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EU's strengths and weaknesses in the global semiconductor sector

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Contents

Abstract

This report provides an in-depth analysis of the European Union's (EU) position in the global semiconductor industry. The analysis reveals that while the EU has long been a significant player in the global semiconductor market, it faces challenges and dependencies that could impact its future competitiveness. The report examines the EU's trade dependencies, equipment ecosystem, chips' market, and implications for end-using sectors, identifying areas of strength and vulnerability. It also delves into the automotive sector, a key driver of the EU semiconductor demand, and highlights the complex and evolving nature of the automotive semiconductor supply chain. This report provides valuable insights for policymakers and stakeholders seeking to strengthen the EU's position in the global semiconductor industry.

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Executive summary

The recent political debate highlights the importance for the European Union (EU) of strengthening its position in the semiconductor industry, given the sector's critical role in the overall economy and the geopolitical implications of the current market dependencies. Indeed, the EU has long been a significant player in the global semiconductor market. However, it still faces numerous challenges and dependencies that could impact its future competitiveness. Thus, an in-depth analysis of this sector is essential to identify potential EU strengths and weaknesses, so as to understand the current state and grasp potential future trajectory of the EU's semiconductor sector.

Firstly, the report examines the trade dependencies of the EU27, providing an overview of the vulnerabilities affecting key products traded along the semiconductor supply chain. A recent revision has improved the coverage of monitored products, and the final list now includes 127 product codes allocated to different segments of the semiconductor supply chain, encompassing raw materials for wafers, key inputs, wafers, equipment, and final products such as chips. Based on the SCAN (Supply Chain Alert Notification) methodology, the analysis reveals that in 2023, the EU27 was, on average, relatively well-positioned from a trade perspective in the equipment segment, while some vulnerabilities are identified in the other segments of the chain. Among all the segments, the final products segment shows a lower potential for substitutability with domestic capacity, despite accounting for a large portion of the total extra-EU imports in the EU semiconductor supply chain.

Secondly, the report delves into the EU equipment ecosystem and the final products. When looking at equipment, the analysis focuses on EU trade dependencies and provide an in-depth market intelligence analysis for specific markets. Findings show that the EU holds a strong position as a net exporter in the equipment segment, with significant domestic production capacity. This is primarily due to European manufacturers' global leadership in specialized machines for wafer and semiconductor manufacturing. For what final products are concerned, the report shows that Europe accounts for 10.6% of worldwide semiconductor shipments. The European semiconductor market amounted to EUR 50 billion in 2023, with projections indicating continued growth in the coming years. The automotive sector is identified as a key driver, receiving 37% of semiconductors shipped to Europe.

The report concludes with a deep dive into the automotive sector, exploring its dependencies on chips and market evolution. As a matter of fact, the automotive industry is a cornerstone of the EU economy, supporting over 13 million jobs and contributing more than 7% to the EU's overall GDP. The report examines the increasing semiconductor content in vehicles, particularly in electric vehicles, which contain upwards of 3 000 semiconductor chips compared to 1 000-1 500 in non-electric vehicles. The European automotive semiconductor market was valued at EUR 13.05 billion in 2023 and is projected to grow to EUR 17.38 billion by 2026, registering a compound annual growth rate (CAGR) of 8.19%. This case study concludes by highlighting the complex and evolving nature of the automotive semiconductor supply chain, emphasizing the need for strategic planning and investment to address challenges and harness future opportunities in this critical industry. It underscores the importance of closer partnerships between car manufacturers and semiconductor companies to secure a stable supply of critical components and drive innovation in the sector.

Introduction

The European Union (EU) has long been a significant player in the global semiconductor market, yet it faces numerous challenges and dependencies that could impact its future competitiveness. This report aims to provide a comprehensive overview of the EU's position within the global semiconductor sector, focusing on trade dependencies, market dynamics, and the implications for key end-using sectors, particularly the automotive industry. The analysis draws on data from the World Semiconductor Trade Statistics (WSTS) and the SCAN monitoring tool, offering insights into the distribution and dynamics of semiconductor shipments to Europe, as well as the structural dependencies that characterize the EU's semiconductor supply chain.

Product-level trade data provide a detailed overview on trade dependencies of the EU27 in the different segments of the value chain. Thanks to a recent revision that has improved the coverage, the list of monitored products now includes 127 product codes allocated to different segments of the semiconductor supply chain, encompassing raw materials for wafers, key inputs, wafers, equipment, and final products such as chips.

Findings show that in 2023, the EU27 was relatively well-positioned from a trade perspective in the equipment segment. An in depth analysis shows that the EU holds a strong position as a net exporter in the equipment segment. This is primarily due to European manufacturers' global leadership in specialized machines for wafer and semiconductor manufacturing. Notably, the EU leads in Microlithography and Mask Making equipment, which accounted for 30% of global sales of wafer fabrication equipment in 2023 (EUR 29.6 billion).

Some vulnerabilities are identified in the other segments of the chain. Notably, the final products (or chips) face import dependences, especially for logic chips and memory chips, which are primarily sourced from Taiwan. For this reason, we turn the attention also to the Europe's semiconductor market focusing on the distribution and dynamics of shipments to end using sectors.[1] Relying on WSTS data, an overview of market size and sector-specific semiconductor flows is provided, with the trajectory of shipment to Europe reviewed from recent years and projected up to 2027. Europe holds a significant yet not dominant position. Indeed, Europe is positioned as the fourth-largest market for semiconductors, with an 10.6% share of shipments in 2023. The market is dominated by China (29%) and the Americas (25%), with Japan and the rest of Asia accounting for a substantial combined share. Europe's semiconductor needs have evolved over the years, with a steady increase in shipments since 2020, reaching $53 billion in 2022. Notably, 2021 saw a 27% increase in shipments, compensating for the declines of 2019 and 2020, with the latter year heavily impacted by the Covid-19 crisis. WSTS forecasts a continued increase in shipments to Europe, predicting a cumulated 75% rise between 2017 and 2027. The distribution of the semiconductor end-using market is influenced by the relative size and strength of end-using sectors in different regions. In Europe, the automotive and industrial sectors receive a larger share of semiconductors compared to the rest of the world, while shipments for computer, consumer goods, and communication manufacturing are lower. Government demand is

1 In this Section Europe is considered as the entire EMEA (Europe, the Middle East and Africa) area. This is the level of aggregation for which WSTS is available.

marginally higher but represents a small fraction of total shipments. Changes in sector-specific demands from 2020 to 2023 indicate growth in the automotive, industry, and communication sectors, accompanied by a decline in consumer, communication, and government semiconductor needs.

Semiconductor shipments are categorized into eight types: discrete, optoelectronics, sensors, actuators (DOSA), analog, micro, logic, DRAM, SRAM, flash memory, and other memory types. European end-users receive fewer logic chips, DRAM, and flash memories than global counterparts, but more micro, DOSA, and analog semiconductors, with Japan outpacing Europe in DOSA shipments. The communication and computer manufacturing sectors are the primary consumers of logic chips and DRAM, while the European automotive and industrial sectors consume most of discrete, analog, micro, SRAM, and other memory types arriving to the market. From 2020 to 2023, shipments of analog, logic, and other memory types to Europe increased by over 40%, while DOSA and micro grew by 30%. Conversely, DRAM and flash memory shipments decreased by over 10% over the same period. As highlighted by the analysis on import dependencies for year 2023, the EU27 is at risk of experiencing import disruptions for few products in the DOSA segment, and for specific kinds of DRAMs and flash memories.

The present report highlights the future growth prospects of the automotive and the industrial sector. Indeed, 37 out of 100 chips shipped nowadays to Europe are for automotive. Given this result, the final chapter provides a deep dive on this industrial sector focusing on the evolution of the automotive market as well as on the type of technologies that this strategic sector will rely on in the years to come. The automotive sector is a vital component of EU's economic fabric, contributing significantly to employment and GDP. In 2023, the sector provided over 13 million jobs and accounted for approximately 6% of the EU's total employment, with a turnover contributing over 7% to the EU's GDP. The industry is heavily reliant on semiconductors, which are essential for a wide range of applications in modern vehicles, from engine control units to advanced driver-assistance systems. The demand for automotive semiconductors is influenced by the increasing number of vehicles, the complexity of electronic features, and the rise of electric vehicles (EVs), which require a higher number of semiconductors than traditional vehicles.

Since the COVID-19 pandemic, the automotive semiconductor sector has encountered significant hurdles, notably a global chip shortage, which caused widespread production delays and a downturn in global auto manufacturing. Although the situation improved somewhat by late 2022, the industry still faces supply chain challenges and the ongoing transition to electric vehicles (EVs). This shift has underscored the necessity for a more robust semiconductor supply chain, prompting increased investment in European semiconductor production. Additionally, the rise of EVs demands that companies adjust their offerings and strategies to meet the specific requirements of this growing market. In early 2024, the influx of Chinese-made EVs into Europe surged, leading to disputes over China's automotive overcapacity and its impact on global trade. These developments are pivotal in assessing the EU's reliance on semiconductors and the anticipated changes in demand as the industry progresses towards more sophisticated automotive technologies.

In 2023, the EU car market expanded by 13.9% compared to the previous year, with a notable increase in the sales of battery-electric vehicles, which surpassed diesel in market share. However, the market has not fully recovered to pre-pandemic levels, with registrations still 19% lower than in 2019. The production of cars in the EU increased by 11.3% from 2022 to 2023, with Germany leading in production growth. Trade dynamics have also evolved, with the EU experiencing growth in both car imports and exports. However, exports to China declined significantly in 2023, while imports from China saw a substantial increase. The European Commission's imposition of higher tariffs on Chinese electric vehicles in 2024 has led to tensions and a complaint filed by China with the World Trade Organization.

The automotive semiconductor market in the European Union is on a trajectory of significant growth, with projections indicating an expansion to EUR 17,377.0 million by 2026. This represents a compound annual growth rate (CAGR) of 8.19% from 2023 onwards. The market's growth is primarily driven by the increasing complexity of vehicles, which now incorporate more electronic components than ever before. This complexity is a result of the industry's shift towards electrification and the development of autonomous driving technologies, both of which rely heavily on advanced semiconductor components.

When examining the market by application, the safety segment emerges as the largest, holding 25.65% of the market revenue in 2023. This segment is projected to grow to EUR 4,564.8 million by 2026, with a CAGR of 9.05%. The prominence of the safety segment is attributed to the growing demand for advanced driver-assistance systems (ADAS) and other safety-related technologies that require high-quality semiconductor components.

Power electronics represents the fastest-growing segment within the market, with a CAGR of 11.1%. This rapid growth is linked to the increasing adoption of electric vehicles (EVs), which necessitate efficient power management systems to handle the high power levels associated with electric powertrains. The development of power electronics is crucial for the performance and efficiency of EVs, making it a key area of focus for semiconductor manufacturers.

The supply chain for automotive semiconductors involves raw material procurement, semiconductor manufacturing, distribution, and integration into vehicles. European semiconductor manufacturers like NXP Semiconductor and Infineon Technologies are key players in the market. The location of these companies' headquarters, however, doesn't wholly embody the extent of its operational or manufacturing reach. Notably, top semiconductor producers often have a considerable portion of their manufacturing capabilities outsourced or situated in various global regions. These leading firms maintain expansive infrastructures, encompassing fabrication units, assembly operations, and design hubs scattered over multiple continents. Distributors play a crucial role in ensuring the availability of components, while car manufacturers integrate these semiconductors into various vehicle systems. The advancement of automotive innovations for the next generation demands that car manufacturers and semiconductor companies collaborate more closely to develop specialized, high-performance semiconductors that are critical for these new technologies.

In conclusion, the EU automotive sector and its semiconductor market are experiencing growth and transformation, driven by technological advancements and changing consumer preferences. Despite challenges such as supply chain disruptions and geopolitical tensions, the industry is adapting and poised for future opportunities.

Chapter 1 – EU Trade dependencies and updated list of products

Recent disruptions affecting global value chains, such as Covid-19 or the Russian aggression in Ukraine or the chips shortage, have highlighted potential risks for the economy related to global trade interdependencies. As a matter of fact, there is increased attention in both policy-oriented and academic literature on monitoring trade statistics to identify vulnerabilities arising from a concentrated sourcing of products or a limited potential to diversify these dependencies. (European Commission, 2021; Korniyenko et al., 2017; Arjona et al., 2023; Reiter and Stehrer 2023; Mejean, Rousseaux, 2024).

This chapter discusses the EU trade dependencies along different segments of the semiconductor supply chain by focusing on the trade of products between the European Union and third countries along these segments. This analysis enhances the first application of the SCAN[2] methodology to the semiconductor supply chain as proposed by Bonnet and Ciani (2023). The main novelties pertain to an extension of the list of monitored products, related to key materials and inputs used for semiconductor manufacturing. Additionally, the analysis now includes an assessment of dependencies for the year 2023.

The first section of this chapter includes a detailed description of the steps taken to expand the list of products, with an overview of the main products and their allocation to the relevant segments, ranging from raw materials for wafers, inputs, wafers, equipment, and final products, i.e. the chips. The second section provides a general overview of the EU trade dependencies for year 2023, using the SCAN metrics. The last section of this chapter is devoted to a brief discussion of the main limitations and potential improvements of the work on monitoring dependencies using trade data. [3]

1.1. The enlarged product list

The first step in monitoring the products traded along the semiconductor supply chain is to identify the relevant product codes in the trade classifications. Building on previous research by OECD (2019), Bonnet and Ciani (2023) carried a first exercise which led to the identification of 74 product codes of the EU Combined Nomeclature (CN),[4] whose products are allocated to different segments of the semiconductor supply chain.

The objective of this chapter is to expand and refine the coverage of this initial list. Since the initial list did not adequately cover raw materials and critical inputs used in the manufacturing of wafers and chips, the new mapping exercise tries to address this gap. Notably, the new list attempts to identify the relevant products related to raw materials, compounds, chemicals, and gases that are imported by

2 SCAN stands for “Supply Chain Alert Notification” and is a methodology developed by DG Grow to monitor the state of a specific value chain based on product-level trade data (Amaral et al., 2022).

3 A more in-depth analysis of the results related to the equipment and final products segments is provided in Chapters 2 and 3, which also includes specialized industry data.

4 The Combined Nomenclature is the EU’s eight-digit coding system for the classification of goods employed in EU trade statistics. It includes the six digits of the HS code (i.e., the World Custom Organization’s Harmonized System nomenclature) with additional two digits: https://taxation-customs.ec.europa.eu/customs-4/calculation-customs-duties/customs-tariff/combined-nomenclature_en

semiconductor manufacturers. To do so, trade codes (CN eight-digit) for non-food, non-fuel (NFNF) raw materials, available in EC's Raw Materials Information System (RMIS),[5] were merged with product-level (CN eight-digit) import data on semiconductor companies provided by one EU member state.[6]

Of course, not all codes related to NFNF raw materials contained in the EC RMIS database are relevant for semiconductors' fabrication. So, by identifying those product codes that are simultaneously present in the RMIS database and are also imported by a sample of semiconductor companies, it is possible to conduct a "reality check" to determine which raw materials-related trade codes of the RMIS database are relevant for semiconductor companies. The list of product codes imported by a sample of semiconductor companies, which are included in the RMIS database, has been further cleaned and crosschecked with JRC experts and against field literature to reduce noise and focus on specific key inputs and materials used for semiconductor manufacturing.[7] Finally, the list has been shared with DG CNECT and with ESIA (European Semiconductor Industry Association) to obtain an external validation from industry experts.

The new mapping exercise resulted in a total of 127 product codes (according to CN 2023) allocated to the different segments of the semiconductor supply chain, from raw materials for wafers to final products, as summarized in Table A1.1. Given the complexity of the production processes and the extremely large combinations of inputs and materials used, the objective of this mapping is to attempt to identify key important materials and associate them with relevant CN codes. Although the ambition of this exercise was to be as extensive as possible, it does not cover the entire universe of semiconductor processes and inputs. In particular, the focus of the input segment is on the main inputs for front-end manufacturing.

The raw materials segment covers CN codes associated with the raw materials used in the initial stage of wafer production, for example, those utilized as a substrate to produce the wafers. These CN codes

5 The EC RMIS provides a structured repository of knowledge related to non-fuel, non-agricultural raw materials from primary and secondary sources. See website at https://rmis.jrc.ec.europa.eu/. This database provides a unique mapping of NFNF raw materials to specific trade codes (CN eight-digit), as well as product-specific information such as the processing stage or the material content of each product (Georgitzikis, 2023). The mapping identifies around 1 600 CN trade codes containing NFNF raw materials within the approximately 10 000 unique codes of the CN classification. This knowledge greatly facilitates the analysis of trade statistics and classifications, as most of this information cannot be retrieved by looking at official trade code descriptions. However, this database is not value-chain specific but rather developed to identify and monitor the universe of critical raw materials. Hence, it does not provide specific information on semiconductor-related raw materials or on their use along the semiconductor supply chain.

6 The list of products (CN8 codes) imported by French semiconductor companies was provided, aggregated at product level, by officials and researchers of the Directorate General for Enterprise (DGE) of the Minister for the Economy, Finance and Industrial and Digital Sovereignty in France.

7 This aspect is particularly relevant as firms typically import a wide range of products, many of which are not necessarily related to their primary production activity. For instance, the original list of imported products provided by France contains approximately 2 000 CN8 codes, some of which are clearly unrelated to the semiconductor manufacturing processes, despite appearing in the imports of semiconductor companies. By focusing on the intersection between the RMIS database and the list of imported products, the number of codes can be reduced to about 470. Still, many of these codes seem to be related to fabricated products made of common metals (e.g., iron, steel, aluminium, copper) that are commonly used in manufacturing facilities or electrical applications rather than specific materials for semiconductor manufacturing. This could result in a noisy list of products, therefore a cleaning process and a validation by field experts are needed to remove unnecessary information and disturbances.

include the ultra-refined silicon for the production of electronic-grade silicon wafers,[8] as well as other materials such as Silicon Carbide, Germanium, Gallium.[9]

The second segment encompasses CN codes potentially associated with key inputs used in a second stage of the semiconductor value chain: wafer fabrication and the manufacturing of chips in foundries. This segment includes fab materials and critical inputs for front-end manufacturing, such as photoresists and photomasks materials, chemical mechanical planarization pads, materials for wafer polishing, gases for cleaning and deposition, wet processing chemicals or other raw materials. In addition, it includes other inputs for foundries used for checking and inspecting semiconductor devices, such as microscopes and optical elements. Wafers are included in a specific segment in our analysis and are considered as intermediary inputs in the chain. This segment includes silicon or wafers done using other materials, such as lithium niobate.

The equipment segment includes machines employed in the manufacturing of chips, for checking their conformity to standards, and testing their proper functioning.

The last segment includes product categories representing the final products of the chain, such as memories, processors, integrated circuits, diodes, and transistors.

1.2. EU trade dependencies: a general overview

This section delves into some EU trade dependencies at both the segment and product level, through the lens of the SCAN ("Supply Chain Alert Notification") visualization tool. SCAN is a methodology developed by the Chief Economist Team of DG GROW to monitor the state of specific supply chains, relying on trade data for products traded along these chains (Amaral et al., 2022; Benoit et al., 2022). SCAN[10] provides a set of structural indicators to assess the ex-ante systemic risk of import disruptions, and high-frequency indicators to detect short-run increases in import prices and reductions in imported quantities as a potential signal of distress.

This section focuses on structural indicators to identify products within the semiconductor value chain where the EU is heavily dependent on third markets and more likely to face supply chains disruptions.[11]

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8 The raw material list includes also product codes related to silica and quartz, as they are used as inputs for the production of electronic-grade silicon. More specifically, ultra-pure quartz is used to make the crucibles in which the high-grade silicon is produced. However, there is one limitation related to available statistics, which is that the trade code related to quartz (CN 25061000) does not distinguish between high-purity quartz and other types of quartz, with only the former being relevant for the semiconductor production chain.

9 Of the raw materials identified, only electronic-grade Silicon and Silicon Carbide can be matched to a single specific CN code, while other materials, such as Gallium Arsenide, are grouped together in one CN code with other materials. For further discussion on this issue related to trade classifications, please refer to Section 1.3.

