced computing and imaging applications.

EMBEDDED DIE TECHNOLOGY

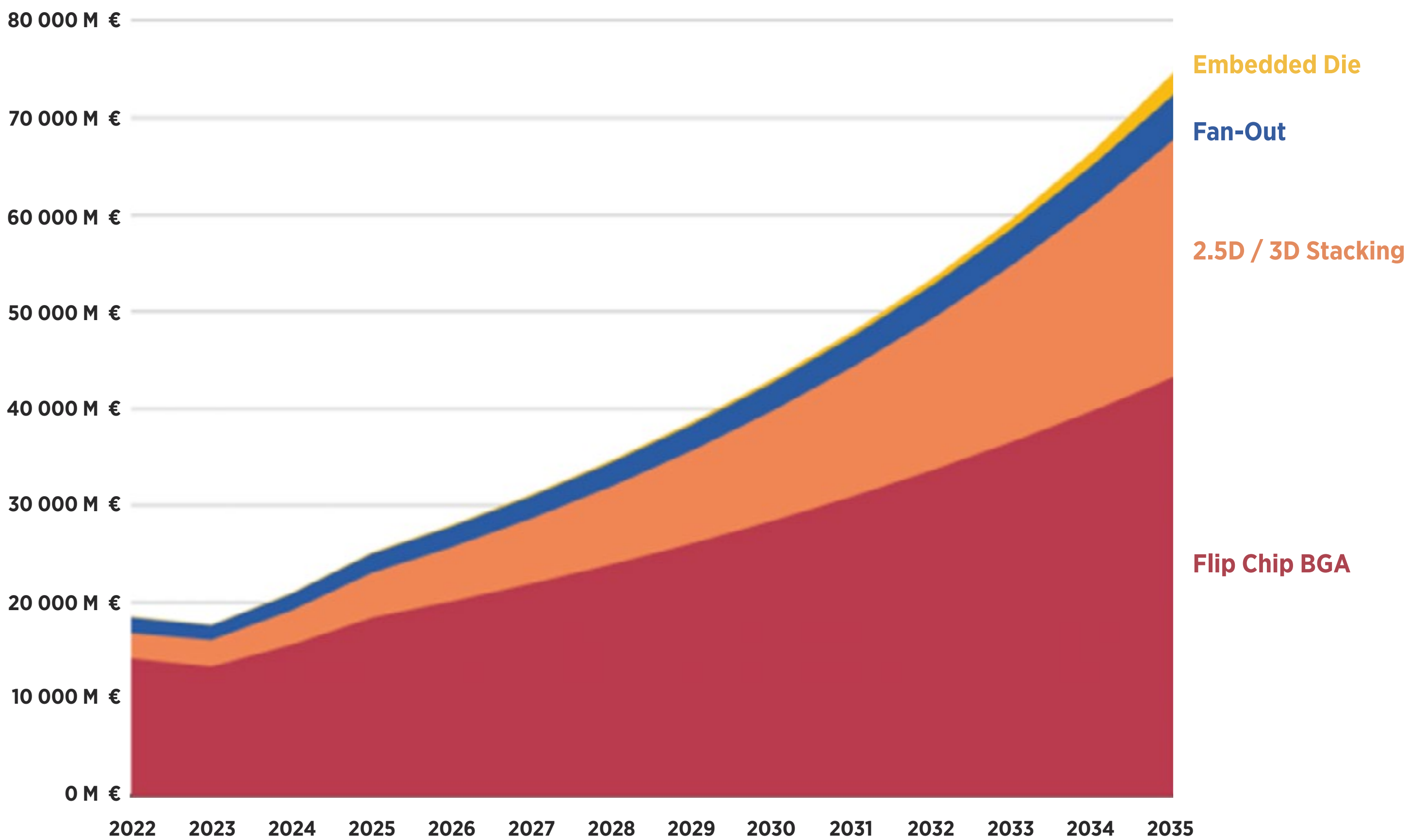
Embedded die (ED) technology involves embedding one or more active and/or passive dies into an organic substrate. Initial production focused on single passive embedded dies, achieving yields above 98% for such structures. The future of ED technology involves embedding more passive and complex active dies with higher I/O counts. Some players are developing substrates that embed over 30 dies, both active and passive. This technology is renowned for its excellent thermal management, including the possibility of a double-sided cooling system, making it suitable for high-power applications.