10 For more details, please refer to Amaral et al. (2022) and Bonnet and Ciani (2023).

11 The SCAN tool developed by JRC also includes the visualization of monthly import flows and quantities for specific products, as well as high-frequency indexes computed to indicate potential signs of short-run distress observed over the last observed quarter, such as increases in import prices and reductions in import quantities. Since high frequency indicators may signal temporary fluctuations and false positives, it is essential to complement them with information from industry experts and industry data, given the numerous factors affecting their dynamics. The analyst can regularly

To assess the level of foreign dependency of a product, the tool monitors the concentration of extra-EU imports, as well as the substitutability potential of these imports with the EU domestic production. The concentration is determined by two indexes: 1) share of the first source in extra-EU import higher than 50%; 2) import concentration of extra-EU imports (measured by the Herfindal-Hirshmann, HHI, index) greater than 0.4. The potential for a lack of substitutability with domestic supply may occur when 1) the ratio between imports from outside the EU and extra-EU exports is higher than one, and 2) the exposure indicator, which is the share of extra EU imports relative to the total EU supply,[12] is greater than 60%. Products are considered at risk for their foreign dependency when at least one of the concentration indicators and one of the substitutability indicators are above the respective thresholds ("medium risk"), or when all four indicators exceed the thresholds ("high risk").[13]

Per each segment of the value chain, Table 1.1 shows the total import and export, which have been calculated by aggregating the values of product-level import and export values. In addition, the table identifies the principal trade partner from which the EU sourced the largest amount of imports (in values) in 2023. The last four columns report the structural indicators for the concentration and the substitutability dimension.

The findings suggest that, on average, the EU is well positioned along the segments of the semiconductor supply chain related to the raw materials for wafers and the equipment segments. In all these segments, the EU is a net exporter (with a ratio import over export well below one) and has significant domestic capacity, as suggested by the relatively low levels in the exposure index. This index ranges between 0.14 for raw materials for wafers, and 0.21 for equipment, suggesting that extra-EU imports account for less than one quarter of total EU domestic supply in each segment. The concentration of extra-EU imports, as measured by the HHI index, is also well below the threshold of 0.4, with indexes approximately around 0.18 for raw materials for wafers, and 0.14 for equipment. The main sourcing partner for both segments is the US, accounting for 31% of the import values for the raw materials for wafers and 27% of the equipment.

Among all the segments, the EU shows the lowest potential for import substitution for final products, considering the combined results of a negative trade balance (with imports that exceed exports by around 75%) and an exposure index close to 0.6. This latter in fact suggests that extra-EU imports account for approximately 60% of total EU domestic supply in this segment. However, the import concentration at this aggregate level is still relatively low, with an HHI index of concentration equal to

check the SCAN dashboard to see how the time series of monthly import quantities, and import prices have evolved over time.

12 More specifically, the exposure indicator is calculated as the share of extra-EU imports over the sum of extra-EU imports and EU domestic production. Domestic production at product-level is sourced from a separate database (PRODCOM), whose data quality might be affected by concerns related to confidentiality, missing values, and aggregation issues when merged with granular trade data. For these reasons, the results related to the exposure indicator should be interpreted with caution and complemented with the evidence obtained from the import/export indicator.

13 The thresholds for the share of the first source, HHI index and ratio between extra-EU imports and exports follow the definition of strategic dependencies presented in previous Commission documents (SWD 2021 352) on strategic dependencies and capacities (European Commission; 2021). The choice of the threshold of the exposure index follows the definition proposed by the Chief Economist Team of DG Grow (Amaral et al.; 2022). On this point, it is worth noting that the European Critical Raw Materials Act sets that, by 2030, not more than 65% of the Union's annual consumption of each strategic raw material at any relevant stage of processing can rely on imports from a single third country.

0.12. Most of these imports come from Taiwan, accounting for 22% of total extra-EU imports for final products. For the inputs segment, the EU exhibits somewhat limited potential for substitutability, as indicated by an import/export ratio close to one, which indicates a balanced dynamic between extra-EU imports and exports. For what concerns the wafers segment, findings reveal low levels of substitutability potential, with imports exceeding exports by around 22% and an exposure indicator close to 0.60. Nevertheless, when considering aggregate imports for both inputs and wafers, these two segments remain relatively diversified, with 29% of inputs coming from South Korea and 32% of wafers from Japan.

Table 1.1: SCAN structural indicators for the semiconductors supply chain at segment level – 2023

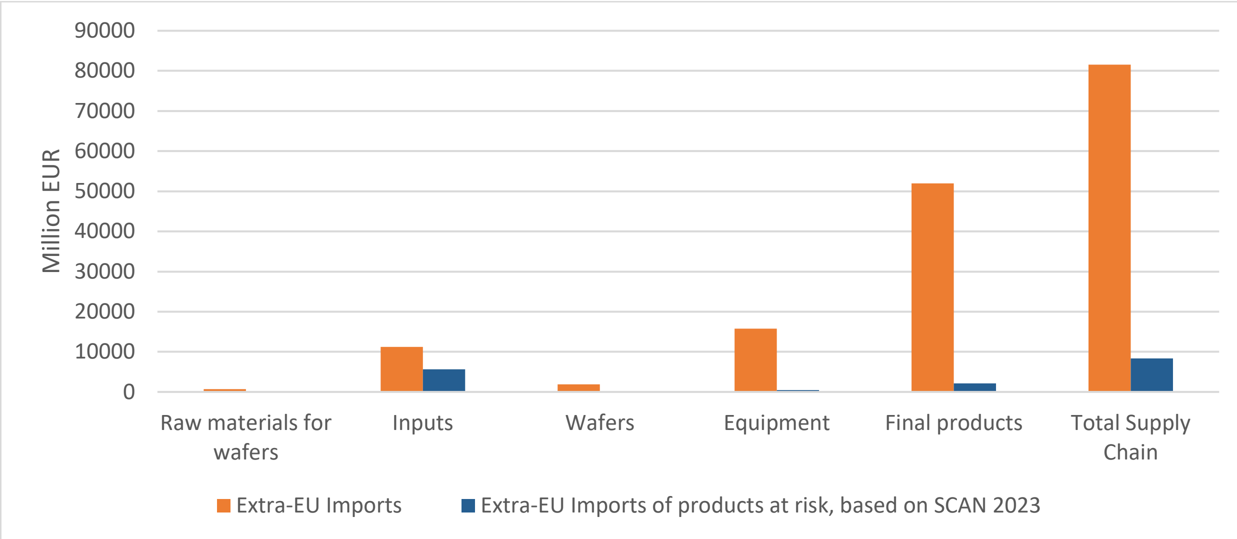
				Concentration		Substitutability	
Segments	**Total Import (*m EUR*)**	**Total Export (*m EUR*)**	**Top Source**	**Top Source Import Share**	**HHI Index**	**Import/ Export**	**Exposure Index**
Raw materials for wafers	**709.35**	**1 963.48**	**US**	**31.28%**	**0.18**	**0.36**	**0.14**
Inputs	**11 232.03**	**11 467.58**	**KR**	**28.97%**	**0.15**	**0.98**	**0.23**
Wafers	**18 79.31**	**15 46.12**	**JP**	**31.98%**	**0.20**	**1.22**	**0.60**
Equipment	**15 763.11**	**45 542.84**	**US**	**26.91%**	**0.14**	**0.35**	**0.21**
Final products	**51 955.65**	**29 653.63**	**TW**	**22.00%**	**0.12**	**1.75**	**0.59**

Source: JRC elaboration on EC customs data and PRODCOM for year 2023

Figure 1.1 shows the total value of extra-EU imports by segments and the contribution, in terms of extra-EU imports, of products identified at risk for year 2023. The equipment and final products segments account for a large portion of the total imports of the semiconductor supply chain (19% and 63% respectively), and around 3% and 4% of imports for equipment and final products are accounted for by products at risk of import disruptions, respectively.

Even though data aggregated at the segment level helps to understand the overall positioning of the EU, granular product-level evidence on dependencies might reveal potential criticalities, which are otherwise hidden in aggregated statistics. According to SCAN structural indicators for the year 2023, 23 out of the 127 monitored products are at risk of import disruptions. These products are characterized by at least one concentration and substitutability indicator above the respective thresholds (medium risk) or all structural indicators above thresholds (high risk) according to the SCAN methodology. In terms of their distribution across segments, two are related to raw materials, 13 to inputs, 3 to equipment, and 5 to final products, while there are no products at risk in the wafers' segment according to SCAN structural indicators. In Appendix 1, Table A1.2 lists these 23 CN codes, as well as their segment's allocation and related CN product descriptions. Additionally, Table A1.3 details the results of the analysis and the related structural indicators for these 23 products, based on the dependencies observed in 2023.

Figure 1.1: Total extra-EU imports and imports of products at risk of import disruption according to SCAN in 2023 by segments



Source: JRC Elaboration on EC customs data for year 2023

Comparing the 2023 results to the previous year, we observe some changes in the list of products potentially at risk. Seven products have dropped off the list, [14] while five new products have entered the list, having been identified at risk in 2023. Interestingly, 18 products that were already flagged as potentially vulnerable in 2022 remain as such (Table 1.2).

The new products include materials, which experienced a deterioration in the import concentration dimension across the two years, namely: materials for manufacturing ("Chlorides")[15], materials related to photomasks and photoresist,[16] one product related to equipment subsystems,[17] and one final product related to "*flash EEPROMs*" memories.[18] Out of the 18 products identified by SCAN as being at potential risk already in 2022, three products related to Germanium and Gallium[19] became subject to potentially disruptive trade restrictions in 2023, following the announcement of export controls by

14 CN 28111910 Hydrogen bromide "hydrobromic acid"; CN 28152000 Potassium hydroxide "caustic potash"; CN 28332500 Sulphates of copper; CN 28469090 Compounds of mixtures of rare-earth metals, yttrium and scandium, inorganic or organic; CN 38249975 Lithium niobate wafer, undoped; CN 84213935 Machinery and apparatus for filtering or purifying gases other than air by a catalytic process; CN 85414900 Photosensitive semiconductor devices (excl. photovoltaic generators and cells)

15 CN 28273985 Chlorides (excl. ammonium, calcium, magnesium, aluminium, iron, cobalt, nickel, tin and mercury chloride)

16 CN 37050090 Photographic plates and films, CN37079090 Preparations of chemicals for photographic uses

17 CN 84141015 Vacuum pumps of a kind used for the manufacture of semiconductors or solely or principally used for the manufacture of flat panel display

18 CN 85423261 Electronic integrated circuits as electrically erasable, programmable read-only memories "flash E^2PROMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)

19 CN 28256000 Germanium oxides and zirconium dioxide; CN 81129289 Unwrought gallium; gallium powders; CN 81129940 Articles of germanium, n.e.s.

China in August 2023.[20] As a matter of fact, they exhibited high levels of import concentration and low levels of substitutability across different years and concerns over potential shortages of these semiconductor materials have fuelled the political debate, given their importance for the production of certain advanced chips, as well as certain optical and military devices.[21]

Table 1.2: 2023 SCAN results vs 2022 SCAN results

Products at risk both in 2022 and 2023	
Germanium oxides and zirconium dioxide	Transistors with a dissipation rate < 1 W
Unwrought gallium; gallium powders	Parts of diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, light emitting diodes and mounted piezoelectric crystals, n.e.s.
Bromine	Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit
Phosphorus	Articles of germanium, n.e.s.
Halides and halide oxides of non-metals	Articles of niobium "columbium", n.e.s.
Artificial corundum, whether or not chemically defined	Fans of a kind used solely or principally for cooling microprocessors
Developers and fixers in the form of chemical preparations for photographic use	Machinery and apparatus for filtering or purifying liquid
Self-adhesive circular polishing pads of a kind used for the manufacture of semiconductor wafers, of plastics	Diodes (excl. photosensitive or light emitting diodes "LED")
Self-adhesive circular polishing pads of a kind used for the manufacture of semiconductor wafers	Chemical products and preparations of the chemical or allied industries
New products at risk in 2023	
Chlorides	Electronic integrated circuits as electrically erasable, programmable read-only memories "flash E^{2}PROMs", with a storage capacity of <= 512 Mbit
Photographic plates and film, exposed and developed	Vacuum pumps of a kind used for the manufacture of semiconductors or solely or principally used for the manufacture of flat panel displays
Preparation of chemicals for photographic uses	
Products at risk only in 2022	
Hydrogen bromide	Compounds of mixtures of rare-earth metals, yttrium and scandium, inorganic or organic
Potassium hydroxide	Machinery and apparatus for filtering or purifying gases other than air by a catalytic process
Sulphates of copper	Lithium niobate wafer, undoped
Photosensitive semiconductor devices (excl. photovoltaic generators and cells)	

Source: JRC elaboration on the SCAN dashboard for year 2022 and 2023 which is based on EC customs data and PRODCOM. Extraction date: 02.09.2024.

Finally, the products that dropped out of the results in 2023 saw an improvement in the concentration and substitution indicators. For example, EU imports of wet chemical hydrogen bromide, which is used

20 https://m.mofcom.gov.cn/article/zwgk/gkzcfb/202307/20230703419666.shtml

21 https://www.ft.com/content/9cd56880-4360-4e11-8c22-e810d3787e88

during etching processes for chip production, became more diversified from 2022 to 2023, with imports from Israel - which in 2022 accounted for more than 65% of total imports - dropping to a share of less than 50%. Notably, given Israel's relevant market share in this product, concerns about shortages were raised[22] after the recent Israel-Hamas war, but trade data seem to show that EU importers were effective in diversifying their supply lines for this product to other countries, such as the US.

Given the relevance of equipment and final products for the EU, in terms of trade with third countries and their implications for the end using markets, Chapter 2 and Chapter 3 focuses on these two segments. To overcoming some potential limitations associated with trade data analysis, the analyses will leverage also other sources of rich industry-specific data to enable a more detailed analysis of EU strengths and weaknesses. Findings for raw materials and inputs are discussed in Appendix 2, as a more in-depth technical review of the criticalities related to raw materials and inputs is beyond the scope of this report.[23]

1.3. Limitations and potential improvements of the mapping of trade codes

When mapping relevant trade codes to the semiconductor supply chain, a primary challenge is that the level of detail provided in the custom classifications for products is not always sufficient for a detailed analysis. Even though the CN8 classification is highly disaggregated, including more than 10 000 goods, some categories might still be too broad and could bundle together several types of materials or products under the same custom code, with only some of them being relevant for the semiconductor value chain.[24] As a matter of fact, current product codes do not enable the analyst to distinguish the most advanced logic chips from mainstream chips, depending on their node size. Therefore, the limited granularity and the high level of complexity and specialization of the materials and processes involved in chip manufacturing present significant challenges and limitations for researchers interested in

22 https://abachy.com/news/israel-hamas-war-raises-concerns-hydrogen-bromide-shortage-koreas-chip

23 Specifically for these two segments, economic analysis based on trade data is constrained by some limitation in available statistics and may not fully capture the magnitude of potential risks. Therefore, the analysis would greatly benefit from a technical perspective provided by semiconductor processes specialists.

24 In custom classifications, some trade codes are defined in more detail than others, allowing the identification of a well-defined product category linked to a single code (one-to-one correspondence). On the other hand, some trade codes could bundle together a broader and more "heterogeneous" group of products. Typical examples of heterogeneous product groups are cases of multiple correspondences (more than one-to-one) between specific raw materials/compounds and trade codes. In other words, multiple raw materials might be aggregated under a single trade code, representing a broader group of materials rather than a specific product or material. This issue may affect the precision and level of detail achievable in the analysis relying on trade data. Furthermore, the CN classification may not detail materials splitting by purity grades, which could be a limitation, as only high-purity materials and chemicals are typically used in semiconductor manufacturing processes. Finally, trade and custom classifications, such as the EU Combined Nomenclature (CN), are "living" classification systems that are regularly updated (the CN is updated yearly) due to changes in international classification standards, reporting requirements, or to better reflect the emergence or phase out of new or obsolete products in the market. It is important to take into account these revisions and update the list of products on a regular basis.

mapping and allocating trade codes to the various stages of semiconductor fabrication.[25] Additionally, the terminology and product aggregation choices within trade classifications may not always align with industry requirements and the categorizations used by companies, leading to potential challenges when interpreting and comparing the data with other sources.

There are also some remarks regarding the use of import data to map key products and track dependencies, as import data may contain noisy information. For example, there could be cases where an imported good by a company is not directly used as an intermediate input in its production process since firms could engage in re-trading or act as intermediate entities by reselling their imports to other companies. Additionally, firms typically import a very broad range of products, most of them not necessarily related to their primary production activity. Similarly, some intermediate inputs could also be sourced domestically and not imported from third markets. Therefore, solely considering only the set of imported goods from abroad may not capture this aspect. Finally, one additional limitation is that certain intangible inputs, like specialised software or core intellectual property for chip design, cannot be effectively tracked using trade or custom data that primarily focuses on physical goods.

To address several of these concerns and challenges effectively, the support of field experts will be essential to further refine the list. Experts can assist not only in refining the list of products by removing irrelevant items, but also in evaluating the relevance and use of each product within the semiconductor production process.[26] Additionally, an expert judgment can confirm and validate the accuracy of the mapping exercise between these codes and the various segment of the value chain.

The possibility to get access to data on products traded by individual companies could also improve the understanding of real dependencies in terms of raw materials and intermediate inputs for companies operating in the EU semiconductor ecosystem.[27] In this respect, collaboration with Member States is also desirable because it could lead to the identification of relevant companies and additional relevant imported products, which are currently not accounted for, thereby enhancing the coverage of the mapping exercise.

Finally, in addition to issues related to granularity or the identification of relevant products in custom classifications, some remarks are more general and highlight the limitations of trade data analysis. First, trade data analysis, while useful for highlighting the concentration of trade flows in specific geographies, does not provide insights on the criticality of traded inputs and the possibility of substitution with alternative products when assessing the risk of import disruptions. Additionally, granular trade data does not provide information on the final uses of the traded products. Finally, the

25 Moreover, it should always be highlighted that, especially in the case of raw materials, chemicals and gases, monitored products might be traded along other supply chains.

26 An expert overview could also provide additional insights on the relevance and criticality of certain key inputs and on the possibility of substitution with alternative products when assessing the risk of import disruptions. Typically, these kinds of evaluations cannot be accounted for in traditional trade data analysis.

27 As this data is currently not available, this mapping exercise had to rely on product-level import data provided by France for their semiconductors companies. The data, as provided by France, is aggregated at the product level and does not include company identifiers for confidentiality. However, a promising avenue of research would be to explore and access more granular company-level information on traded products (e.g., custom declaration data), which could be valuable for refining the list of products and improving the understanding of real dependencies for EU firms.

evaluation of foreign dependencies using trade data analysis might also be affected by the issue re-exports, as goods might undergo different stages of fabrication in various countries before reaching the final destination for ultimate use.

Bearing this in mind, the SCAN methodology and trade data analysis can still provide valuable insights on the functioning of the semiconductor supply chain, in particular allowing a preliminary assessment of the EU dependencies on foreign jurisdictions and risks related import disruptions of key imported products. This view should then be complemented with other dimensions and data to monitor, for example sourced from industry data on specific segments of the semiconductor value chain.

Main takeaways

- The SCAN tool currently monitors 127 semiconductor-related product codes allocated to different segments of the semiconductor supply chain, from raw materials for wafers, key inputs for manufacturing, wafers, equipment, to final products.

- 23 products have been found at risk of import disruption according to SCAN structural indicators for 2023 - two related to raw materials, 13 to inputs, 3 to equipment, and 5 to final products.

- SCAN evidence for the year 2023 suggests that, on average, the EU is well-positioned in the equipment segment of the semiconductor supply chain, both in terms of aggregate segment-level structural indicators, as well as in terms of a low number of products found at risk of import disruptions. No products at risk of import disruption are found in the wafers' segment, while potential vulnerabilities might affect specific products of the raw materials for wafers and input segments.

- Among all the segments, the final products segment shows, on average, a lower potential for substitutability with domestic capacity, while accounting for most of the total extra-EU imports of the semiconductor value chain

Chapter 2 – The EU equipment ecosystem: trade dependencies and market intelligence

Fabrication is the process of converting the design of an integrated circuit in a semiconductor chip. Wafers of silicon or other semiconductor materials go through numerous manufacturing processes (such as deposition, lithography, etching, implantation, metallization) to physically form transistors, other electronic devices and their metal interconnections. Throughout these manufacturing processes, the inspection of the wafer and its chips is performed using "process control" tools to verify the absence of errors or inaccuracies. After the manufacturing, specialised equipment cut the wafer into separate chips and assemble them on a frame; finally, the assembled chip is wired to connect it to external devices, and enclosed in a protective case or package. [28] All these processes require extremely sophisticated and expensive[29] equipment produced by specialised companies around the globe.

The general overview of EU trade dependencies provided in Chapter 1 has shown that, overall, the EU is well positioned in the equipment segment, holding a strong position as a net exporter and having significant domestic production capacity in this segment. This is primarily due to the global leading position of European manufacturers in the market for specialized machines used in the manufacture of wafers and semiconductors. Nevertheless, as the equipment ecosystem is complex and highly specialized, a more detailed analysis of this segment may reveal potential criticalities related to specific sub-segments where the EU companies hold a weaker position in the global market.

This chapter supplies two complementary sets of analysis. The first is an overview of EU trade dependency based on the SCAN structural indicators for the monitored products in the equipment segment (Section 2.1).[30] This will give a picture of the position of the EU with respect to its main sourcing partners. The chapter will then delve into a detailed analysis of the equipment market, identifying the main companies and their global market share (Section 2.2). This market data will allow for a thorough exploration of different equipment sub-segments, from wafer fabrication equipment to testing systems and assembly and packaging equipment and it will provide insights on global market shares and sales trends in each equipment sub-segment by major geographies.

2.1 EU trade dependencies in the equipment segment

Table 2.1 provides the analysis of the SCAN structural indicators for year 2023 for the CN codes related to equipment. The EU reported significant domestic capacity for most of the products related to the segment's "core" machinery equipment. These include the machines, apparatus, and parts used in the manufacture of wafers and semiconductor devices (covered by the following CN product codes:

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28 See Cerutti, I. and Nardo, M. (2023).

29 High-NA Twinscan EXE, the latest ASML cutting-edge High-NA extreme ultraviolet equipment to manufacture sub-3 nm chips will cost around $380 million per unit and weigh as much as two Airbus A320s. ASML will manufacture 5 units in 2024 all already purchased by Intel. The installation process of one unit requires 250 engineers, and six months to complete.

30 List of CN8 product codes and descriptions related to the equipment segment is available in Appendix 3.

84861000, 84862000, 84864000, and 84869000).[31] The EU is a net exporter in each one of these product categories (with a ratio import over export always below one). The values of the exposure indexes are also relatively low, apart from product CN 84864000 ("Machines and apparatus specified in Note 11 C to chapter 84").[32] This suggests that overall EU domestic production for specialized equipment for semiconductor manufacturing accounted for a significant portion of the EU total supply. Imports for these products are also rather differentiated (with a HHI index ranging between 0.20 and 0.27) and mostly sourced from countries such as US and Japan. In 2023, the most traded product in the segment between the EU and third countries was the product "Machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits" (CN 84862000). It accounted for approximately 42% of total segment's export values (approximately EUR 19.2 billion) and for approximately 25% total segment's import values (approximately EUR 4 billion). In fact, trade flows of lithography machines or EUV machines are recorded under this product, for which the Dutch company ASML holds a global leadership, confirmed by market share data.

Additionally, the structural indicators for year 2023 related to the equipment for measuring or checking wafers and semiconductors, electrical quantities, and controlling instruments (CN 90112010, CN 90308200, CN 90308400, CN 90308900, CN 90314100) show that imports of these products are on average rather differentiated and have a high potential for substitution with EU domestic capacity. Among these products, only the product "Optical instruments and appliances for inspecting semiconductor wafers or devices or for inspecting photomasks or reticules used in manufacturing semiconductor devices" (CN 90314100) has low substitutability potential, with extra-EU imports accounting for almost 75% of EU total supply (exposure index) and import levels exceeding exports in 2023 (import/export ratio equal to 1.29). However, import concentration is relatively low (HHI index equal to 0.25), with imports mainly sourced from Singapore (40%). Market share data confirm the prominent market position of Singapore in assembly inspection equipment and in bonding equipment. Notice that among the top players in Singapore, the listed company ASMPT (ASM pacific technology) was originally a branch of the Dutch ASM which is currently also its largest shareholder.

In the equipment segment, according to SCAN indicators for year 2023, the only three products that are found at risk import disruptions are related to subsystems used for air, gas, and fluid management. Some of these products might also be relevant for other value chains and do not pertain to "core" semiconductor manufacturing equipment. As reported in Table 2.1, these products are "Vacuum pumps of a kind used for the manufacture of semiconductors" (CN 84141015), "Fans of a kind used solely or principally for cooling microprocessors" (CN 84145915), and "Machinery and apparatus for filtering or purifying liquids" (CN 84212920). They show relatively high levels (above the thresholds) in all concentration and substitutability indexes, suggesting that there is limited capacity for the EU to

31 More specifically, CN 84861000 covers the machines and apparatus for the manufacture of boules or wafers and CN 84862000 covers the machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits. CN 84864000 covers the "Machines and apparatus specified in Note 11 C to chapter 84". CN 84869000 includes parts and accessories of these machines.

32 According to Note 11 (C) of Chapter 84, this product code includes the machines used for the manufacture or repair of masks and reticles, assembling semiconductor devices or electronic integrated circuits, lifting, handling, loading or unloading of boules, wafers, semiconductor devices, electronic integrated circuits and flat panel displays: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302364

substitute extra-EU imports for these products. They are also characterized by imports concentrated in the following geographies: Japan (56%), China (67%), and the US (67%), respectively.

Table 2.1: SCAN structural indicators for the CN8 products for equipment – 2023

CN8 code	CN8 description (abbr.)	Total Import (*m EUR*)	Total Export (*m EUR*)	Top Source	Concentration		Substitutability		S-Risk
					Top Source Import Share	HHI Index	Import/ Export	Exposure Index	
84141015	Vacuum pumps of a kind used for the manufacture of semiconductors…	94.01	20.47	JP	56%	0.41	4.59	0.81	**
84145915	Fans of a kind used solely or principally for cooling…	219.2	80.49	CN	67%	0.46	2.72	0.89	**
84145925	Axial fans (excl. table, floor, wall, window, ceiling or roof fans,…	434.4	1 226.43	CN	49%	0.28	0.35	0.23	
84145935	Centrifugal fans (excl. table, floor, wall, window, ceiling or…	257.5	1092.34	CN	47%	0.26	0.24	0.14	
84145995	Fans (excl. table, floor, wall, window, ceiling or roof fans,…	287.95	326.66	CN	39%	0.20	0.88	0.23	
84149000	Parts of: air or vacuum pumps, air or other gas compressors, fans and …	1 531.98	2 793.99	CN	32%	0.15	0.55	0.42	
84195020	Heat exchange units made of fluoropolymers…	49.09	52.27	US	38%	0.23	0.94	0.27	
84195080	Heat-exchange units (excl. those used with boilers and those…	946.2	2 833.10	CN	33%	0.17	0.33	0.13	
84212920	Machinery and apparatus for filtering or purifying liquids,…	123.9	85.06	US	67%	0.48	1.46	0.62	**
84212980	Machinery and apparatus for filtering or purifying liquids…	1 176.18	2 798.73	US	44%	0.26	0.42	0.32	
84213915	Machinery and apparatus for filtering or purifying gases,…	20.79	25.35	US	23%	0.16	0.82	0.33	
84213925	Machinery and apparatus for filtering or purifying air…	618.8	1 874.86	CN	25%	0.16	0.33	0.16	
84213935	Machinery and apparatus for filtering or purifying gases…	331.2	690.52	ZA	32%	0.18	0.48	0.23	
84213985	Machinery and apparatus for filtering or purifying gases other than ai…	500.2	923.83	ZA	20%	0.14	0.54	0.36	
84219910	Parts of machinery and apparatus of subheadings…	39.04	89.69	CN	54%	0.34	0.44	0.28	
84219990	Parts of machinery and apparatus for filtering or purifying liquids or…	1 147.93	3 034.25	CN	31%	0.19	0.38	0.26	
84431940	Printing machinery for use in the production of semiconductors…	0.12	2.59	GB	94%	0.88	0.05	0.01	
84861000	Machines and apparatus for the manufacture of boules or wafers…	314.48	608.75	JP	38%	0.27	0.52	0.21	
84862000	Machines and apparatus for the manufacture of semiconductor…	4 008.08	19 252.5	US	32%	0.22	0.21	0.12	
84864000	Machines and apparatus specified in Note 11 C to chapter…	546.6	950.99	SG	29%	0.20	0.57	0.69	
84869000	Parts and accessories for machines and apparatus…	1 978.20	4 920.15	US	43%	0.26	0.40	0.38	
90112010	Photomicrographic optical microscopes fitted with…	1.63	3.19	CN	47%	0.35	0.51	0.39	
90308200	Instruments and apparatus for measuring or checking…	276.5	894.99	MY	38%	0.23	0.31	0.32	
90308400	Instruments and apparatus for measuring or checking…	197.3	334.50	MY	50%	0.31	0.59	0.49	
90308900	Instruments and apparatus for measuring or checking electrical…	256.5	313.17	US	18%	0.12	0.82	0.56	
90314100	Optical instruments and appliances for inspecting semiconductor…	404.9	313.95	SG	40%	0.25	1.29	0.74	

Source: JRC B.1 elaboration on EC customs data and PRODCOM (extraction 02.09.2024). Thresholds for concentration indexes are 50% for the share of the top source in extra-EU imports and 0.4 for the HHI index. Thresholds for substitutability indexes are equal to 1 for the ratio of extra-EU imports and extra-EU exports, and to 60% for the exposure index. indicates products in medium risk for which at least one concentration index and at least one substitutability index are above the respective thresholds, ** indicates products in high risk for which all structural indicators are above the thresholds. Please refer to Appendix 3 for a complete reference of CN8 product descriptions.*

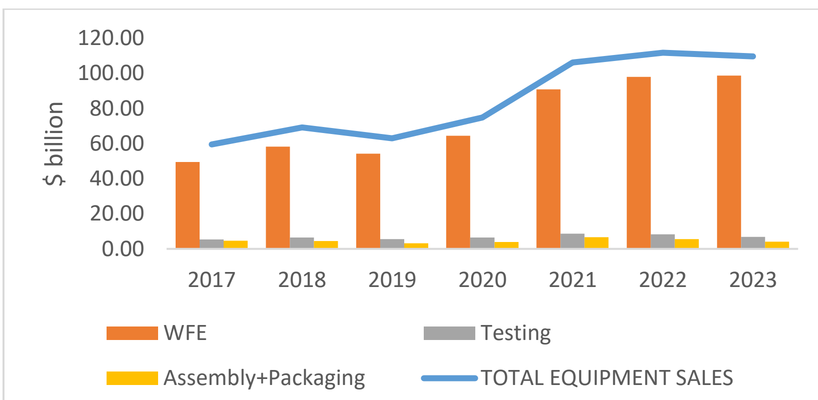
2.2 World equipment market shares

This section provides an overview of the main trends in equipment sales distinguishing equipment for manufacturing chips (wafer fabrication equipment), from equipment for testing errors and inaccuracies and equipment for cutting, assembling and packaging (assembling equipment). The main actors and their market shares are also reported, with the aim to highlight production concentration and dependencies. Market intelligence data come from TechInsights.[33]

2.2.1 Global equipment sales

After the uptake observed in the period 2019-2021, global equipment sales stabilized at $109.6bn in 2023 (Figure 2.1). About 90% of all equipment sales in 2023, $98.6bn, were related to Wafer Fabrication Equipment for chip production (up from 83% in 2017). Testing accounted for 6% of global sales followed by Assembly&Packaging with 4% (down from 9% and 8% respectively in 2017)[34]. Forecasts for 2024 remain stable, reaching $113bn. An uptake of equipment sales is foreseen in 2025-26 fueled by the expansion of chip production for AI and other advanced applications. Equipment expenses are expected to reach $180bn in 2029 (Figure 2.2), with a CAGR close to 10% (Table 2.2). Double digit growth is expected for testing, assembling and packaging, mainly due to advanced packaging. Fan-Out Wafer Level Packaging, for example, is expected to increase on average by 45% each year in the period 2024-29.

Figure 2.1: Global equipment sales with breakdown by segment

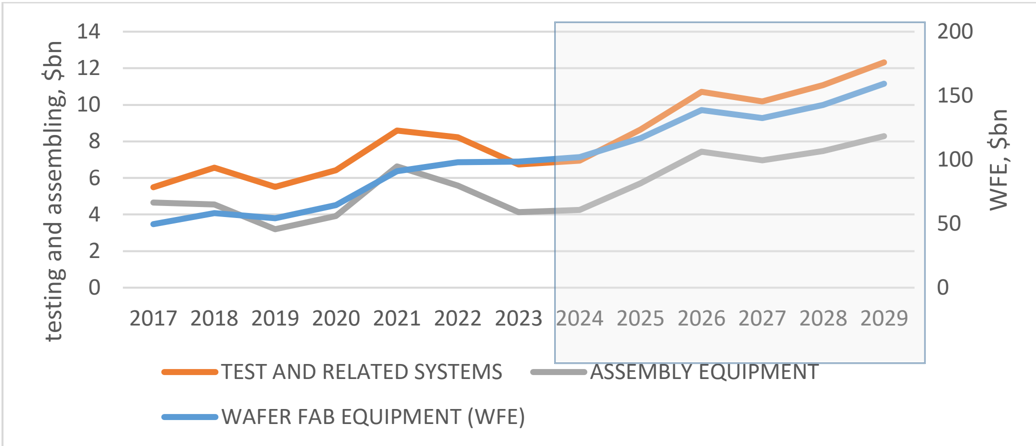


Source: JRC elaboration on TechInsight data, downloaded April 2024. WFE stands for Wafer Fabrication equipment. Testing stands for Test and Related Systems and includes Automated Test Systems and Handlers&Probers. Assembly and Packaging equipment includes Assembly, Dicing, Bonding and Packaging.

33 https://www.techinsights.com/

34 All the sales data in this section are based on Techinsights' Equipment database. Data have been retrieved between April and May 2024. The time window covered is 2017-2023. However, for some of the segments, sales are only available from 2019. Companies are assigned to countries according to the location of the headquarters.

Figure 2.2: Global equipment sales, trend and forecast with breakdown by segment



Source: JRC elaboration on TechInsight data, downloaded September 2024. WFE stands for wafer fabrication equipment for chip production and is measured in the right axis. Testing stands for test and related systems. Assembly stands for assembly and packaging. Testing and assembling are measured in the left axis.

Table 2.2: Global equipment sales. Compound annual growth rate by type of equipment

	2018 - 23 CAGR	**2024 - 29 CAGR**
WAFER FAB EQUIPMENT (WFE)	11.0%	9.3%
Microlithography and Mask Making Eqpt	15.9%	8.2%
CMP Equipment*	8.7%	10.2%
Ion Implanters	17.1%	6.5%
Deposition & Related Tools	11.7%	9.9%
Etching & Cleaning Tools	4.8%	10.4%
Process Diagnostic Equipment	14.1%	9.2%
Other Equipment	2.6%	7.2%
TEST AND RELATED SYSTEMS	0.7%	12.2%
Automated Test Systems	2.7%	11.3%
Handlers and Probers	-3.3%	14.7%
ASSEMBLY EQUIPMENT	-1.8%	14.2%
Assembly Inspection Equipment	-2.7%	13.3%
Dicing Equipment	8.6%	7.3%
Bonding Equipment	-6.0%	19.0%
Packaging Equipment	-5.4%	13.6%
Integrated Assembly Systems	-12.0%	11.1%
TOTAL SYSTEM SALES	9.5%	9.7%

Source: TechInsight, downloaded September 2024. (*) CMP stands for chemical and mechanical planarization.

Table 2.3: Equipment market share 2023

Equipment	Market share, 2023							Total sales	
	North America	**EU**	Taiwan	South Korea	Japan	China	RoW	2023, $bn	CAGR 2019-23
Total equipment	**40.8%**	**26.4%**	**0.3%**	**2.7%**	**24.6%**	**3.3%**	**1.9%**	**109.6**	**15%**
Wafer Fabrication Eqpt	43%	**29%**	0%	2%	22%	3%	1%	98.6	16%
Test and Related Systems	30%	**1%**	2%	9%	50%	4%	3%	6.8	5%
Assembly and Packaging Eqpt	4.5%	**14.5%**	1.0%	6.7%	47.8%	3.5%	22.0%	4.2	7%

Note: the market share for assembly corresponding to the ROW is almost entirely attributable to Singapore. Source: JRC elaboration on TechInsight data, downloaded April and July 2024. EU stands for EU27

2.2.2. Wafer Fabrication Equipment for chip production

The production of Wafer Fabrication Equipment for chip production (WFE) is a business dominated by North America, the EU and Japan. North America (principally the US) had a global WFE market share close to 43% in 2023 (Table 2.3) followed by the EU (29%) and Japan (22%). The EU market share has grown by 63% in this segment over the last six years, while the shares of Japan and the US have decreased by 24% and 8% respectively.

South Korea and Taiwan are marginal players in WFE for chip production, with no sign of improvement in the time window observed (Table 2.4). In the last five years, China displayed the highest compound annual growth rate (49%[35]), although still with a very low world market share. This is mainly due to a growing presence of China in Chemical Mechanical Planarization[36], in Deposition and related tools[37], and in Etching and Cleaning Tools[38]. Globally, no jurisdiction dominates all the sub-segments of wafer fabrication equipment. Instead, each jurisdiction seems increasingly specialised in the production of a particular type of equipment.

35 CAGR 19-23 is calculated as the compound annual growth rate of sales.

36 Where China had 11% global market share in 2023, up from 1% in 2017, mainly thanks to Hwatsing.

37 Where China had 5% of global market share in 2023, up from 1% in 2017, thanks to Naura and Piotech.

38 Where China had 7% of global market share in 2023, up from 1% in 2017, thanks to Naura and Advanced Micro-Fabrication Equipment.

Table 2.4: World sales of wafer fabrication equipment for chip production: market share by jurisdiction and compound annual growth rate (CAGR) 2019-2023

	2017	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	*CAGR 2019-2023*
North America	46.7%	42.7%	42.4%	43.7%	44.0%	47.7%	43.1%	17%
EU	17.6%	20.5%	22.5%	22.1%	21.4%	20.6%	28.7%	23%
Taiwan	0.2%	0.1%	0.1%	0.2%	0.1%	0.1%	0.1%	5%
South Korea	4.5%	4.0%	2.7%	3.4%	4.2%	2.8%	2.1%	9%
Japan	28.9%	30.5%	30.2%	28.3%	27.8%	25.8%	21.9%	7%
China	0.7%	1.0%	1.2%	1.3%	1.5%	2.0%	3.2%	49%
RoW	1.3%	1.3%	0.9%	0.9%	1.0%	1.0%	0.9%	16%

Source: JRC on TechInsights sales data (download April 2024). North America includes the US and Canada. RoW stands for Rest of the World. CAGR stands for compound annual growth rate of sales

.**Table 2.5**: Wafer fabrication equipment for chip production market share 2023

	Market share, 2023							**Total sales**	
	North America	**EU**	Taiwan	S.Korea	Japan	China	RoW	2023, $bn	CAGR 2019-23
Wafer Fabrication Equipment	**43.1%**	**28.7%**	**0.1%**	**2.1%**	**21.9%**	**3.2%**	**0.9%**	**98.4**	**16%**
Microlithography and Mask Making Equipment	***0.7%***	***80.8%***	***-***	***0.2%***	***18.1%***	***0.3%***	***0.0%***	***29.6***	***20%***
Resist Processing Eqpt	*0.1%*	*2.3%*	*-*	*1.5%*	*95.2%*	*0.8%*	*0.2%*	*3.4*	*12%*
Optical Exposure Eqpt	*0.4%*	*93.0%*	*-*	*0.0%*	*6.3%*	*0.2%*	*0.0%*	*25.1*	*21%*
Direct Write Systems	*-*	*32.9%*	*-*	*-*	*67.1%*	*-*	*-*	*0.04*	*-4%*
Mask Exposure Eqpt	*8.1%*	*46.2%*	*-*	*-*	*45.7%*	*-*	*-*	*1.1*	*9%*
CMP Equipment (*)	***56.7%***	***-***	***-***	***1.0%***	***31.4%***	***10.9%***	***-***	***2.7***	***17%***
Ion Implanters	***95.9%***	***-***	***0.5%***		***3.2%***	***0.3%***	***-***	***3.2***	***32%***
Deposition & Related Tools	***67.1%***	***11.4%***	***0.0%***	***2.8%***	***13.0%***	***4.6%***	***1.1%***	***25.5***	***18%***
Etching & Cleaning Tools	***53.3%***	***0.6%***	***0.2%***	***4.5%***	***34.1%***	***7.0%***	***0.4%***	***21.7***	***10%***
Process Diagnostic Equipment	***70.7%***	***6.5%***	***-***	***0.5%***	***16.0%***	***0.9%***	***5.4%***	***12.8***	***19%***
Other Equipment (**)	***0.3%***	***15.4%***	***0.8%***	***6.8%***	***75.9%***	***0.4%***	***0.5%***	***2.9***	***4%***

(*) Chemical-mechanical planarization.