Embedded die technology has gained traction in Europe, with companies like AT&S and Schweizer leading its development, and Würth Elektronik also actively participating. Although the first patents for ED technology were filed by General Electric in 1968, significant market adoption only began in 2010. Since then, ED technology has demonstrated its value in various applications, particularly in mobile phones. However, its expected growth will come from automotive and telecom infrastructure applications, driven by the rise of vehicle electrification and the demand for efficient 5G infrastructure. Mass production of ED technology is anticipated by the early 2030s, fueled by investments from both European and Asian players. The potential of ED technology is substantial, particularly for high-power applications where its superior heat management properties enhance performance and reduce power consumption. Further development and testing are ongoing, with ED players working to prove this technology's advantages over existing packaging methods.

Currently, Flip Chip Ball Grid Array (FC BGA) technology is the most prevalent and widely produced form of advanced packaging. However, significant advancements in research and development are poised to dramatically increase the production of Fan-Out and stacking technologies in the near future. These innovations are being driven by the rising demand for high-performance, miniaturised electronic components.

Additionally, while Embedded Die technology is also expected to see growth, its mass production is not anticipated to begin until the latter half of the 2020s. This delay is due to the ongoing need for further development and scaling efforts to meet market demands and achieve widespread adoption.

GLOBAL ADVANCED PACKAGING MARKET 2020-2035 BY TECHNOLOGY



ADVANCED PACKAGING BY PACKAGE TECHNOLOGY IN 2020 & 2035

TECHNOLOGIES IN ADVANCED PACKAGING	SIZE OF THE MARKET IN 2022 (M€)	SIZE OF THE MARKET IN 2035 (M€)	CAGR 2020-2035
FAN-OUT	1 622	4 662	8%
FLIP-CHIP BGA (FC BGA)	14 240	43 273	9%
EMBEDDED DIE	96	2 313	28%
2.5D / 3D STACKING	2 588	24 515	19%

ADVANCED PACKAGING MARKET APPLICATIONS

Advanced packaging offers substantial growth prospects, necessitating expertise across multiple levels of the semiconductor value chain. This has attracted a variety of players, including Outsourced Semiconductor Assembly and Test (OSAT) providers, Integrated Device Manufacturers (IDMs), PCB manufacturers, and IC substrate providers. Notably, TSMC, which dedicates 20% of its activities to back-end processes and packaging, highlighted by a €13 billion revenue in 2022, is heavily investing in this domain. The strategic appeal of advanced packaging lies in its three main advantages: faster time-to-market, reduced development costs by packaging legacy components instead of creating entirely new complex ones and fostering direct customer relationships. This last point is particularly valuable as it allows for better identification of customer needs and enhanced quality monitoring through direct feedback.

However, the integration of advanced packaging technologies is not without challenges. One significant concern is the ambiguity surrounding reliability guarantees and responsibilities, especially in cases of heterogeneous integration. When technical failures occur, it is often unclear which supplier of which subsystem is liable. This unresolved issue undermines the attractiveness of advanced packaging and poses a significant hurdle in achieving standardisation across key verticals such as smartphones, servers, and automotive applications. The lack of clear accountability complicates risk management and could hinder broader adoption despite the evident advantages and growth potential. Addressing these concerns through industry-wide standards and clear liability frameworks will be crucial for the future success of advanced packaging technologies.

CONSUMER & DIGITAL APPLICATIONS

The consumer and digital segment, encompassing smartphones, telecommunications infrastructure, consumer PCs, and servers, represents the largest market by volume for advanced packaging. This market's sheer size makes it highly attractive, especially for 2.5D and 3D stacking technologies. These advanced packaging methods are crucial for integrating the latest front-end nodes to achieve the most advanced functionalities in logic and RF applications. However, in the smartphone sector, companies like Qorvo and Skyworks hold strong positions in RF. This entrenched market presence makes it difficult for new entrants to penetrate and compete directly, despite innovations in advanced packaging.