(**) Other Wafer Manufacturing Equipment (Crystal Growing Furnaces, Crystal Machining, Wafer bonders and Aligners), Automated Handling Systems, Reticle Repair Systems, Wafer Marking Systems.

Source: JRC elaboration on TechInsight sales data, downloaded April 2024. EU stands for EU27

2.2.3 Test and Related Systems

Testing is a set of processes aiming at identifying and eliminating defective chips thereby ensuring the quality and reliability of semiconductor devices. World sales for testing equipment reached $6.8bn in 2023, increasing on average by 5% every year since 2019 (Table 2.3). The world market for the production of this type of equipment is dominated by Japan with over 50% of world market share in 2023, up from 35.6% in 2017. Japanese companies are especially strong in the production of memory testers (48.4% of the world market in 2023, Table 2.7), Systems-on-a-Chip (SoC[39]) test systems (59.5% of the world market in 2023) and wafer probing[40] equipment (72% of the world market in 2023). Japan is weak, instead, in burn-in[41] testers, dominated by South Korea and the US with a global market share in 2023 of 43% and 35% respectively. The US had a strong presence in all segments of Test and Related Systems. In 2023, US market share ranged from 35% for SoC test systems and burn-in testers to 13% for wafer probers.

Despite the growth observed in the past 5 years, **the EU is almost absent from the global stage**, with a market share of 1.4% in 2023, practically unchanged from 2017 (Table 2.6). EU presence is mostly concentrated in the production of burn-in testers and in package handling equipment (Table 2.7). **The EU has no relevant companies both in memory testers and in wafer probing[42]**.

China has a modest but growing global market share in Test and Related Systems, 4.4% in 2023, up from 1.4% in 2017. Looking at single technologies, however, Chinese presence is very high for linear and discrete testers[43] with a global market share of 58.6% in 2023 (up from 45% in 2019). Chinese presence is also increasing in burn-in and SoC test systems with a global market share of 3.1% and 3.2% respectively in 2023 (up from negligible presence in 2019).

Besides memory testers, South Korea has some stakes in handlers and probers (especially in package handling equipment with 15.6% of global market share in 2023) and in memory testers holding 20% global market share in 2023. Other minor players in package handling systems are Taiwan, Singapore and Malaysia.

39 SoC is an integrated circuit combining most or all the components of a computer (or other electronic systems) onto a single chip. SoC test systems can test logic, memory, mixed, and analog circuits.

40 Wafer probing is the process of electrically testing each die on the wafer to verify its functionality or identify defects before further manufacturing steps.

41 During burn-in testing, the device under test (i.e., chip or circuit board) is stressed at or above their operating conditions (e.g., temperature, power, frequency) in order to detect any component that would prematurely fail.

42 The German ERS electronics is present in wafer probing with unknown market share.

43 Testing equipment for linear integrated circuits (analog chip) and discrete semiconductor devices.

Table 2.6: World sales for Test and Related Systems: market share by jurisdiction and compound annual growth rate (CAGR) 2019-2023

	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	***CAGR 2019-2023***
North America	39.1%	29.8%	31.6%	38.0%	35.5%	30.0%	29.9%	**3.6%**
EU	1.1%	1.0%	1.1%	1.0%	0.9%	1.0%	1.4%	**12.5%**
Taiwan	4.4%	3.2%	3.7%	3.4%	2.7%	2.8%	2.4%	**-5.2%**
Singapore	1.3%	1.3%	1.3%	1.2%	1.2%	0.9%	0.8%	**-6.3%**
Malaysia	1.7%	1.8%	2.3%	1.5%	1.4%	1.5%	1.7%	**-1.9%**
South Korea	14.9%	15.2%	9.4%	9.6%	10.8%	9.6%	9.0%	**4.0%**
Japan	35.6%	46.1%	48.5%	42.4%	43.2%	48.0%	50.5%	**6.1%**
China	1.4%	1.3%	1.9%	2.7%	4.0%	5.9%	4.4%	**30.1%**
RoW	0.4%	0.4%	0.3%	0.2%	0.2%	0.2%	0.2%	**1.2%**

Source: JRC on TechInsights sales data (download April 2024). North America includes the US and Canada. RoW stands for Rest of the World

Table 2.7: Test and related systems market share 2023

	Market share, 2023									Total sales	
	North America	**EU**	Taiwan	Singapore	Malaysia	S.Korea	Japan	China	RoW	2023, $bn	CAGR 2019-23
Test and Related Systems	**29.7%**	**1.4%**	**2.4%**	**0.8%**	**1.7%**	**9.0%**	**50.3%**	**4.4%**	**0.2%**	**6.8**	**5%**
Automated Test Systems	***33.4%***	***1.3%***	***1.5%***	***0.0%***	***0.1%***	***6.6%***	***52.8%***	***3.9%***	***0.3%***	***4.8***	***7%***
Memory Test Systems	*31.5%*	-	-	-	-	*20.1%*	*48.4%*	-	-	*1.1*	*14%*
Linear and Discrete Test Systems	*24.4%*	*0.1%*	-	-	*2.0%*	*1.3%*	*12.7%*	*58.6%*	*1.0%*	*0.2*	*10%*
Systems-on-a-Chip Test Systems	*34.5%*	*1.5%*	*2.0%*	-	-	-	*59.5%*	*2.3%*	*0.3%*	*3.3*	*5%*
Burn-in Test Systems	*34.8%*	*6.5%*	*2.8%*	-	-	*43.2%*	*8.3%*	*3.1%*	*1.3%*	*0.2*	*0.5%*
Handlers and Probers	***20.6%***	***1.6%***	***4.7%***	***2.8%***	***5.8%***	***14.8%***	***43.9%***	***5.6%***	***0.1%***	***1.9***	***2%***
Wafer Probing	*13.1%*	-	-	-	-	*13.9%*	*71.9%*	*0.9%*	*0.2%*	*1.0*	*5%*
Package Handling Equipment	*28.3%*	*3.3%*	*9.6%*	*5.8%*	*11.9%*	*15.6%*	*15.1%*	*10.6%*	-	*1.0*	*-0.2%*

Source: JRC elaboration on TechInsight sales data, downloaded April 2024. EU stands for EU27

2.2.4. Assembly Equipment

Assembly and Packaging are the final steps transforming the finished wafers into packaged chips and boards for the end users. Packaging provides electrical connections for signal transmission, power input, and voltage control. It also provides for thermal dissipation and the physical protection required for reliability. The global advanced semiconductor packaging market size ($35.6bn in 2023), is expected to reach around $83.3bn by 2034, expanding at a CAGR of 8% from 2024 to 2034[44].

After a peak in 2021 ($6.6bn), sales in assembling and packaging equipment stabilised at $4.2bn in 2023, an amount similar to that observed in pre-COVID period ($4.5bn in 2017 and 2018). The business of assembly and packaging principally involves Japan and Singapore (Table 2.8), while the EU holds the third position mainly thanks to German companies.

Japan held not only 48% of the global market in 2023 (up from 33% in 2017), but also displayed the highest compound annual growth rate (15%) among all top countries during COVID and its aftermath. Japan is a monopolist in dicing equipment[45] controlling over 92% of the market in 2023. Japan also held 51.4% of the global market in packaging equipment in 2023, reaching 75.3% in molding[46] and sealing systems (Table 2.9).

Singapore global market share (21% in 2023, down from 35% in 2017) is due to its strong presence in bonding, particularly wire bonding[47], where Singapore originated over 81% of the global sales in 2023 (up from 75% in 2017). Singapore also holds the monopoly in integrated assembly systems, with a market share of 97% in 2023. The remaining 3% is in the hands of the German company Grohmann Engineering.

In 2023, the EU held 14.5% of the global market for assembly and packaging equipment, down from 16% in 2017. The EU has little or no presence in dicing and assembly equipment market, but held 26% of global market share in 2023 in bonding equipment, especially in die attaching[48] where EU market share reached 43%. Among the packaging equipment, the EU is top player in the segment of lead-finishing[49] and marking systems[50] together with Korea with 34% of global market share in 2023. Finally, with 13% of the global market in 2023, the EU is second to Japan in molding and sealing systems.

44 Advanced Semiconductor Packaging Market Size, Share, and Trends 2024 to 2034, https://www.precedenceresearch.com/advanced-semiconductor-packaging-market

45 Dicing is the process of cutting wafers into individual chips.

46 Molding is the process of covering the chip with resin to electrically insulate it.

47 Wire bonding is the process of creating electrical interconnections (or wire) between the chip and its package.

48 Die attach or die bonding is the process of attaching the chip (or die) to a package a substrate such as a printed circuit board (PCB) or another die.

49 Lead finish is the process of covering the lead of a chip with a layer of another metal, to protect it from corrosion.

50 Marking is the process of putting marks (such as identification, traceability and other distinguishing marks) on the package of a chip.

The fourth relevant player in assembling and packaging is South Korea which ranks first in the packaging equipment segments of lead finishing&marking, of singulation systems[51], and of transfer tools[52].

The US has negligible presence in dicing and bonding, with the exception of interconnect tools where it held 18% of global market share in 2023. US presence is strong only in assembly inspection equipment with 52% of global market share in 2023.

China, with 3.5% of global market share in 2023, has a weak presence in dicing and assembly inspection equipment (with no presence in laser sawing equipment). Instead, Chinese market share in bonding reached 6.6% in 2023, thanks to Chinese sales in die attaching and other interconnect tools (in 2023 6% and 25% market share respectively). In packaging equipment, China had relevant global market share only in transfer tools (7% in 2023) and no presence in the segment of singulation systems.

Table 2.8: World sales for Assembly Equipment: market share by jurisdiction and compound annual growth rate (CAGR) 2019-2023

	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	*CAGR 2019-2023*
North America	3.9%	4.5%	5.7%	5.3%	5.0%	5.2%	4.5%	0.8%
EU	15.9%	14.2%	13.3%	13.0%	13.3%	13.2%	14.5%	9.1%
Taiwan	1.3%	1.3%	1.4%	1.2%	0.8%	0.9%	1.0%	-3.3%
Singapore	34.9%	35.5%	30.9%	31.6%	36.1%	29.8%	21.1%	-2.9%
South Korea	7.1%	7.7%	7.3%	7.8%	7.1%	7.5%	6.7%	4.6%
Japan	32.6%	32.2%	35.6%	35.6%	33.8%	39.3%	47.8%	15.0%
China	3.3%	3.6%	4.8%	4.5%	3.3%	3.5%	3.5%	-1.0%
RoW	0.9%	1.0%	1.0%	0.9%	0.6%	0.6%	0.9%	2.7%

Source: JRC on TechInsights sales data (download April 2024). North America includes the US and Canada. RoW stands for Rest of the World

51 Singulation is the process of identifying and cutting the individual packages from the substrate.

52 Transfer tools are automatic machines for transferring wafers from carrier i.e., a substrate for thin wafers to be bonded during the packaging steps) to carrier.

Table 2.9. Market share for assembling and packaging, 2023

	Market share, 2023								Total sales	
	North America	**EU**	Taiwan	Singa-pore	S.Korea	Japan	China	RoW	2023, $bn	CAGR 2019-23
Assembly Equipment	**4.5%**	**14.5%**	**1.0%**	**21.1%**	**6.7%**	**47.8%**	**3.5%**	**0.9%**	**4.2**	**7%**
Dicing Equipment	***0.1%***	***0.5%***	***0.6%***	***2.3%***	***3.0%***	***92.2%***	***0.4%***	***0.8%***	***1.5***	***19%***
Blade Sawing Equipment		*0.3%*	*0.6%*	*0.4%*	*9.7%*	*86.3%*	*0.5%*	*2.2%*	*0.4*	*21%*
Laser Sawing Equipment				*8.0%*		*91.6%*		*0.4%*	*0.4*	*14%*
Backside Grinding Equipment	*0.2%*	*1.2%*	*0.3%*			*98.1%*	*0.3%*		*0.54*	*24%*
Mounting Equipment	*1.2%*		*4.3%*		*1.4%*	*89.4%*	*2.9%*	*0.6%*	*0.1*	*11%*
Assembly Inspection Equip-ment	***52.2%***	***3.4%***	***7.0%***	***25.1%***	***10.4%***	***0.3%***	***0.8%***	***0.8%***	***0.2***	***-4%***
Bonding Equipment	***2.8%***	***26.1%***	***0.3%***	***41.1%***	***5.7%***	***16.6%***	***6.6%***	***0.9%***	***1.8***	***3%***
Die Attaching Equipment	*0.2%*	*43.9%*	*0.1%*	*23.0%*	*8.0%*	*17.8%*	*6.3%*	*0.7%*	*0.9*	*4%*
Wire Bonding Equipment	*1.1%*	*7.1%*	*-*	*81.3%*		*8.8%*	*0.4%*	*1.4%*	*0.6*	*3%*
Other Interconnect Tools	*18.5%*	*2.6%*	*1.6%*	*7.3%*	*11.5%*	*32.9%*	*25.3%*	*0.1%*	*0.2*	*-2%*
Packaging Equipment	***2.4%***	***18.7%***	***1.6%***	***4.6%***	***17.0%***	***51.4%***	***3.1%***	***1.2%***	***0.6***	***4%***
Molding & Sealing Systems	*2.9%*	*13.3%*	*0.9%*	*4.2%*	*0.2%*	*75.3%*	*2.9%*	*0.3%*	*0.4*	*5%*
Lead Finishing & Marking Sys-tems	*1.9%*	*34.3%*	*2.8%*	*5.9%*	*39.5%*	*9.7%*	*4.1%*	*1.7%*	*0.2*	*2%*
Singulation Systems		*8.2%*	*2.1%*	*1.5%*	*63.7%*	*24.5%*			*0.05*	*-1%*
Transfer Tools	*1.7%*		*5.1%*	*10.3%*	*45.3%*		*6.8%*	*30.8%**	*0.01*	*-0.2%*
Integrated Assembly Systems		***2.6%***		***97.4%***					***0.02***	***-9%***

Source: JRC elaboration on TechInsight sales data, downloaded April 2024. EU stands for EU27

Main takeaways

- The uptake in equipment sales induced by the chip shortage during COVID times seems over. Since 2021 global sales stabilized around $110bn per year and they are expected to increase to $180bn by 2029, with a CAGR 2024-29 of 9.7%
- Altogether, the main global chip manufacturers, Taiwan, South Korea and China, are marginal in equipment production, and depend totally on other jurisdictions (US, Japan, EU). However, China in the last five years displayed the highest compound annual growth rate in the segment of wafer fabrication equipment (49%). This is mainly due to a growing presence of China in chemical mechanical planarization, in deposition and related tools, and in etching&cleaning tools. In spite of this growth China does not seem to be able to compete in the equipment segment.
- Wafer fabrication equipment for chip production (WFE) represents 90% of global equipment sales in 2023 ($98.6bn), up from 83% in 2017. The remaining 10% of global sales ($11bn in 2023) is shared between testing and assembling&packaging equipment.
    - WFE is a business dominated by the US, the EU and Japan depending on the technological sub-segment considered.
    - The EU leads in Microlithography and Mask Making equipment , which accounted for 30% of the global sales of WFE in 2023 ($29.6bn up from $14.5bn in 2019).
- The world market for the production of equipment to test chips, that reached $6.8bn in 2023, is dominated by Japan with over 50% of world market share in that year.
    - The EU is almost absent from the global stage in this subsegment.
    - China has a modest but growing global market share in testers, 4.4% in 2023, up from 1.4% in 2017. Specialised in traditional testers, Chinese presence is however increasing in burn-in and SOC test systems.
- Assembly and packaging equipment sales, $4.2bn in 2023, are mainly originated in Japan (48%) and Singapore (21%), with the EU holding the third position (14.5%).
    - EU is present in the segment of bonders and packaging equipment but is absent in dicing, where Japan is the absolute monopolist.

Chapter 3 – The EU chips' market: trade dependencies and end using markets.

Relying on evidence from SCAN alongside data obtained from World Semiconductor Trade Statistics (WSTS), this chapter delves into the final products of the chain, given their shipments to European end-using sectors.[53] Products are here categorized according to the WSTS classification.

WSTS collects information from semiconductor manufacturing companies on shipments of different chip types to end-using sectors around the globe providing yearly and monthly figures on shipments, as well as forecasts for the next three years. Being administered by the Semiconductor Industry Association this data source is one of the most favoured sources of information employed by players in the industry. Since information on shipments is directly collected from manufacturers, this data provides valuable information on the last downstream step in the chips' supply chain. Indeed, while trade statistics are aggregated for trade codes defined according to international customs standards, with no information on the final destination or the sectors utilizing the traded products, WSTS data is available according to the product categories used by companies operating in the industry.

Section 3.1 offers an analysis of their trade dependencies, providing insights into the main foreign vulnerabilities in this market and the primary sourcing partners. Section 3.2 delves into the chips' shipments to end-using sectors. This section provides information on the EU market size of the main chip categories and their distribution in terms of sales across end-using sectors.

3.1 EU trade dependencies in the final product segment

In order to facilitate the comparison between the SCAN product-level results, which are based on the EU custom classification, with industry data from WSTS, CN codes related to the final products' segment have been mapped into WSTS categories (see Appendix 4 Table A4.1).[54] Indeed, the terminology used in trade and custom classifications, such as the Combined Nomenclature, in some cases may not reflect the terminology used by the industry. This could create challenges when interpreting and comparing trade data with other sources.

The WSTS classification is highly detailed and comprises products that can be grouped into eight categories (DOSA - discrete, optoelectronics, sensors, actuators; analog; micro; logic; DRAM; SRAM; flash memory; and other memory types) and four macro segments. **Logic chips' segment** encompasses (micro) processors and (micro) controllers. **Memory chips** include SDRAM, DRAM, flash memory chips, and the **analog segment** encompasses amplifiers. Furthermore, **DOSA** (which stands from discretes, optoelectronics, sensors, and actuators) includes discrete chips such as diodes, transistors, and

53 Refer to https://www.wsts.org/61/MARKET-STATISTICS

54 In the case of semiconductors, the World Semiconductor Trade Statistics (WSTS) product classification represents a reference taxonomy used by the industry associations to collect and analyze survey data from affiliate companies.

thyristors, as well as optoelectronics, sensors, and actuators.[55] In the case of multicomponent or combined integrated circuits, WSTS classification takes into account the main function of the component. The classification is determined based on whether at least 50% of the total die area of the integrated circuits is dedicated to a particular type of chip, such as analog or logic.

The JRC has developed a mapping from the CN eight-digit codes of the final products into the eight WSTS categories. Such a mapping may still present potential discrepancies, because the CN trade classification does not offer the high level of precision of the WSTS classification to properly identify multicomponent or combined integrated circuits. The "Other chips" category groups then together all CN product codes that cannot be assigned to WSTS classes. Nonetheless, this mapping is essential to interpret evidence from trade data in the context of the classification provided by WSTS and the information made available by the industry.

The results of the structural indicators are reported in Table 3.1. In 2023, EU imports of ICs related to logic chips (including micro) and memory chips (such as DRAM, SRAM, and flash memory chips) are mainly sourced from Taiwan. The potential for substitutability with domestic capacity is particularly low for the memory chips classes, where extra-EU imports, on average, more than triple exports, with exposure indexes well above 0.8. This implies that more than 80% of EU domestic supply comes from extra-EU imports.

Table 3.1: SCAN structural indicators for final products aggregated at WSTS class – 2023

		Concentration		**Substitutability**	
WSTS Class	**Top Source**	**Top Source Import Share**	**HHI Index**	**Import/Export**	**Exposure Index**
DOSA	CN	36%	0.19	1.30	0.48
Analog	MY	20%	0.13	1.39	0.54
Logic (incl. micro)	TW	22%	0.13	1.76	0.70
DRAM	TW	43%	0.24	4.27	0.85
SRAM	TW	43%	0.27	5.84	1.00
Flash Memory Chips	TW	42%	0.23	3.38	0.86
Rest of Memories	TW	30%	0.19	1.42	0.45
Other	TW	28%	0.15	1.98	0.50

Source: JRC elaboration on EC customs data and PRODCOM (extraction 02.09.2024)

55 Definitions are in the appendix to chapter 3. Note that the logic chips segment mapped to the CN classification include both WSTS categories of "logic" and "micro" ICs, due to the higher level of aggregation of CN codes.