AUTOMOTIVE APPLICATIONS

Although smaller in volume compared to the consumer market, the automotive sector presents significant opportunities for advanced packaging, particularly using Fan-Out (FO) and Flip Chip Ball Grid Array (FCBGA) technologies. Advanced packaging is essential for key automotive applications, such as power electronics for electric vehicles and advanced RF and logic components for ADAS, infotainment systems, and connected vehicle architectures. Tier 1 automotive suppliers, like Valeo and Bosch, strive to maintain direct relationships with automakers (e.g., Renault) and differentiate through packaging innovations. This creates both challenges and competitive pressure for semiconductor companies offering advanced packaging solutions in the automotive sector.

INDUSTRIAL IOT & AEROSPACE APPLICATIONS

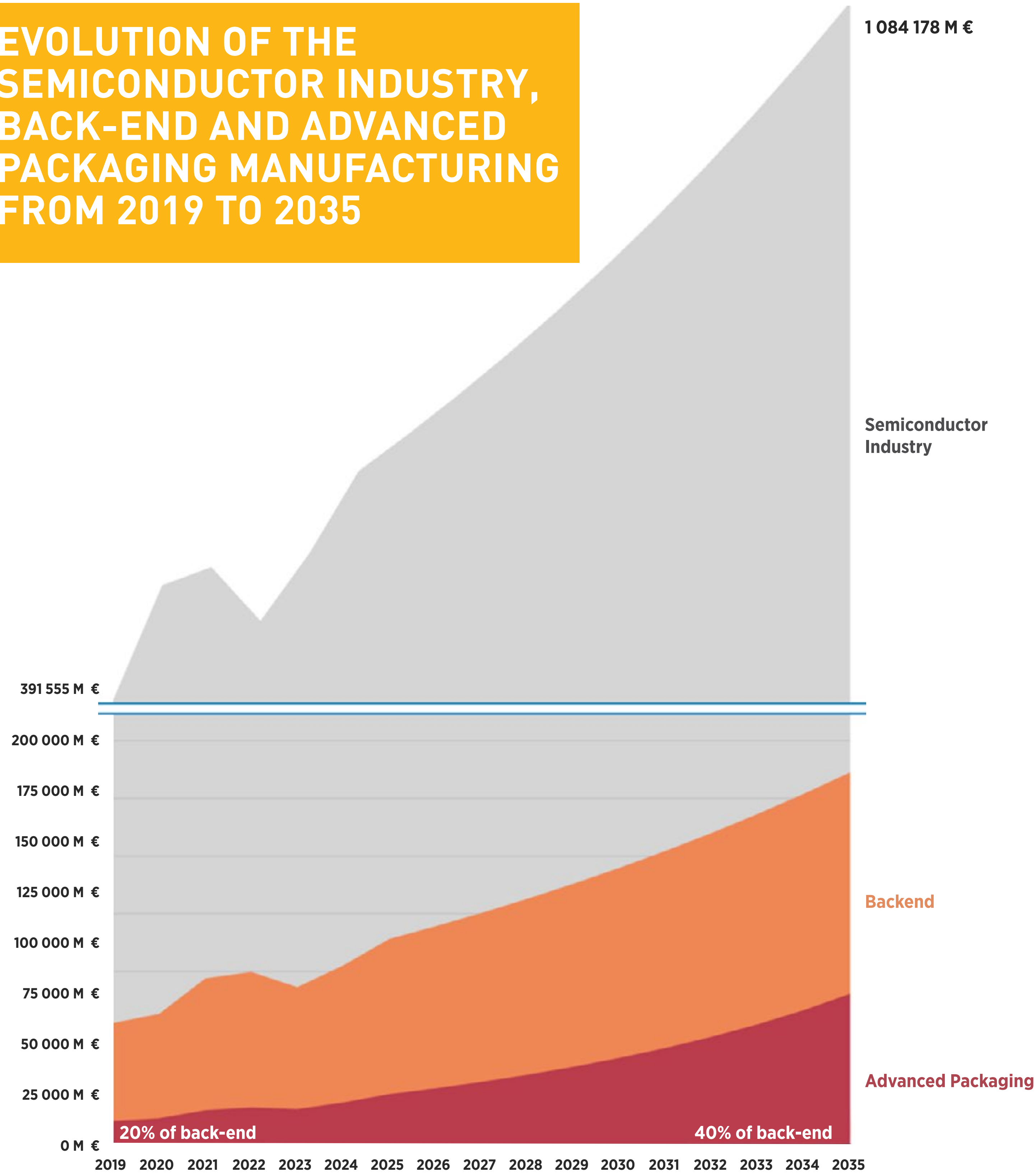
The industrial IoT market, which includes power, RF, and logic applications, offers promising but currently limited volume opportunities. This market is characterised by a diverse client base, making it less favourable compared to more consolidated segments. Applications include industrial electronics, healthcare, and renewable energies. Meanwhile, the aerospace sector, though even smaller in volume, sees companies like Thales engaging in advanced packaging primarily to meet stringent end-customer demands.