On the other hand, the classes related to DOSA (discretes, optoelectronics, sensors, and actuators) products and analog chips have more substitutability potential with EU domestic production and are mainly sourced from two geographies: China and Malaysia,[56] respectively.

Delving into the dependencies of products, Table 3.2 reports the SCAN dashboard for all final products**.** Five final products are found in risk of import disruption and have high levels of import concentration and low potential of substitutability with domestic production, with indexes above the thresholds in both dimensions for the year 2023. Three of these products are classified in the DOSA[57]. They show high levels of import concentration from China but also have a discrete potential of substitutability with domestic production (import/export index ranging between 1.3 – 1.6, and exposure index between 0.3 – 0.6). Two products belong to the memory chips segment[58] and are mostly sourced from Taiwan. Domestic capacity for these products is very scarce, with import/export indexes ranging between 3.3 to 5.6 and exposure indexes between 0.85 - 0.95.

56 Malaysia has emerged as an import hub for back-end semiconductor manufacturing (ATP, Assembly, Test, Packaging) and is also home to several subsidiaries of EU semiconductor companies, including Infineon, NXP, and STMicroelectronics. For instance, Infineon recently inaugurated a new SiC power semiconductor fab in Malaysia, see https://www.infineon.com/cms/en/about-infineon/press/press-releases/2024/INFXX202408-133.html

57 CN 85411000 – Diodes, excl. photosensitive or light emitting diodes "LED", CN 85412100 - Transistors with a dissipation rate < 1 W (excl. photosensitive transistors), CN 85419000 - Parts of diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, light emitting diodes and mounted piezoelectric crystals, n.e.s.

58 CN 85423231 - Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits), CN 85423261 - Electronic integrated circuits as electrically erasable, programmable read-only memories "flash E^2PROMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)

Table 3.2: SCAN structural indicators for the CN8 products for final products – 2023

					Concentration		Substitutability		
CN8 code	**WSTS class**	**Total Import (*m EUR*)**	**Total Export (*m EUR*)**	**Top Source**	**Top Source Import Share**	**HHI Index**	**Import/Export**	**Exposure Index**	**S-Risk**
85412900	DOSA	2 776.64	2 314.50	CN	31%	0.19	1.20	0.38	
85411000	DOSA	1 295.47	823.07	CN	53%	0.32	1.57	0.63	*
85414100	DOSA	1 168.80	572.77	CN	38%	0.24	2.04	0.79	
85423911	DOSA	1 059.54	758.82	PH	28%	0.15	1.40	0.45	
85414900	DOSA	968.91	1 021.42	CN	31%	0.17	0.95	0.53	
85412100	DOSA	344.79	260.95	CN	57%	0.37	1.32	0.42	*
85419000	DOSA	222.84	144.05	CN	56%	0.35	1.55	0.31	*
85413000	DOSA	196.56	254.45	CN	60%	0.40	0.77	0.00	
85365003	DOSA	20.21	22.24	CN	50%	0.32	0.91	0.32	
90330010	DOSA	9.08	12.78	US	39%	0.21	0.71	0.00	
85423390	Analog	1 157.37	665.63	MY	20%	0.14	1.74	0.77	
85423310	Analog	40.74	24.98	MY	19%	0.14	1.63	0.75	
85415100	Analog	34.07	196.32	JP	17%	0.12	0.17	0.05	
85423190	Logic (incl. micro)	23 441.41	13 156.12	TW	21%	0.13	1.78	0.77	
85423111	Logic (incl. micro)	766.31	519.97	CN	34%	0.23	1.47	0.25	
85423119	Logic (incl. micro)	354.74	249.65	TW	35%	0.19	1.42	0.24	
85365005	Logic (incl. micro)	61.85	88.84	CN	55%	0.36	0.70	0.27	
85423290	DRAM	945.19	130.92	TW	42%	0.23	7.22	0.79	
85423239	DRAM	809.40	284.53	TW	44%	0.29	2.84	0.91	
85423231	DRAM	74.88	13.34	TW	56%	0.40	5.61	0.95	*
85423245	SRAM	164.05	28.08	TW	43%	0.27	5.84	1.00	
85423269	Flash Memory	211.42	58.93	TW	30%	0.19	3.59	0.87	
85423261	Flash Memory	205.84	64.39	TW	54%	0.33	3.20	0.85	*
85423275	Rest of Memory	179.58	154.66	TW	27%	0.20	1.16	0.68	
85423211	Rest of Memory	53.32	27.93	CN	38%	0.27	1.91	0.29	
85423219	Rest of Memory	52.26	19.95	TW	41%	0.25	2.62	0.32	
85423255	Rest of Memory	7.20	3.24	CN	33%	0.18	2.23	0.16	
85423990	Other	14 493.10	7 201.59	TW	29%	0.15	2.01	0.55	
85423919	Other	480.04	136.11	MY	19%	0.12	3.53	0.68	
85429000	Other	222.37	258.21	CN	22%	0.12	0.86	0.09	
85415900	Other	137.67	185.18	US	37%	0.21	0.74	0.16	

Source: JRC elaboration on EC customs data and PRODCOM (extraction 02.09.2024). Thresholds for concentration indexes are 50% for the share of the top source in extra-EU imports and 0.4 for the HHI index. Thresholds for substitutability indexes are equal to 1 for the ratio of extra-EU imports and extra-EU exports, and to 60% for the exposure index. indicates products in medium risk for which at least one concentration index and at least one substitutability index are above the respective thresholds, ** indicates products in high risk for which all structural indicators are above the thresholds. Please refer to Table A4.1 in Appendix 4 for a complete reference of CN8 product descriptions.*

3.2 Shipments to European end-using sectors

The section extends the analysis on end using sectors leveraging WSTS industry data to assess potential criticalities related to these final products. Specifically, it delves into an analytical exploration of the semiconductor market, focusing on the distribution and dynamics of shipments across different geographical areas, with a particular emphasis on Europe's standing within this ecosystem.[59]

The analysis starts with a quantitative investigation, to gauge the market size and assess the flow of semiconductor shipments to various end-using sectors across the globe.[60] Europe is confirmed to be a significant but not dominant player in this market, capturing 11 percent of total shipments. Europe's semiconductor intake is compared with that of market leaders—China and the Americas—and the contributions of Japan and the rest of Asia is explored.

The temporal scope of our analysis allows to track the trajectory of semiconductor shipments over the past few years, providing insights into the economic shifts and future trends anticipated through 2027. Europe's semiconductor market recovered from the Covid-19 crisis, with a forecasted increase in shipments that flags a robust growth trajectory for the coming three years.

This part of the report also navigates through the sectoral distribution of semiconductor utilization within Europe. By identifying disparities in semiconductor allocations across various industries, Europe's distinct market composition is uncovered. Shipments to this market are characterized by a higher intake in the automotive and industry sectors, and a comparatively lower consumption of chips, with respect to the rest of the World, for the manufacture of computer, consumer, and communication goods.

WSTS data on the eight categories of semiconductors mentioned above offers a granular view of the types of semiconductors that fuel Europe's end-using sectors.[61] This segmentation reveals notable variances in the demand for specific semiconductor types, such as logic chips, DRAM, and flash memories, when compared with Europe's global counterparts.

As the complexity of semiconductor shipments to Europe is unravelled, this analysis provides an overview of Europe's role in the global semiconductor landscape, the sectoral nuances within its

59 In this Section, Europe refers as the entire EMEA (Europe, the Middle East and Africa) area. This is the level of aggregation for which WSTS is available. The EU27, with more than 18 trillion USD accounts for over 51% of total EMEA's GDP in 2023, according to World Bank data.

60 End using sectors include: automotive, communication, computer, consumer, government, industrial. Details of the chips end-using items included in the different sectors is in Appendix 6.

61 Following the WSTS classification, these are the chips categories taken under analysis: i. dosa (i.e. discrete, optoelectronics, sensors, and actuators); ii. analog; iii. micro; iv. logic; v. dram; vi. sram; vii. flash memory; viii. rest of memory. A list of the components included in these eight categories, is included in Appendix 6.

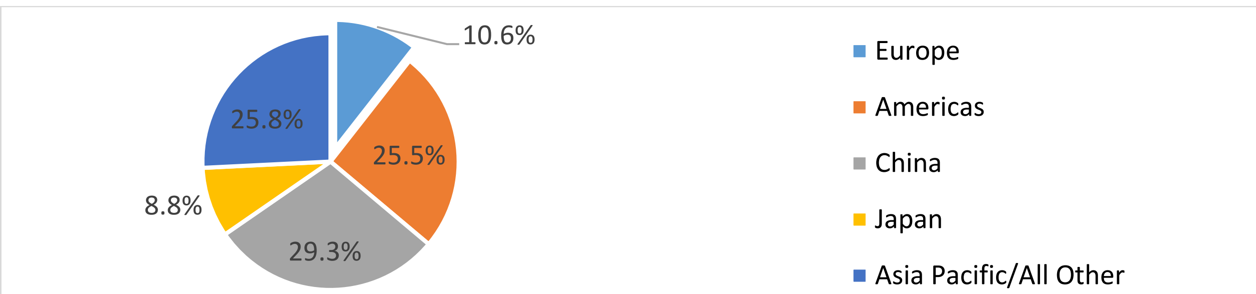
market, and the potential implications for the future economic and technological development of the European economy.

3.2.1 Shipments of semiconductors to Europe: an overview

As a first step, evidence on the size of the different markets given by the shipments of semiconductors to end-using sectors is provided. The different geographical areas under observation are: Europe, Americas, China, Japan, and Asia-Pacific.[62]

Focusing on data for 2023, Europe emerges as the fourth market for semiconductors, accounting for almost 11 percent of shipments (Figure 3.1). The semiconductor market is larger in China and the Americas, which account for 29 and 25 percent of shipments, respectively. Japan (with 9 percent) and the rest of Asia (with 26 percent) account together for almost a third of total shipments.

Figure 3.1: Total semiconductors shipments to different geographical areas



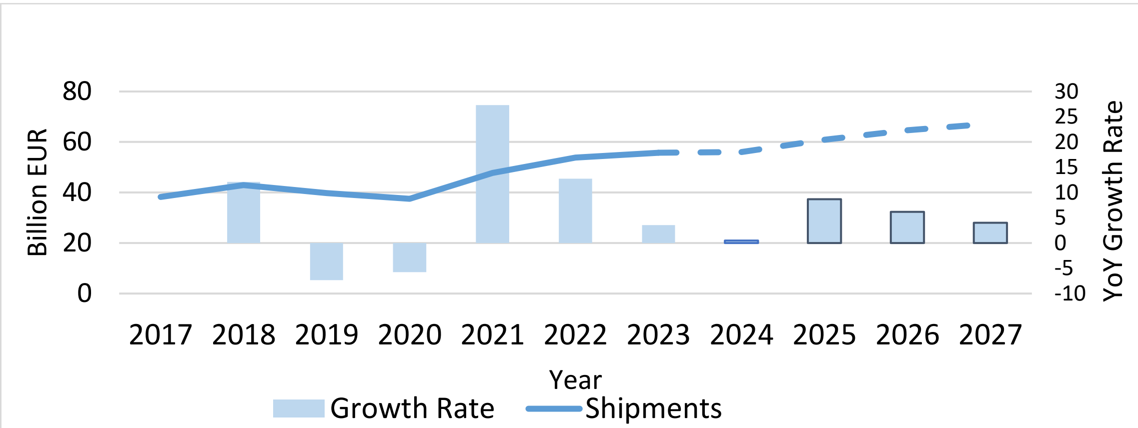
Source: JRC Elaboration on WSTS data for year 2023.

The analysis of the evolution over time of the amount of semiconductors shipped to Europe gives an overview on how the needs of the European economy in terms of semiconductors evolved over the last years and on their evolution in the near future. Shipments of semiconductors to Europe have grown steadily since 2020, reaching a total of $53 billion (circa EUR 50 billion) in 2022, while they have remained constant in year 2023 (Figure 3.2). In 2021, European end-using sectors received 27 percent more shipments relative to 2020. This jump has compensated reductions in shipments reported both in 2019 and in 2020, with a stronger reduction reported in 2020 due to the impact of the Covid-19 crisis on European end-users. WSTS forecasts for the period 2024-2027 an increase in shipments of semiconductors to Europe, reaching $67 billion in 2027. This would imply a 76 percent increase in

62 For a complete list of counties included in the different geographical areas, refer to the Appendix 6.

semiconductors' shipments to Europe over the decade 2017-2027. As further detailed in the coming section, this increase will be mostly fuelled by an increase in shipments to the automotive and the industry sectors.

Figure 3.2: EU Semiconductors Demand 2017 – 2027



Source: JRC Elaboration on WSTS data for years 2017-2027. Entries for the period 2024-2027 are forecasts made by WSTS.

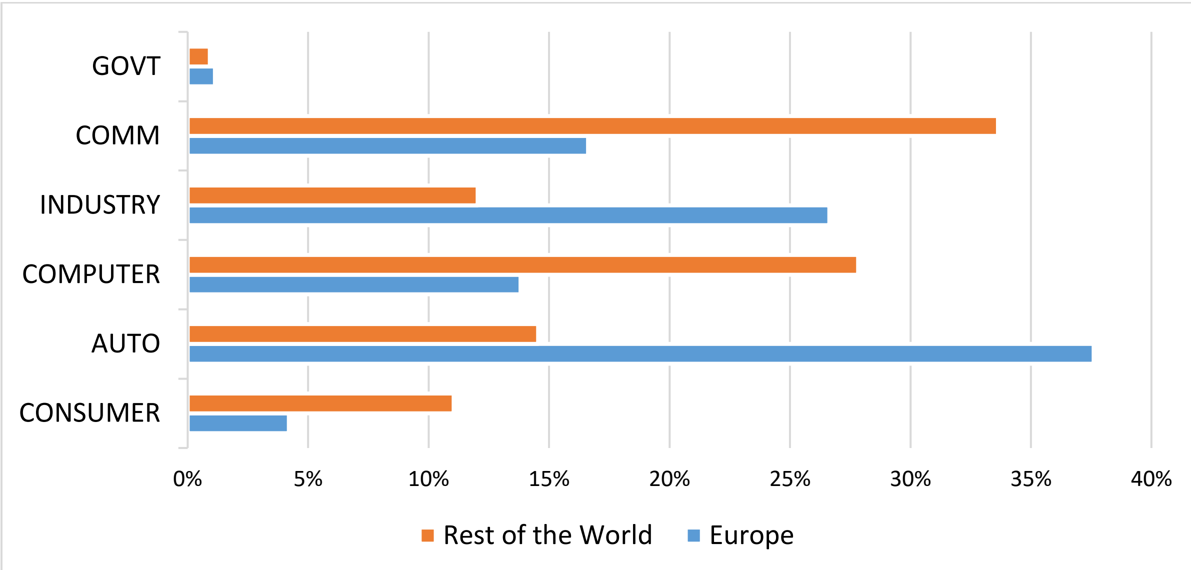
3.2.2 Sectoral decomposition of European demand of semiconductors

The size and the relative strengths of end-using sectors in the different geographies ultimately determine the amount of chips shipped to the different geographical areas. For example, areas in which the communication and the computer manufacturing sector account for a higher share of GDP or employment should supposedly receive a higher share of shipments for companies operating in these sectors.

In line with this pattern, the European automotive and industry sectors receive more semiconductors than the same sectors do in the Rest of the World.[63] The automotive sector alone receives more than 37% of semiconductors shipped to Europe. The industry sector is second in line, with 26% of shipments. On the contrary, less semiconductors are shipped to Europe for the manufacturing of computers, consumer goods, and communication products than to the rest of the world. European demand for semiconductors by governments (i.e. space and defence) is slightly higher than elsewhere, yet accounting for only 1% of total semiconductors shipped to Europe (Figure 3.3).

63 The automotive sector accounts for 7% of EU27 GDP in 2023. Refer to https://single-market-economy.ec.europa.eu/sectors/automotive-industry_en.

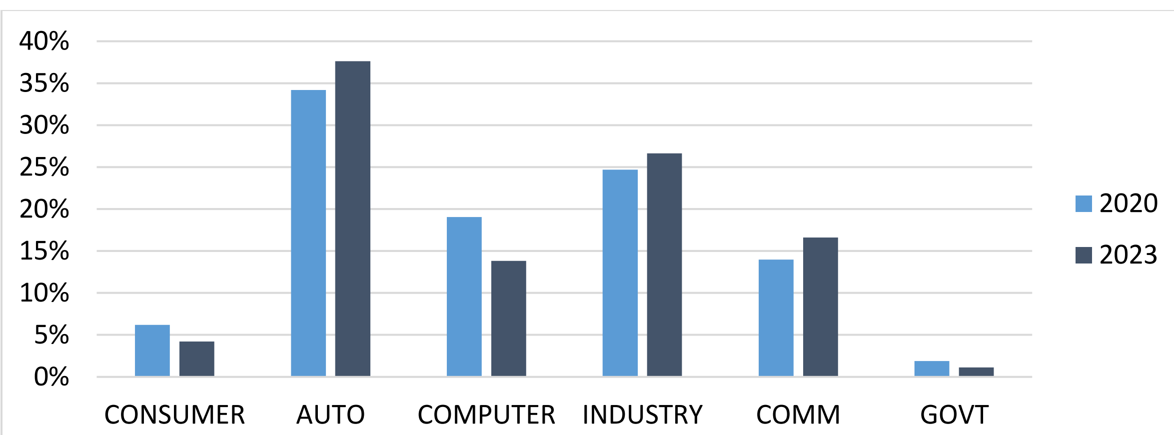
Figure 3.3: Semiconductors Demand by End Using Sectors. Europe - Rest of the World, relative shares



Source: JRC Elaboration on WSTS data for year 2023.

Comparing shipments of semiconductors to European end-using sectors in 2023 with the same number for year 2020, it is possible to notice that the automotive, industry, and communication increased their share in the European semiconductors' market, while consumer, communication, and government reported a reduction in their needs of semiconductors (Figure 3.4).

Figure 3.4: Semiconductors shipments to end-using sectors, Europe, 2020 Vs 2023, relative shares



Source: JRC Elaboration on WSTS data for year 2023 and 2020

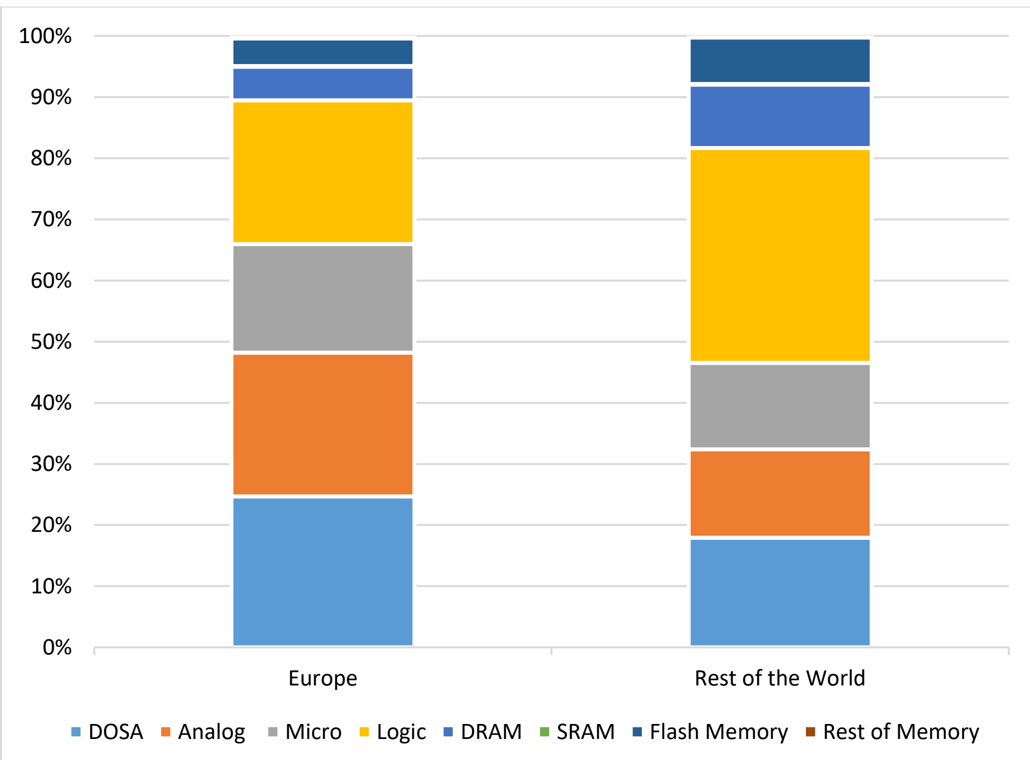
3.2.3 Demand by chips type, comparison across geographies

Total shipments of semiconductors are the result of shipments recorded in eight different categories of semiconductors: i. DOSA (i.e. discrete, optoelectronics, sensors, and actuators); ii. analog; iii. micro; iv. logic; v. dram; vi. sram; vii. flash memory; viii. rest of memory.