Overall, European suppliers are primarily focusing on automotive applications for advanced packaging, given the significant opportunities and growth potential in this sector. However, the market prospects in other segments remain limited. The lack of standardisation in advanced packaging also poses a challenge, as it complicates the legal landscape regarding reliability guarantees and responsibilities. Addressing this issue through industry-wide standardisation could mitigate legal risks and foster broader adoption of advanced packaging technologies.

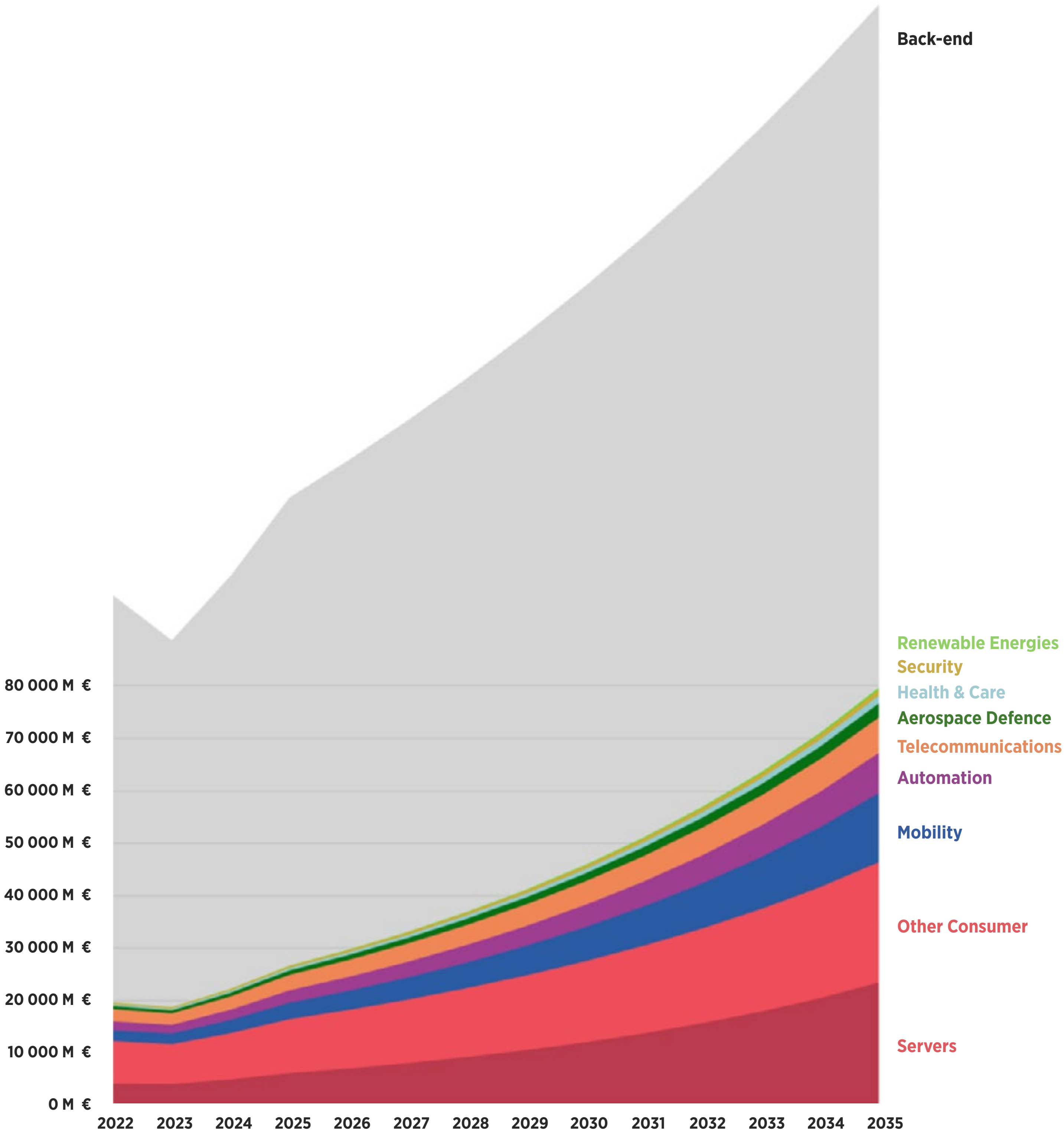
The market for advanced packaging is expected to grow 11.4% annually from 2022 to 2035, significantly outpacing the growth rates of overall back-end manufacturing. This robust expansion is anticipated to propel the market from €20 billion in 2022 to approximately €80 billion by 2035. The driving factors behind this growth include increasing demand for high-performance computing, miniaturisation of electronic devices, and advancements in semiconductor technologies that necessitate more sophisticated packaging solutions.

When examining the end applications of advanced packaging, consumer electronics—including mobile phones and PCs—dominated the market in 2022, accounting for 41% of the overall advanced packaging applications. Servers and telecommunications infrastructure followed, with shares of 21% and 12%, respectively. The automotive sector, driven by technologies like Flip Chip Ball Grid Array (FC BGA) and Fan-Out, represented 10% of the market. Other segments such as automation, renewable energies, healthcare, aerospace and defence, and security collectively accounted for 16%. By 2035, it is projected that the share of advanced packaging used in traditional consumer segments and automotive will decline. Conversely, there will be a notable increase in advanced packaging utilisation within servers and telecommunications infrastructures, driven by the escalating demand for data processing and connectivity. Additionally, embedded applications, although on a smaller scale, are expected to see growth, reflecting the broader trend towards more integrated and efficient electronic systems.

EVOLUTION OF THE SEMICONDUCTOR INDUSTRY, BACK-END AND ADVANCED PACKAGING MANUFACTURING FROM 2019 TO 2035



GLOBAL ADVANCED PACKAGING MARKET 2020-2035 BY APPLICATION



MIX OF END-APPLICATIONS OF ADVANCED PACKAGING IN 2020 & 2035

ADVANCED PACKAGING IN END-APPLICATION	SIZE OF THE MARKET IN 2022 (M€)	SIZE OF THE MARKET IN 2035 (ME)	CAGR 2022-2035
AUTOMOTIVE	1 892	12 588	16%
AUTOMATION	748	3 361	12%
RENEWABLE ENERGIES	45	386	18%
HEALTH & CARE	320	1 458	12%
AEROSPACE & DEFENCE	605	2 721	12%
SECURITY	297	1 126	11%
OTHERS: MAINLY MOBILE & PCS	8 142	22 950	8%
TELECOMMUNICATION	2 337	6 729	8%
SERVERS	4 154	23 443	14%

ADVANCED PACKAGING MARKET IN THE EU: CURRENT STATE & FUTURE PROSPECTS

In the EU, the advanced packaging sector represents a minor share of the global market due to a relatively low number of back-end facilities, including IDM back-end and OSAT facilities. In 2023, the EU's advanced packaging production is estimated at €300 million, which accounts for a mere 1.8% of global production. Significant facilities in the EU with advanced packaging capacities include those operated by Amkor in Portugal, Infineon in Germany, and STMicroelectronics in Malta. Together, these facilities employ approximately 5,200 individuals, focusing on various advanced packaging technologies such as Fan-Out (FO) and Flip Chip Ball Grid Array (FC BGA) with some potential advanced power packaging capabilities in future.