Shipments in these eight categories provide an interesting overview on the type of semiconductors needed by European end-using sectors. This segmentation of the market shows that European end-users receive from chips manufacturers less logic chips, DRAM memories, and flash memories than their counterparts in the rest of the world. Interestingly, data on EU27 imports discussed above shows high import dependencies for DRAM memories and flash memories below 512MB. These products are mostly sourced from Taiwan. EU27 domestic capacity for these products is scarce, with imports being a multiple of exports.

On the contrary, shipments to Europe of micro, DOSA and analog are higher than those recorded for the rest of World, with the exception of Japan, when focusing at DOSA (Figure 3.5; Table 3.3). As reported in the previous section, EU27 imports in the DOSA group report high structural dependencies in year 2023. These products show high levels of EU import concentration from China but seem to have a discrete potential of substitutability with domestic production.

Figure 3.5: Semiconductor shipments by type. Europe Vs Rest of the World, 2023



Source: JRC Elaboration on WSTS data.

Having a look at the same numbers for Chinese and American end-using sectors, it is important to observe that end-users in these two geographical areas receive more logic chips and DRAM memories than Europe and less DOSA/analog semiconductors. This is clearly determined by the higher specialization of this areas in the manufacturing of computers and communications products with respect to Europe. Communications and computer manufacturing are in fact the main users of logic chips and DRAM memories (Table 3.4). The European automotive and industry sector absorb most of discrete, analog, micro, SRAM, and rest of memory.

Table 3.3: Decomposition of semiconductors shipments by geography

2023	DOSA	Analog	Micro	Logic	DRAM	SRAM	Flash Memory	Rest of Memory
Europe	24.7%	23.5%	17.8%	23.5%	5.5%	0.1%	4.5%	0.4%
Americas	14.5%	11.7%	14.8%	37.1%	13.1%	0.1%	8.5%	0.2%
China	20.2%	16.6%	11.3%	32.0%	11.9%	0.1%	7.7%	0.2%
Japan	24.2%	16.7%	16.0%	30.1%	6.1%	0.2%	5.7%	1.0%
Asia Pacific/ All Other	16.7%	14.0%	15.9%	38.5%	7.4%	0.1%	7.2%	0.2%

Source: JRC Elaboration on WSTS data for year 2023.

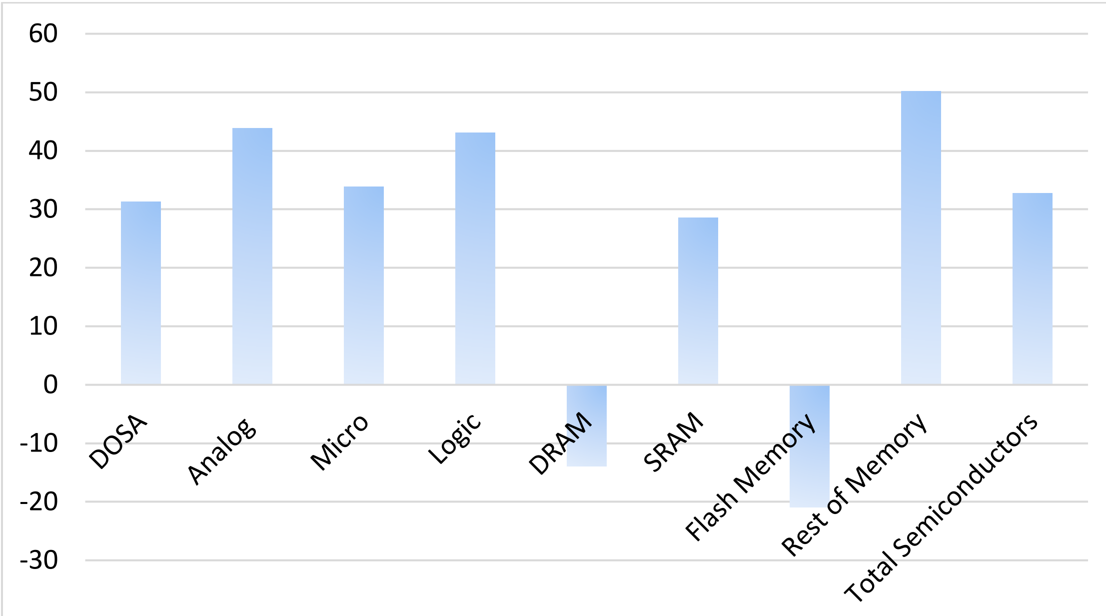
Table 3.4: Top 2 End-Using Sectors

2023	Top 2 End-Using Sectors
DOSA	Automotive, Industry
Analog	Automotive , Industry
Micro	Automotive , Industry
Logic	Communications, Computer
DRAM	Computer, Communications
SRAM	Industry, Automotive
Flash Memory	Automotive , Communications
Rest of Memory	Industry, Automotive

Source: JRC Elaboration on WSTS data for year 2023.

Between 2020 and 2023, shipments to Europe of semiconductors increased by more than 30%. Focusing on the different types of semiconductors it us worth highlighting that shipments of analog, logic, and rest of memory have increased by more than 40% in the same period, while shipments of DOSA and micro have grown by more than 30%, in line with the aggregate. On the contrary, shipments to Europe of DRAM and flash memories decreased by more than 10% during the period 2020-2023 (Figure 3.6).

Figure 3.6: Shipments of semiconductors to Europe, different types, growth rates 2020-2023



Source: JRC Elaboration on WSTS data.

Main takeaways

- EU27 imports of logic and memory chips are primarily sourced from Taiwan. Substitutability indicators for 2023 also suggest that the EU27 has limited capability to substitute with EU27 domestic production several categories of memory chips.
- According to SCAN indicators for year 2023, five final products are at risk of import disruption in the EU27, three of them are part of the DOSA (i.e. discrete, optoelectronics, sensors, and actuators) category, while two products belong to the memory segment.
- European end-using sectors receive 10.6% of worldwide shipments of semiconductors.
- The European semiconductor market amounted to EUR 50 billion in 2023. Shipments of semiconductors to Europe have grown since 2020 (with an average growth rate of 14%), and will keep growing in the coming three years.
- European end-using sectors receive more DOSA (i.e. discrete, optoelectronics, sensors, and actuators) and analog chips than their Chinese and American counterparts, which instead receive more logic chips and DRAM memories from manufacturers. This difference reflects the industrial structure of Europe. Indeed, Europe needs more semiconductors than the Rest of the World for the automotive and the industry sectors. Less semiconductors are instead needed for manufacturing computers, consumer goods, and communication products with respect to the Rest of the World.
- The amount of semiconductors shipped to the automotive and industry sectors has grown between 2020 and 2023 by 63% and 60%, while shipments of chips to produce consumer goods and computers have increased only by 0.85%. Automotive and industry demand most of DOSA, analog, micro, SRAM, and rest of memory shipped to Europe. Between 2020 and 2023, shipments to Europe of these items have increased by more than 40%.
- Logic chips are mostly shipped to European producers of communications and computer products.

Chapter 4. Deep dive into the EU Automotive sector, dependencies on chips and market evolution

Chapter 3 revealed that the automotive is one of the most important semiconductor end-using sectors in the European Union. As a matter of fact, it stands as a cornerstone of its economic strength and industrial prowess. The sector has a rich heritage of innovation and a robust manufacturing base, and it significantly contributes to the EU’s employment and GDP. In 2023, the European automotive sector supported a significant portion of the workforce, providing over 13 million jobs - both direct and indirect - which accounts for approximately 6% of the EU's total employment. Within the industry, more than 2.6 million people were employed in direct motor vehicle manufacturing, about 8.5% of the EU's manufacturing workforce. Furthermore, the sector's economic impact was substantial, with its turnover contributing over 7% to the EU's overall GDP.

Semiconductors are the backbone of modern automotive technology, integral to a myriad of applications ranging from engine control units to advanced driver-assistance systems (ADAS), infotainment, and beyond. There are three main trends that influence the demand for automotive semiconductors. Firstly, as the number of vehicles on the road continues to rise worldwide, the demand for these critical components is surging. Secondly, this increase is not just in terms of the sheer volume of cars but also in the complexity and capability of each vehicle. Modern cars are becoming more like computers on wheels, with the number of semiconductors per car escalating to support a growing array of features and functionalities that enhance safety, efficiency, and the overall driving experience. Thirdly, electric vehicles (EVs), which are gaining popularity due to environmental concerns, subsidies and advancements in technology, require a significantly higher number of semiconductors compared to their internal combustion counterparts. This is due to the complex power electronics involved in battery management, energy distribution, and motor control, as well as the additional sensors and controllers required for EV-specific features. As a result, the semiconductor content per vehicle is expected to continue its upward trajectory.

However, the automotive semiconductor industry is navigating through turbulent times. The global semiconductor shortage put immense pressure on supply chains, leading to production delays and increased competition for these essential components. Additionally, socio-demographic changes, such as urbanization and the rise of shared mobility, could influence vehicle ownership patterns and, consequently, the demand for automotive semiconductors. The industry is also contending with the accelerated shift towards electric vehicles, which, while driving semiconductor demand, also requires companies to adapt their product portfolios and strategies to cater to the unique needs of this burgeoning segment. Finally, the import of Chinese-made electric vehicles in Europe increased significantly in the beginning of 2024. Overcapacity in China’s auto manufacturing has become a significant point of contention between China and other major economies. Western countries broadly argue that Beijing’s industrial policy has unfairly benefited Chinese companies, leading to a potential surge of below-cost exports[64]. These challenges necessitate a strategic and flexible approach from semiconductor manufacturers to ensure they can meet the evolving demands of the automotive sector.

From 2020 to 2023, the automotive industry faced a severe semiconductor shortage triggered by the COVID-19 pandemic. The crisis began in March 2020 when the pandemic led to widespread shutdowns. Automakers were forced to halt production and cut orders from suppliers, while the electronics industry saw a boom in demand for various consumer products due to stay-at-home orders. Chipmakers, in response, prioritized the electronics sector, which was willing to pay more. As automotive manufacturers reduced their output in the early stages, they found themselves at the end of a long waiting list when vehicle demand unexpectedly rebounded in the summer of 2020.

Cars largely depend on older, less advanced "mainstream" chips that are cheaper and yield lower profit margins, making them less attractive for chipmakers to prioritize. These chips, while inexpensive, are critical for numerous vehicle functions, from door locks to advanced driver-assistance systems. Suppliers prefer manufacturing more advanced chips that offer higher returns and can be made with newer technology, allowing for more chips per silicon wafer.

The chip industry, which had shifted its focus to more profitable electronics clients, was slow to respond to the automotive sector's needs. The resulting shortage of semiconductors led to significant production delays and a slump in global auto production, which fell by 26% during the first nine months of 2021[65].

Ramani et al. investigated the origins, spread, and persistence of disruptions by studying the semiconductor chip shortage that affected the automotive industry after 2020's Covid-19 outbreak. They conducted an analysis to categorize and understand patterns within 209 newspaper articles, which led to the development of a thematic model (see Figure 4.1 below) that illustrates the complex factors contributing to the extended challenges faced by the auto industry.

Although the semiconductor supply situation began to improve by the end of 2022, some shortages continued into 2023. The prolonged shortfall highlighted the need for a more resilient semiconductor supply chain and has since spurred investments in semiconductor manufacturing capacity in Europe and other regions.

The future of the EU automotive semiconductor market is crucial to understanding the region's dependence on chips, its position in the global market, and the anticipated shifts in demand. The automotive sector's evolution towards more technologically advanced vehicles will likely drive an increased need for semiconductors, emphasizing the importance of strategic planning and investment to address the challenges and harness future opportunities in this critical industry.

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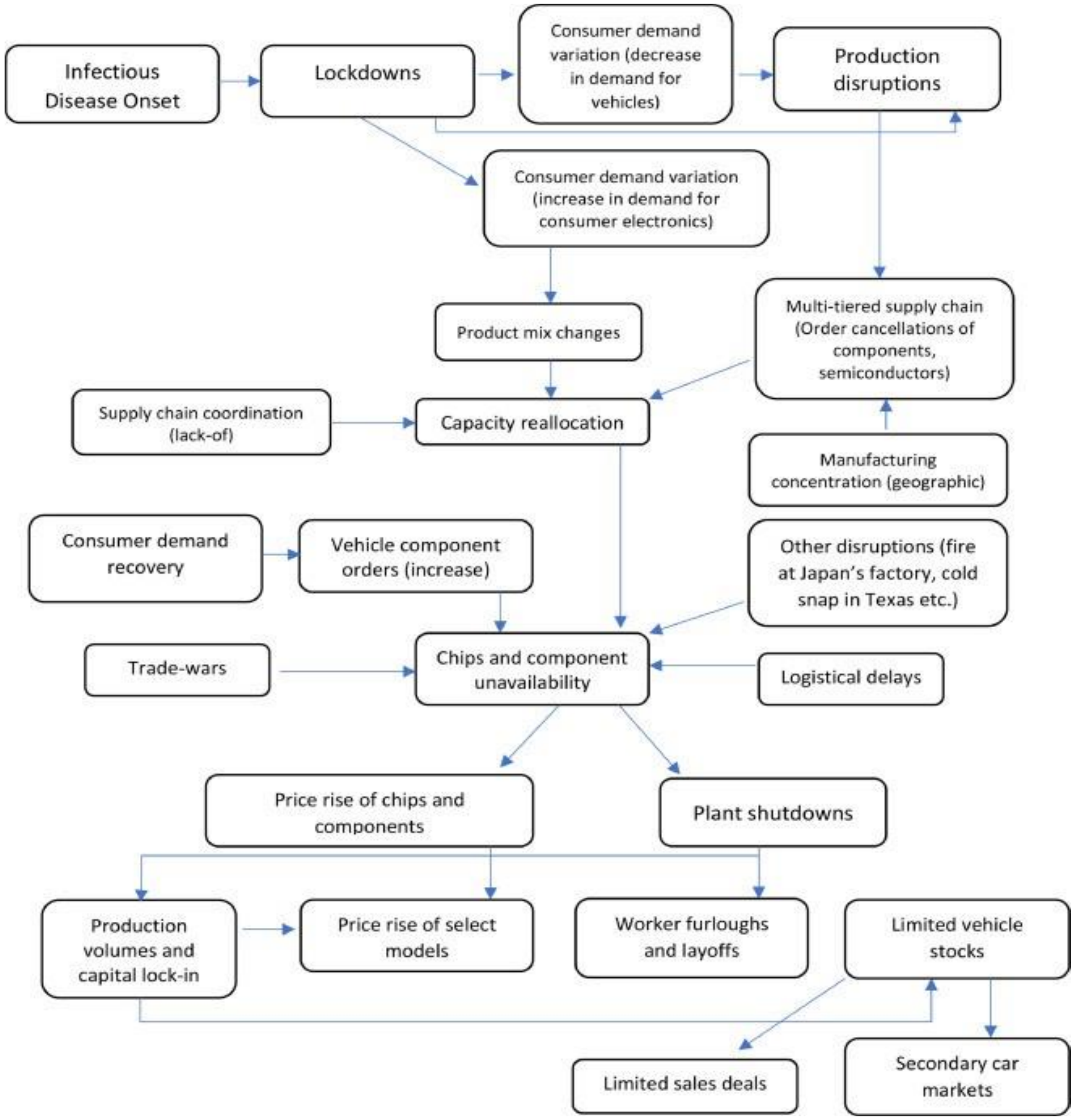
64 Financial Times: China-made EVs registered in Europe jump almost a quarter this year. June 4 2024. https://www.ft.com/content/1e8791b5-277a-4e03-ab72-b73218c4bd4f

65 How and When the Chip Shortage Will End, in 4 Charts. https://spectrum.ieee.org/chip-shortage.

The growth of automotive semiconductor sales in Europe depends on the number of cars being sold and manufactured in Europe, and on the growing number of semiconductors used in each car due to the increase in electronic features. Europe's strict safety and regulatory standards mean that automotive semiconductors must pass rigorous quality tests, be designed to function safely, be highly reliable, require a lot of time to design, and have long lifespans. The following sections will review the European car market and some predictions on its future evolution and the functionality and categories of semiconductors used in cars, their future evolutions and finally the supply chain of the automotive semiconductor industry.

Figure 4.1. A thematic model of the 2020-2023 systemic disruption to the auto industry, particularly in relation to shortage of semiconductor chips



Source: from Ramani, V., Ghosh, D., Sodhi, M.S (2022)[66]

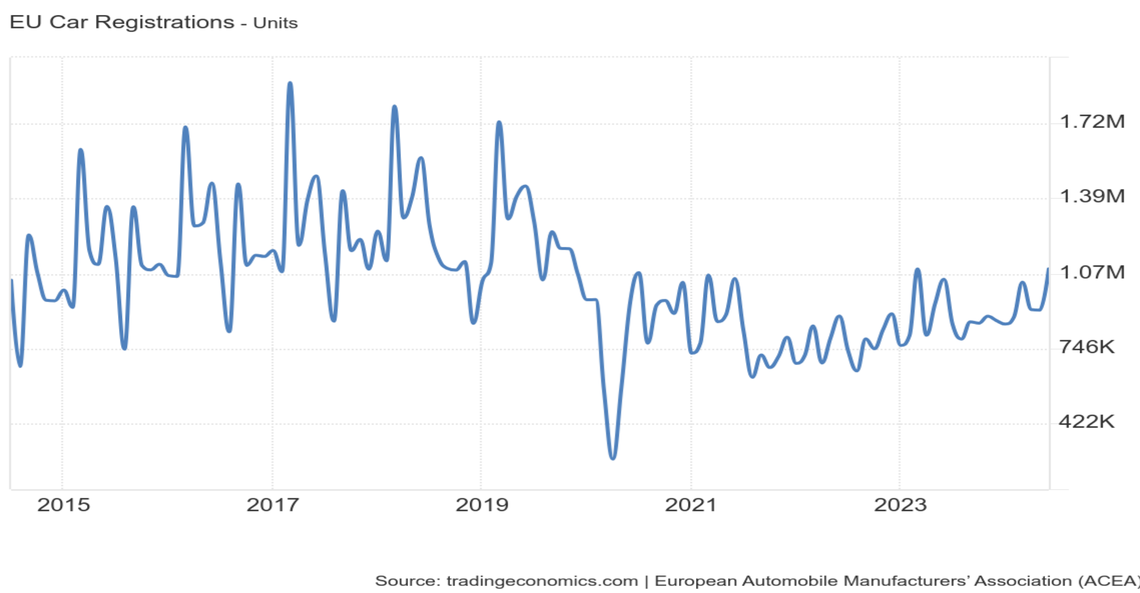
66 Ramani, V., Ghosh, D., Sodhi, M.S: Understanding systemic disruption from the Covid-19-induced semiconductor shortage for the auto industry, Omega, Vol. 113, December 2022: https://doi.org/10.1016/j.omega.2022.102720

4.1 European Union automotive sector overview

According to the European Automobile Manufacturers' Association (ACEA)[67], in 2023, the EU car market expanded by 13.9% compared to 2022, reaching 10.5 million units. Figure 4.2 illustrates the monthly passenger car sales in the European Union from 2014 to 2024.

Before the COVID-19 pandemic, the monthly passenger car registration data for the European Union exhibited a consistent pattern with noticeable peaks in March and June and trough in August each year. These peaks can be attributed to several factors. March often saw a surge in registrations due to the introduction of new models and the end of the financial year for many companies, prompting fleet renewals and purchases. June typically experienced another peak as consumers took advantage of mid-year sales promotions and the start of the summer season, which often coincided with increased travel and the need for new vehicles. The trough in August can be attributed to the summer holiday season, when many consumers and businesses are on vacation, leading to a slowdown in economic activities, including car purchases.

Figure 4.2: New Passenger Car Registrations in the EU (2014-2024)[68]



67 ACEA Economic and Market Report Global and EU auto industry: Full year 2023, March 2024. https://www.acea.auto/files/Economic_and_Market_Report-Full_year_2023.pdf

68 https://tradingeconomics.com/european-union/car-registrations

After the COVID-19 pandemic, several factors contributed to the sustained lower levels of new passenger car registrations in the European Union, preventing a full market recovery by 2024. In 2020, COVID lockdowns and restrictions led to the closure of car dealerships and manufacturing plants, causing a sharp decline in car registrations. Economic uncertainty and reduced consumer confidence further dampened demand. Persistent supply chain disruptions, particularly the global semiconductor shortage, significantly hampered vehicle production and availability. Economic uncertainty and cautious consumer spending further dampened demand, as many individuals and businesses remained wary of large expenditures amid lingering financial instability. Additionally, the pandemic accelerated shifts in consumer behaviour, with more people working remotely and relying less on personal vehicles, while the rise of alternative mobility solutions like car-sharing also reduced the urgency to purchase new cars. Stricter emission regulations and the gradual transition to electric vehicles, although environmentally beneficial, introduced higher costs and slowed the market's rebound. Furthermore, post-pandemic inflation and rising costs of raw materials and logistics increased vehicle prices, making new cars less accessible to a broader audience.

Table 4.1 describes the new car registrations in the EU by country. In 2023, most EU markets experienced strong growth, particularly the four largest: Italy (+18.9%), Spain (+16.7%), France (+16.1%), and Germany (+7.3%). Despite this growth, current registrations are 19% lower than the pre-pandemic volume of 13 million units recorded in 2019.

Table 4.1. Top Four – New EU Car Registrations 2022-2023

COUNTRY	2023	2022	% CHANGE 23/22
GERMANY	2 844 609	2 651 357	+7.3%
FRANCE	1 774 723	1 529 035	+16.1%
ITALY	1 565 331	1 316 926	+18.9%
SPAIN	949 359	813 376	+16.7%
EU TOTAL	10 547 716	9 263 509	+13.9%

Source: ACEA[69]

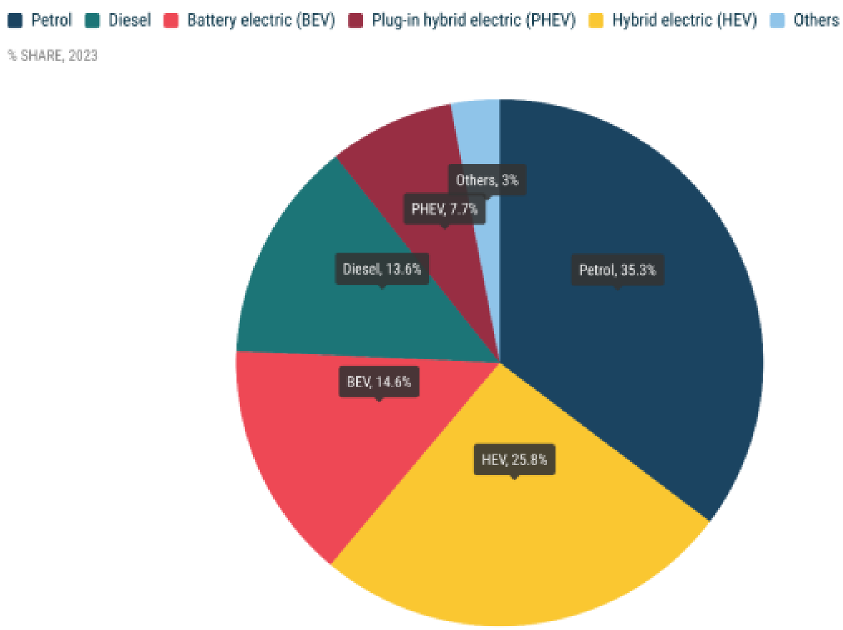
Figure 4.3 describes new car registrations by power source. Battery-electric vehicles emerged as the third most popular choice among buyers. In December 2023, their market share surged to 18.5%, contributing to a full-year share of 14.6%, surpassing diesel, which remained steady at 13.6%. The volume of battery-electric cars exceeded 1.5 million units, marking a substantial 37% increase compared to 2022. Petrol cars continued to dominate with a market share of 35.3%, while hybrid-electric vehicles secured the second spot with a 25.8% market share.

The spread of electric vehicles (EVs) has significantly contributed to the rising demand for semiconductors. EVs require a higher semiconductor content compared to traditional internal

69 https://www.acea.auto/files/Economic_and_Market_Report-Full_year_2023.pdf

combustion engine vehicles due to their reliance on electronic systems for battery management, power conversion, and electric drive control. This increased demand for semiconductors is driven by the need for efficient energy management, enhanced safety features, and advanced connectivity solutions in EVs. As the adoption of EVs continues to grow, the automotive semiconductor market is expected to expand further, highlighting the critical role of semiconductors in the future of the automotive industry.

Figure 4.3. New EU car registrations by power source in 2023



Source: ACEA[70]

4.1.1 Production

Table 4.2 reveals several interesting trends in car production among the top ten EU producers from 2022 to 2023. Germany continues to dominate the European automotive industry, with a significant 18.7% increase in production, reaching nearly 4 million units in 2023. Spain and Czechia also show notable growth, with increases of 7.4% and 14.9%, respectively, solidifying their positions as key players. On the other hand, Romania is the only country in the top ten to experience a decline, with a 1.6% decrease in production, possibly due to economic challenges or shifts in manufacturing priorities. Belgium stands out with an impressive 18.1% surge in production, indicating a strong recovery or

70 https://www.acea.auto/files/Economic_and_Market_Report-Full_year_2023.pdf

expansion in its automotive sector. Overall, the total car production in the European Union increased by 11.3%, reflecting robust growth across the region.

Table 4.2: Top Ten EU Car Producers 2022-2023 (units produced)

COUNTRY	2023	2022	% CHANGE 23/22
GERMANY	3 959 322	3 336 546	+18.7%
SPAIN	1 869 988	1 741 084	+7.4%
CZECHIA	1 395 211	1 214 746	+14.9%
SLOVAKIA	1 062 058	970 275	+9.5%
FRANCE	959 404	948 341	+1.2%
ITALY	542 218	484 345	+11.9%
HUNGARY	504 907	452 551	+11.6%
ROMANIA	501 337	509 465	-1.6%
BELGIUM	287 211	243 293	+18.1%
SWEDEN	276 070	251 446	+9.8%
EU TOTAL	**12 126 604**	**10 896 821**	**+11.3%**

Source: S&P Global Mobility[71]

Table 4.3 indicates that Volkswagen Group remained the largest car manufacturer by sales in Europe in 2023, followed by Stellantis and Renault. In addition to these figures, it's noteworthy that the Tesla Model Y was the best-selling car in Europe in 2023. This marks a significant milestone as it is the first time an electric vehicle has topped the sales charts for a full year in Europe. The Tesla Model Y sold 254 822 units, surpassing its closest competitor, the Dacia Sandero, which sold 235 893 units.

71 S&P Global Mobility: https://www.spglobal.com/mobility

Table 4.3: Top-Selling Car Brands in Europe (2022-2023) (units sold)

BRAND	SALES 2023	SALES 2022	% CHANGE 23/22
VOLKSWAGEN	1 357 139	1 209 665	+12.2%
TOYOTA	828 484	767 068	+8.0%
AUDI	733 176	614 900	+19.2%
BMW	728 991	647 464	+12.6%
MERCEDES	682 498	634 763	+7.5%
RENAULT	681 023	583 227	+16.8%
DACIA	557 253	475 748	+17.1%
KIA	572 297	542 852	+5.4%
HYUNDAI	534 170	518 103	+3.1%
PEUGEOT	639 848	619 517	+3.3%

Source: Best-Selling Cars[72]

4.1.2. Trade

In 2023, the European Union (EU) saw significant growth in both the import and export of cars, as reported by the European Automobile Manufacturers' Association (ACEA). This growth was largely attributed to enhanced production capabilities and the resolution of previous supply chain disruptions. Despite these changes, the overall trade surplus remained stable, underscoring the EU's robust position in the global automotive market.

Exports

The EU's car export value rose by 12.7%, reaching €162.8 billion. The export volume also saw a 12.4% increase, totalling 4.73 million units. The primary destinations for EU car exports were the United States, the United Kingdom, and Japan. The United States emerged as the top destination in terms of value, with exports amounting to nearly €40.3 billion. This indicates a strong preference for EU-made cars in the US market. Meanwhile, the United Kingdom led in terms of volume, reflecting a high

72 Best-Selling Cars: https://www.best-selling-cars.com/europe/2023-full-year-europe-best-selling-car-manufacturers-and-brands/

demand for EU cars. However, exports to China experienced a notable decline, with a decrease of over 20% in value and around 14.4% in volume. The decline in EU car exports to China in 2023 can be attributed to several factors. China's economic growth slowed down, which impacted consumer spending and demand for imported cars. Additionally, changes in trade policies and tariffs between the EU and China may have affected the competitiveness of EU-made cars in the Chinese market. The rise of Chinese automotive brands, particularly in the electric vehicle sector, provided strong local competition, with Chinese consumers increasingly favouring domestic brands due to more competitive pricing. Geopolitical tensions between China and Western countries, including the EU, also influenced trade dynamics and consumer preferences. Despite overall improvements in supply chain issues, specific disruptions or logistical challenges could still have impacted the timely delivery and availability of EU cars in China. These combined factors created a challenging environment for EU car exports to China, leading to the observed decline.

Imports

The import value of cars into the EU surged by 34.6%, reaching €72.2 billion, with import volumes increasing by 23.7% to 3.35 million units. China remained the leading source of car imports (12 812 million euro in 2023), with a 37.1% increase in value and a 39.6% increase in volume, capturing a significant share of the EU market. Other major contributors to the EU's car imports included the United Kingdom, Japan, South Korea, and the United States, all of which saw impressive double-digit growth rates. This surge in imports reflects the EU's diverse automotive market and its reliance on a variety of international sources to meet consumer demand.

4.1.3. Future Trends

There are significant risks facing the European car market, both in terms of the number of cars sold and the share that will be European made. Looking ahead, the EU automotive market is expected to continue its growth trajectory, albeit at a slower pace. According to the newest data from the first half of 2024, new passenger vehicle registrations in Europe (European Union, EFTA, and UK) increased by 4.4% during the first half of 2024 to 6 879 438 cars. The total European new car market still remained 18% smaller than in the first semester of 2019.

The demand for battery-electric vehicles (BEVs) was projected to rise significantly, however, according to the newest data from the first half of 2024, the sales of battery-electric vehicles in Europe increased only by a moderate 1.3% to 954 094 electric cars — around 15 000 more than during the first half of 2023 and a market share of only 12.5% compared to 12.9% in January to June 2023. Table 4.4 shows that Germany, despite being the largest market with 184 125 battery electric vehicles (BEV) sold, experienced a significant decline of 16.4% compared to the same period in 2023. This decline is largely attributed to the abrupt removal of purchase subsidies in 2023, which significantly dampened market momentum.[73] Germany's coalition government, however, recently has agreed to a proposal for tax reductions to promote the use of electric cars designed to help speed up the green transition. According to the proposal, companies will be able to deduct up to 40% of the cost of new electric and zero-emission vehicles from their taxes in the purchase year, decreasing to 6% over time. Additionally, company cars valued at up to 95 000 euros, increased from 75 000 euros, will receive tax benefits.[74] The Tesla Model Y, which was the best-selling model in Europe in 2023, was the worst-performing top model in Europe during the first half of 2024. Tesla Model Y sales were down 26%, or around 35 000 cars, to drop from first place to 8th. The Tesla Model Y remained Europe's best-selling battery-electric car during the first half of 2024.

Table 4.4. Top ten EU countries by BEV sales in the first half of 2024

COUNTRY	BEV 1-6/2024	BEV 1-6/2023	% CHANGE
GERMANY	184 125	220 244	-16.4
FRANCE	158 402	137 919	14.9
BELGIUM	64 404	43 578	47.8
NETHERLANDS	60 338	57 940	4.1
SWEDEN	41 998	52 445	-19.9
DENMARK	38 961	26 152	49.0
ITALY	34 932	32 660	7.0
SPAIN	25 141	23 892	5.2
AUSTRIA	22 178	23 372	-5.1
PORTUGAL	19 214	17 074	12.5
EU TOTAL	**712 637**	**703 392**	**1.3**

Source: Best-Selling Cars[75]

In June 2024, the European Commission concluded that China's battery electric vehicle (BEV) value chain benefits from unfair subsidies, posing a threat to EU BEV producers. Consequently, the EU imposed higher tariffs on Chinese electric vehicles, with new rates ranging from 17.4% to 37.6%, in addition to the existing 10% duty. These measures aim to level the playing field, encourage local production, and protect the European automotive sector and jobs.[76] However, this decision has sparked

73 https://www.transportenvironment.org/articles/germany-held-back-eu-electric-car-market-in-first-half-of-2024-t-e-analysis

74 https://www.reuters.com/business/autos-transportation/german-cabinet-agrees-proposals-tax-relief-evs-source-says-2024-09-04/

75 https://www.best-selling-cars.com/europe/2024-half-year-europe-car-and-bev-sales-by-country-eu-uk-efta/

76 https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_24_3231/IP_24_3231_EN.pdf

tensions, with China filing a complaint with the World Trade Organization, arguing that the EU's actions are protectionist and lack a factual and legal basis.[77]

According to some analysts[78], the imposition of duties in the 15-30% range, however, is unlikely to slow significantly the market share gains of Chinese automakers in Europe. Chinese manufacturers enjoy substantial cost advantages, allowing them to maintain comfortable profit margins even with the added tariffs. According to these analysts, to deter effectively Chinese EV imports, much higher duties, potentially in the 40-50% range, would be necessary.

In conclusion, while the European car market shows signs of recovery and growth, it faces significant challenges, including fluctuating sales of battery-electric vehicles and geopolitical tensions affecting trade policies. The market's future will depend on how these risks are managed and the ability of European manufacturers to adapt to changing consumer preferences and regulatory landscapes. The imposition of higher tariffs on Chinese electric vehicles is expected to have a significant impact on the market dynamics, potentially leading to increased prices for consumers. European manufacturers may need to accelerate their innovation and production capabilities to remain competitive.

77 China files WTO complaint about EU's punitive EV tariffs - Electrive: https://www.electrive.com/2024/08/12/china-files-wto-complaint-about-eus-punitive-ev-tariffs/

78 G. Sebastian, N. Barkin and A. Kratz: "Ain't No Duty High Enough," https://rhg.com/research/aint-no-duty-high-enough/

4.2 Semiconductors in the automotive sector: current state and projected future of the market

The automotive industry is undergoing a significant transformation, driven by advancements in semiconductor technology, which has led to the development of smart vehicles. Semiconductors are the backbone of modern automotive electronics, enabling a wide range of functionalities from basic operations to advanced driver assistance systems (ADAS) and autonomous driving. On average, non-electric vehicles contain between 1000 to 1500 semiconductor chips.[79] Electric vehicles typically contain upwards of 3000 semiconductor chips, more than double the number found in non-electric vehicles[80]. This increase is due to the additional systems required for battery management, electric motor control, and charging infrastructure. Modern vehicles rely heavily on semiconductors for various functions,[81,82] such as Engine and Power Management for non-electric vehicles or battery and thermal management for electric vehicles (refer to Appendix 7 for additional information on the different functionalities of vehicles).

These tiny components are used for the efficient, safe, and reliable performance of vehicles. The main categories of semiconductors in automotive applications include discrete semiconductors, optoelectronics, sensors and actuators, logic semiconductors, memory, analog ICs, and microcontrollers/microprocessors (refer to Appendix 8 for a detailed description of the use of different classes of chips in the automotive sector). Each category plays a specific role in ensuring the optimal functioning of various vehicle systems. As the industry moves towards electric vehicles (EVs) and self-driving cars, the demand for sophisticated semiconductors is expected to grow exponentially.

The European automotive semiconductor market was valued at EUR 13 722.9 million in 2023 and is projected to grow to EUR 17 377 million by 2026, registering a compound annual growth rate (CAGR) of 8.19% during the forecast period[83]. This growth reflects the increasing complexity and electronic content of modern vehicles, as well as the push towards electrification and autonomous driving technologies.

Key drivers include the increasing vehicle production and adoption of EVs, as well as the growing demand for advanced safety and comfort systems augmented by government regulations. These factors are propelling the market forward, as semiconductors play a critical role in enhancing vehicle performance, efficiency, and safety features. However, the market faces a significant restraint in the form of increasing costs associated with the integration of advanced features. Despite this challenge,

[79] https://polarsemi.com/blog/blog-semiconductor-chips-in-a-car/

[80] https://www.repairerdrivennews.com/2022/11/22/increasing-number-of-chips-in-evs-what-that-means-for-cybersecurity-repairs/

[81] https://www.appventurez.com/blog/semiconductor-in-automobile-industry

[82] https://www.monolithicpower.com/en/learning/mpscholar/automotive-electronics/introduction/evolution-of-electronics-in-automotive-systems

[83] https://www.mordorintelligence.com/industry-reports/europe-automotive-semiconductor-market

the market is poised for growth, driven by technological advancements and the rising popularity of EVs and autonomous vehicles.

4.2.1. Market Segmentation by Vehicle Type

Table 4.5 presents sales data on the Europe Automotive Semiconductor Market, measured in EUR Million, segmented by vehicle type for the years 2022 to 2026. The base year is 2023, and the forecast period spans from 2024 to 2026. The market is segmented by vehicle type, including passenger vehicles, light commercial vehicles, and heavy commercial vehicles. Passenger vehicles constitute the largest segment, with a revenue share of 74.84% in 2023, and are expected to reach EUR 12 811.5 million by 2026. Heavy commercial vehicles, while a smaller segment, are the fastest growing, with a CAGR of 10.9% over the forecast period.

Table 4.5. European Automotive Semiconductor Market, Sales in EUR Million, by Vehicle Type, Base Year: 2023, Forecast Period: 2024-2026

VEHICLE TYPE	2022	2023	2024	2025	2026	CAGR 23-26
PASSENGER VEHICLE	9 814.5	10 270.7	11 012.2	11 854.9	12 811.5	7.65%
LIGHT COMMERCIAL VEHICLE	2 428.2	2 581.9	2 812.8	3 076.8	3 378.5	9.38%
HEAVY COMMERCIAL VEHICLE	805.0	870.2	962.5	1 067.4	1 187.0	10.90%
TOTAL	***13 047.7***	***13 722.9***	***14 787.6***	***15 999.0***	***17 377.0***	***8.19%***

Source: Mordor Intelligence: European Automotive Semiconductor Market

In the **Passenger Vehicle** segment, the market size is projected to grow from EUR 9 814.5 million in 2022 to EUR 12 811.5 million in 2026, with a Compound Annual Growth Rate (CAGR) of 7.65%. This indicates a steady increase in demand for semiconductors in passenger vehicles, driven by advancements in vehicle technology and the rising adoption of electric and autonomous vehicles.

For **Light Commercial Vehicles**, the market is expected to increase from EUR 2 428.2 million in 2022 to EUR 3 378.5 million in 2026, achieving a CAGR of 9.38%. This growth reflects the expanding use of semiconductors in light commercial vehicles, which are becoming increasingly sophisticated with enhanced safety features and connectivity.

The **Heavy Commercial Vehicle** segment shows the highest growth rate, with the market forecasted to rise from EUR 805.0 million in 2022 to EUR 1 187 million in 2026, resulting in a CAGR of 10.9%. This significant growth is attributed to the increasing integration of advanced semiconductor technologies in heavy commercial vehicles to improve efficiency, safety, and performance.

This comprehensive growth across all vehicle types highlights the increasing importance of semiconductors in the automotive industry, driven by technological advancements and the shift towards more connected and autonomous vehicles.

4.2.2. Market Segmentation by Functionality

By application, the safety segment held the largest share in 2023, accounting for 25.65% of the market revenue. It is expected to reach EUR 4 564.8 million by 2026, growing at a CAGR of 9.05%. Power electronics was identified as the fastest-growing segment, with a CAGR of 10.1%.