Infineon's facility in Regensburg, Germany, employs 3,000 workers and is involved in FO eWLB and embedded die technologies, while the majority of Infineon's advanced packaging capacities are located in Asia. STMicroelectronics has a facility in Kirkop, Malta, with 1,600 employees focused on FC BGA, and a smaller FO manufacturing site near Naples, Italy. Additionally, Amkor's Porto, Portugal site, with 600 employees, has capacities for Fan-Out and Wafer-Level Packaging (WLP)and some potential power packaging in the future. Despite the presence of these facilities, the EU's contribution to global advanced packaging remains modest. The upcoming Intel back-end facility in Poland, expected to be operational by 2027, is anticipated to significantly boost the EU's production capacity, especially when integrated with Intel's front-end operations in Ireland and Germany. Nevertheless, global developments are likely to outpace the EU's growth, leading to a gradual decline in its share of global production despite an average annual growth rate of 6% from 2022 to 2035.

THE EUROPEAN ADVANCED PACKAGING ECOSYSTEM

The European advanced packaging ecosystem includes notable investments and collaborations that may enhance the region's capabilities. For example, TSMC's co-investment in Dresden with NXP, Infineon, and Bosch could potentially incorporate advanced packaging capacities. Thales in France also produces advanced packaging for aerospace and defence purposes, specifically through FO and FC BGA technologies. Additionally, SMEs like France's 3DiS Technologies and the Netherlands' Sencio are involved in 3D integration and WLP technologies, although they lack manufacturing facilities within the EU. Würth Elektronik contributes to the ED field by supplying substrates.

Furthermore, Europe houses back-end equipment and tools manufacturers such as BESI (Netherlands) and Süss MicroTec (Germany). The EU consortium Pack4EU is set to propose a roadmap for investment in advanced packaging, which will include at least one pilot line financed by the European Chips Act, focusing on 3D packaging for RF. Leading European research centres like IMEC and Fraunhofer are involved, with CEA Leti considering participation, aiming to solidify this plan by 2025.

SHIFTING END-APPLICATION MIX IN ADVANCED PACKAGING PRODUCTION

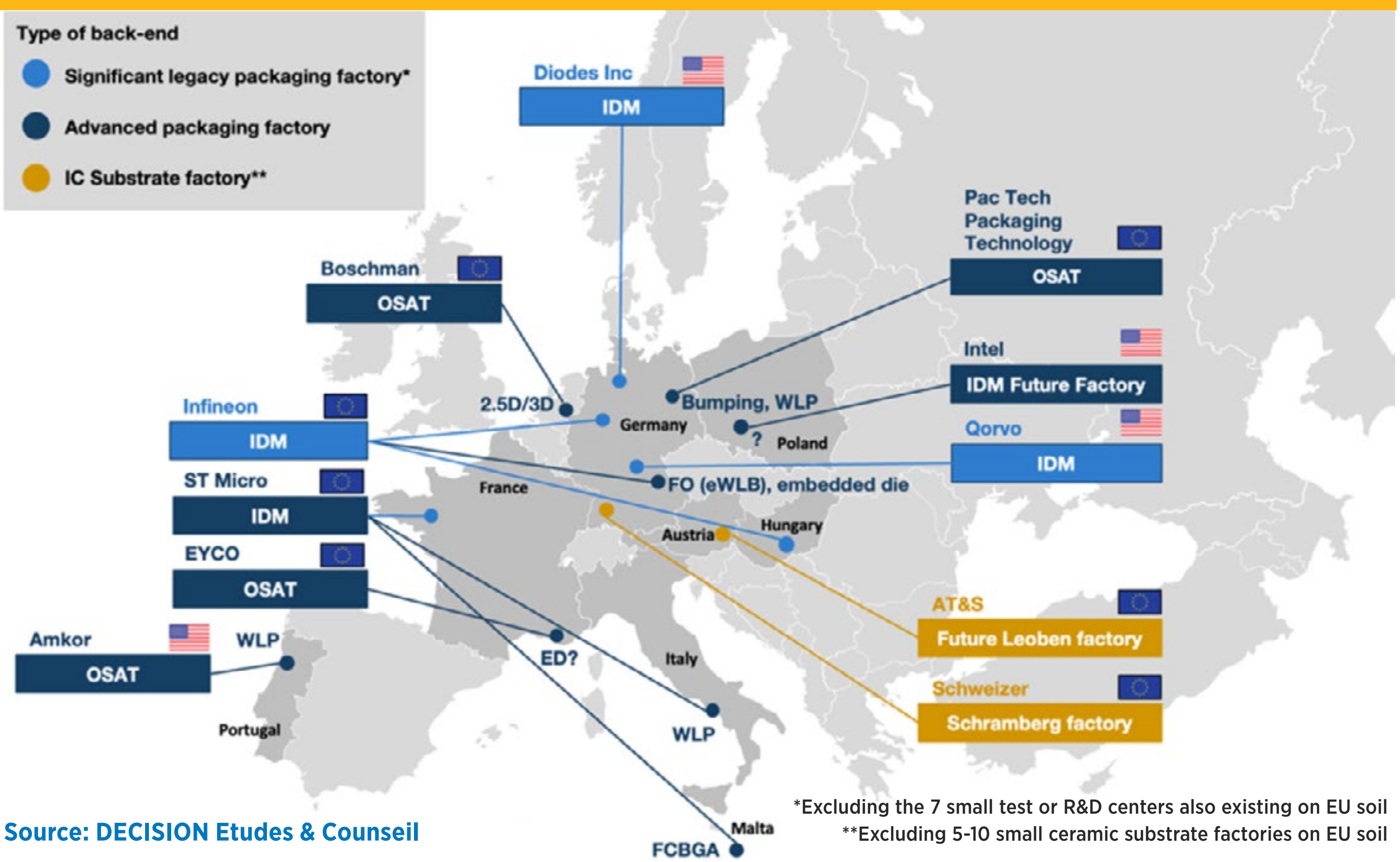
In 2022, the leading segments for advanced packaging in the EU were Consumer, Telecommunication, and Servers, accounting for 60% of production. The remaining segments, including automotive, automation, renewable energies, healthcare, aerospace and defence, and security, made up 40%. By 2035, this end-application mix is expected to shift, with Consumer, Telecommunication, and Server segments projected to hold a 53% share. This anticipated change reflects a relatively higher growth rate in the other segments, which will account for 47% of advanced packaging production by 2035.

Overall, while the EU's advanced packaging sector is poised for growth, significant challenges remain. Investments in new facilities and technologies are crucial for maintaining and potentially increasing the EU's share of the global market. Strategic initiatives, collaborations, and continued R&D investments will play a pivotal role in shaping the future of advanced packaging in Europe.

EU BACK-END FACILITIES WITH ADVANCED PACKAGING CAPACITIES

COMPANY	CITY	COUNTRY	TYPE OF ADVANCED PACKAGING
AMKOR	Vila do Conde	Portugal	WLP
BOSCHMAN	Duiven	Netherlands	2.5D/3D packages
PAC TECH PACKAGING TECHNOLOGY GMBH	Nauen	Germany	Bumping, WLP
STMICROELECTRONICS	Kirkop	Malta	FOBGA
STMICROELECTRONICS	Macianise	Italy	WLP
INFINEON	Regensburg	Germany	Fan-Out (eWLB), embedded die
INTEL	Wroctaw	Poland	
EYCO	Trets	France	Advanced packaging for health & care, embedded die considered

EUROPEAN ECOSYSTEM OF ADVANCED PACKAGING



*Excluding the 7 small test or R&D centers also existing on EU soil

**Excluding 5-10 small ceramic substrate factories on EU soil

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