Table 4.6. European Automotive Semiconductor Market, Sales in EUR Million, by Application, Base Year: 2023, Forecast Period: 2024-2026

Application	***2022***	***2023***	***2024***	***2025***	***2026***	***CAGR 23-26***
Chassis	1 629.9	1 688.6	1 792.3	1 910.0	2 043.4	6.56%
Power Electronics	1 300.6	1 392.5	1 527.5	1 682.4	1 860.2	10.1%
Safety	3 320.0	3 519.8	3 823.2	4 169.5	4 564.8	9.05%
Body Electronics	2 696.9	2 835.0	3 053.4	3 301.9	3 584.5	8.13%
Comfort/Entertainment	1 961.9	2 055.1	2 205.7	2 376.9	2 571.2	7.75%
Other Applications	2 138.4	2 231.9	2 385.4	2 558.3	2 752.7	7.24%
Total	***13 047.7***	***13 722.9***	***14 787.6***	***15 999.0***	***17 377.0***	***8.19%***

Source: Mordor Intelligence: European Automotive Semiconductor Market

Table 4.6 presents sales data for the European automotive semiconductor market, segmented by application, from 2022 to 2026. This data highlights the market's growth trajectory in various application areas, reflecting the increasing demand for semiconductors in the automotive industry.

Chassis: The chassis segment shows a steady increase from EUR 1629.9 million in 2022 to EUR 2043.4 million in 2026. This growth indicates a consistent demand for semiconductor components in vehicle chassis systems, driven by advancements in vehicle dynamics and safety features.

Power Electronics: Starting at EUR 1 300.6 million in 2022, the power electronics segment is projected to grow significantly, reaching EUR 1 860.2 million by 2026. This substantial growth can be attributed to the rising adoption of electric vehicles (EVs) and the need for efficient power management systems.

Safety: The safety segment, which includes systems like advanced driver-assistance systems (ADAS) and other safety-related technologies, shows a robust growth from EUR 3 320.0 million in 2022 to EUR 4 564.8 million in 2026. This trend underscores the increasing emphasis on vehicle safety and regulatory requirements.

Body Electronics: This segment, encompassing various electronic systems within the vehicle body, grows from EUR 2 696.9 million in 2022 to EUR 3 584.5 million in 2026. The growth reflects the integration of more sophisticated electronic features in modern vehicles, enhancing comfort and functionality.

Comfort/Entertainment: Starting at EUR 1 961.9 million in 2022, the comfort and entertainment segment is expected to reach EUR 2 571.2 million by 2026. This growth is driven by consumer demand for enhanced in-car entertainment systems and comfort features.

Other Applications: This category, which includes various other semiconductor applications in vehicles, shows growth from EUR 2 138.4 million in 2022 to EUR 2 752.7 million in 2026. The diverse nature of this segment indicates a broadening scope of semiconductor usage in automotive applications.

Total Market: The overall market for automotive semiconductors in Europe is projected to grow from EUR 13 047.7 million in 2022 to EUR 17 377.0 million in 2026. This growth, averaging a compound annual growth rate (CAGR) of 8.19%, highlights the increasing reliance on semiconductor technology in the automotive sector, driven by trends such as electrification, automation, and enhanced connectivity.

4.2.3. Market Segmentation by Vehicle Type and Categories

The tables below provide a detailed breakdown of the European automotive semiconductor market by vehicle type—Passenger Vehicles, Light Commercial Vehicles, and Heavy Commercial Vehicles—up to the year 2026, including the Compound Annual Growth Rate (CAGR) for each type of semiconductors.

Table 4.7 indicates that the Sensors & Actuators in the passenger vehicles segment has the highest CAGR at 9.58%, indicating significant growth in this area. Sensors and actuators, crucial for vehicle safety and performance, are expanding rapidly, highlighting their growing importance in the industry. The discrete and optoelectronics segments are seeing consistent growth, reflecting the rising integration of advanced lighting and display systems in modern cars. The memory and logic segments are also on the rise, supporting the increasing need for data storage and processing power in vehicles. Overall, the total market value is set to grow significantly, underscoring the critical role of semiconductors in the future of passenger vehicles. This growth is not just about numbers; it is about the evolution of the automotive industry towards smarter, safer, and more efficient vehicles.

Table 4.7: Europe Automotive Semiconductor Market, Sales in EUR Million, by Passenger Vehicle, Base Year: 2023, Forecast Period: 2024-2026

Application	***2022***	***2023***	***2024***	***2025***	***2026***	***CAGR 23-26***
Discrete	721.4	740.6	778.9	822.6	872.1	5.60%
Optoelectronics	1 277.8	1 326.6	1 410.9	1 506.8	1 615.3	6.79%
Sensors & Actuators	2 045.3	2 179.0	2 378.3	2 606.4	2 867.4	9.58%
Logic	664.4	698.1	751.5	812.2	881.3	8.08%
Memory	1 401.5	1 481.3	1 604.2	1 744.2	1 903.8	8.72%
Analog IC	2 234.8	2 327.0	2 482.5	2 659.1	2 859.3	7.11%
Micro	1 469.2	1 518.3	1 605.9	1 703.6	1 812.3	6.08%
Total	*9 814.5*	*10 270.7*	*11 012.2*	*11 854.9*	*12 811.5*	*7.65%*

Source: Mordor Intelligence: European Automotive Semiconductor Market

The semiconductor market for light commercial vehicles also demonstrates robust growth. Table 4.8 shows that the total market value is rising from EUR 2,428.2 million in 2022 to EUR 3 378.5 million in 2026, achieving a CAGR of 9.38%. Sensors & Actuators again lead with a CAGR of 11.56%, highlighting the increasing importance of these components.

Table 4.8: Europe Automotive Semiconductor Market, Sales in EUR Million, by Light Commercial Vehicle, Base Year: 2023, Forecast Period: 2024-2026

Application	***2022***	***2023***	***2024***	***2025***	***2026***	***CAGR 23-26***
Discrete	171.2	177.5	188.5	201.0	215.2	6.64%
Optoelectronics	325.4	342.9	370.2	401.3	436.6	8.39%
Sensors & Actuators	514.8	558.3	620.4	692.2	775.3	11.56%
Logic	149.8	159.9	174.9	192.1	211.8	9.81%
Memory	342.6	368.0	404.9	447.3	496.1	10.47%
Analog IC	559.0	592.0	642.3	699.8	765.4	8.94%
Micro	365.4	383.4	411.6	443.0	478.1	7.64%
Total	***2 428.2***	***2 581.9***	***2 812.8***	***3 076.8***	***3 378.5***	**9.38%**

Source: Mordor Intelligence: European Automotive Semiconductor Market

Table 4.9 presents European Automotive Semiconductor Sales for Heavy Commercial Vehicle segment. This segment shows the highest overall growth rate, with the total market expanding from EUR 805.0 million in 2022 to EUR 1 187.0 million in 2026, resulting in a CAGR of 10.9%. Sensors & Actuators have the highest CAGR at 12.9%, underscoring their critical role in heavy commercial vehicles.

Table 4.9: Europe Automotive Semiconductor Market, Sales in EUR Million, by Heavy Commercial Vehicle, Base Year: 2023, Forecast Period: 2024-2026

APPLICATION	2022	2023	2024	2025	2026	CAGR 23-26
DISCRETE	54.9	58.0	62.8	68.1	74.1	8.46%
OPTOELECTRONICS	100.0	107.2	117.6	129.4	142.8	10.01%
SENSORS & ACTUATORS	178.2	196.1	220.8	249.3	282.2	12.90%
LOGIC	52.1	56.5	62.8	69.9	78.0	11.34%
MEMORY	111.5	121.7	136.0	152.3	171.1	12.01%
ANALOG IC	187.2	201.3	221.5	244.5	270.5	10.35%
MICRO	121.2	129.3	140.9	153.9	168.3	9.20%
TOTAL	***805.0***	***870.2***	***962.5***	***1 067.4***	***1 187.0***	***10.90%***

Source: Mordor Intelligence: European Automotive Semiconductor Market

4.3 The Automotive Semiconductor Supply Chain

The automotive semiconductor supply chain is a complex and multi-faceted process that involves several key phases, each playing a crucial role in the production and integration of semiconductor components into vehicles. This value chain can be broadly divided into five main segments: raw materials, semiconductor manufacturers, distributors, Tier 1 suppliers, and car manufacturers. Understanding each phase provides insight into how these components are developed, distributed, and ultimately utilized in the automotive industry.

4.3.1 Segments of the supple chain

1. **Raw Materials and equipment**

The first phase of the value chain involves the procurement of raw materials necessary for semiconductor fabrication. This includes wafer substrates, which are thin slices of semiconductor material like silicon, used as the foundational layer for microelectronic devices. Bonding materials, such as adhesives and solders, are essential for attaching semiconductor components to their packages. Packaging binders, which protect the semiconductor devices from physical damage and environmental factors, are also supplied at this stage. Various vendors specialize in providing these materials, ensuring the quality and consistency required for high-performance semiconductor devices.

In addition to raw material suppliers, semiconductor equipment manufacturers play a crucial role in the value chain by providing the advanced machinery and technology necessary for semiconductor fabrication. Companies like ASML, Applied Materials, Lam Research, and Tokyo Electron are at the forefront of this industry, offering a range of equipment used in processes such as lithography, etching, and deposition. These manufacturers invest heavily in research and development to innovate and improve the precision and efficiency of their tools, which are essential for producing the increasingly complex and miniaturized semiconductor devices demanded by the market. Their equipment ensures that the raw materials are processed accurately and consistently, contributing to the overall quality and performance of the final semiconductor products.

2. **Automotive Semiconductor Manufacturers**

In the second phase, semiconductor manufacturers such as NXP Semiconductor NV, Infineon Technologies AG, Renesas Electronics Corporation, Texas Instruments Inc., and STMicroelectronics NV play a pivotal role. These companies design and produce a wide range of semiconductor devices, including power devices, microcontrollers, sensors, and integrated circuits, which are integral to automotive electronics. They often subcontract the packaging of these devices to Outsourced Semiconductor Assembly and Test (OSAT) companies. However, some foundries, including industry giants like Intel, Samsung, and TSMC, manage the packaging process internally. This phase is critical as it transforms raw materials into functional semiconductor components ready for integration into automotive systems. Table 4.10 presents a snapshot of the industry's leading players, showcasing a mix of well-established companies with a long history, such as Robert Bosch GmbH founded in 1886, and relatively newer entities like NXP Semiconductors N.V., established in 2006. These companies are geographically diverse, with headquarters spanning from the United States to Europe and Asia, indicating a global presence in the semiconductor market. It's important to note that the headquarters of these firms do not fully represent their operational or production footprints. Many of these leading semiconductor manufacturers have a significant portion of their production capacities outsourced or located in various parts of the world. Companies like NXP Semiconductors, Texas Instruments, and Infineon Technologies have extensive networks of fabrication plants, assembly facilities, and design centres across different continents.

The key automotive products offered by these companies range from vehicle electrification systems, MEMS safety and security, to advanced driver-assistance systems (ADAS), and power management integrated circuits (ICs). The operating revenues reflect the scale of these companies, with Robert Bosch GmbH leading the pack with an operating revenue of over 98 billion USD, while ROHM Company Limited shows a more modest figure of approximately 3 billion USD. The number of employees also varies significantly, from 21 204 at Renesas Electronics Corporation to a staggering 413 811 at Robert Bosch GmbH, demonstrating the varying sizes and capacities of these organizations. The companies listed in the table demonstrate a strong international presence, with only a limited portion of their revenues coming from Europe. Even those headquartered in the EU, such as Infineon Technologies and STMicroelectronics, show substantial engagement in the global market. This internationality highlights their strategic importance and adaptability in catering to diverse regional demands, ensuring robust market integration and competitive positioning worldwide.

From the competitive landscape, several general trends and common features emerge among the firms. Firstly, innovation and specialization in key product areas such as ADAS, power semiconductors, and vehicle electrification systems are evident, with companies focusing on developing cutting-edge technologies that cater to the evolving needs of the automotive industry. Secondly, there is a clear trend towards the electrification of vehicles and the integration of smart technologies, which is driving demand for advanced semiconductor solutions. Thirdly, the companies show a commitment to research and development, as seen in their diverse product portfolios that address various aspects of automotive technology, from safety and security to power management and efficiency.

Moreover, the firms exhibit a strong global footprint, not only in terms of their headquarters but also through their operational reach and supply chains, which are essential for serving the automotive industry's international market. The substantial revenues and employee numbers reflect the significant investments these companies make in their workforce and R&D capabilities, ensuring they remain at the forefront of technological advancements. Lastly, the presence of legacy companies alongside newer entrants suggests a dynamic market where experience and innovation go hand in hand, driving competition and growth in the automotive semiconductor sector.

Table 4.10: Main Automotive Semiconductor Manufacturers

Company Name	Founded	Headquarters	Key Automotive Products	Operating Revenue in 2023 (m USD)	Number of Employees	Revenue Shares from Europe	Website Address
ANALOG DEVICES INC	1965	Wilmington, United States	Vehicle Electrification System, MEMS Safety and Security	12 305.539	26 000	24.39%	www.analog.com
INFINEON TECHNOLOGIES AG	1999	Neubiberg, Germany	MOSFET, Chassis Safety and ADAS, Battery Management ICs	17 481.151	58 590	26.73%[84]	www.infineon.com
MICRON TECHNOLOGY INC	1978	Boise, United States	DRAM, eMMC, GDDR6, Multichip, Packages	15 540.0	43 000	4.39%	www.micron.com
NXP SEMICONDUCTORS N.V	2006	Eindhoven, Netherlands	Processors and Microcontrollers, Audio and Radio, Sensors	13 286.0	33 857	11.6%[85]	www.nxp.com
ON SEMICONDUCTOR CORP	1999	Arizona, United States	Image Sensors, Image Signal Processors, IGBTs, Photodetectors	8 253.0	30 100	21.2%[86]	www.onsemi.com
RENESAS ELECTRONICS CORPORATION	2002	Tokyo, Japan	Photocouplers, MCUs, Battery Management, Sensors	10 669.741	21 204	17.82%	www.renesas.com
ROBERT BOSCH GESELLSCHAFT MIT BESCHRAENKTER HAFTUNG	1886	Stuttgart, Germany	Systems ICs, MEMS Sensors, Power Semiconductors	98 824.709	413 811	51.06%	www.bosch.com
ROHM COMPANY LIMITED	1958	Kyoto, Japan	Power Management Products, Memory Products, ADAS Products	3 092.760	23 319	9.54%	www.rohm.com
STMICROELECTRONICS N.V.	1987	Geneva, Switzerland	Logic ICs, Chassis and Safety, ADAS, Motor Control	17 487.0	51 323	27.98%[87]	www.st.com

84 Europe, Middle East and Africa
85 Only Germany and Netherlands
86 Lists revenue share only of the UK as a European country
87 Europe, Middle East and Africa

Company Name	Founded	Headquarters	Key Automotive Products	Operating Revenue in 2023 (m USD)	Number of Employees	Revenue Shares from Europe	Website Address
TEXAS INSTRUMENTS INC	1930	Texas, United States	ADAS, Sensor Fusion, Body Electronics and Lighting	17 519.0	34 000	26.5%[88]	www.ti.com
TOSHIBA CORPORATION	1875	Tokyo, Japan	MOSFETs, Interface Bridge ICs, Photocouplers, Transistors and Logic ICs	26 283.496	106 648	7.2%	www.toshiba.co.jp

Source. JRC elaboration from Mordor Intelligence, 2024. Revenue shares from Europe are collected from 2023 annual reports by Mordor Intelligence. Operating revenue and number of employees are derived from Moody's Orbis for the last available year.

3. **Distributors**

The third phase involves distributors who bridge the gap between semiconductor manufacturers and Tier 1 suppliers. Companies such as Allied Electronics, Arrow Electronics, Avnet, Digi-Key, and Mouser Electronics operate in this segment, providing a wide range of semiconductor products through both offline and online channels. These distributors ensure that Tier 1 suppliers have access to the necessary semiconductor components, offering logistical support, inventory management, and technical assistance. Their role is essential in maintaining a steady supply chain and facilitating the efficient distribution of semiconductor products.

4. **Tier 1 Suppliers**

Tier 1 suppliers, such as Continental and Valeo, play a critical role in the automotive semiconductor supply chain. These companies are responsible for integrating semiconductor components into advanced automotive systems, including advanced driver assistance systems (ADAS), in-vehicle infotainment (IVI) systems, and powertrain control units. Unlike semiconductor manufacturers, which produce the semiconductor chips, Tier 1 suppliers focus on the design, development, and assembly of these components into functional modules that can be directly used by car manufacturers. They collaborate closely with semiconductor manufacturers to ensure that the components meet the specific

[88] Europe, Middle East and Africa

requirements of the automotive industry, such as high reliability, durability, and performance under various operating conditions. By bridging the gap between semiconductor manufacturers and car manufacturers, Tier 1 suppliers ensure that the latest semiconductor technologies are effectively utilized in modern vehicles, enhancing their safety, efficiency, and connectivity.

5. **Car Manufacturers**

The fifth and final phase encompasses the integration of automotive semiconductors into various vehicle types. Car manufacturers, such as Toyota, Ford, and Volkswagen, are responsible for the final assembly of vehicles. They integrate various subsystems and modules provided by Tier 1 suppliers into the complete vehicle. This includes both passenger vehicles and commercial vehicles, where semiconductors are used in numerous applications such as engine control units, infotainment systems, ADAS, and electric powertrains. The integration process involves embedding these semiconductor components into the vehicle's electronic systems, ensuring they function seamlessly to enhance performance, safety, and efficiency. This phase highlights the end-use of semiconductors, demonstrating their critical role in modern automotive technology.

4.3.2 Import dependences

To identify potential import dependences, one would look at direct connections between firms but typically these are not disclosed to the public, and even when accessible, they do not specify the traded product. While it could be possible to extract this information from individual-level trade data, this information is unfortunately not easily accessible. The rest of the chapter provides some estimation, based on the aggregate trade data and strong assumptions, about the import dependencies of the automotive semiconductor industry.

Two main sources of data provide insights into the import dependencies of the European automotive semiconductor market: World Semiconductor Trade Statistics (WSTS) and EU27 customs data. WSTS data breaks down chip shipments by type and end-use sector, while EU27 customs data reveals the reliance on imports for specific products or chip types[89]. Without detailed and consistent firm-level data on product-specific dependencies, combining these two sources, one can get a broad indication of the reliance of European industrial sectors on semiconductor imports. Table 4.11's initial column reveals

89 As stated above, trade data report information on the last country from which products are shipped to the EU27, therefore considerations about re-exports shall be taken into account in this context. To have a proper assessment on value chain dependencies this data shall be implemented with Input/Output information, which, to our knowledge, is not available for specific categories of chips.

that of every 100 semiconductor chips received by the European automotive industry, 30 are from the DOSA segment, 34 are analog chips, and 30 are logic chips.[90]

This data should be considered alongside information about the EU27's import dependencies for each category of chip, which is found in the subsequent columns of the table. Specifically, the data indicates that China (CN) is the primary supplier of DOSA chips to the EU27, Malaysia (MY) is a significant provider of analog semiconductors, and Taiwan (TW) is a key source of logic, micro, and memory chips. If the distribution of imported chips across sourcing partners for a specific sector, such as the automotive industry, mirrors the EU-wide distribution, then the dependencies of the automotive sector can be inferred from the 'Top 2 Sources' column in Table 4.11

This assumption might be reasonable when the domestic end-using sector absorbs a relevant portion of chips shipped to Europe, such as the DOSA and analog chips for the automotive industry (see Table 3.4 of Chapter 3). However, this evidence should still be interpreted with caution, as there might be specific categories of chips for certain end-using sectors that are exclusively sourced from particular geographic locations, and this information remains hidden in aggregated trade statistics at the product level. Future research on extracting data on traded products between companies and countries could alleviate this issue and provide a more accurate analysis of sectoral dependencies on imported chips.

Table 4.11: Europe Shipments composition and EU27 import data

2023	**WSTS European Automotive**	**EU27 Import Data**	**EU27 Import Data**
	Chips Shipments Composition	**Top 2 Sources**	**Top 2 Source Share**
DOSA	30.5%	CN - MY	35.9% - 18.5%
Analog	34.2%	MY - US	19.9% - 19.4%
Logic (incl. micro)	30.2%	TW - MY	21.7% - 17.8%
DRAM	1.9%	TW - KR	43.3% - 18.4%
SRAM	0.1%	TW - TH	42.8% - 25.2%
Flash Memory	2.7%	TW - CN	41.7% - 15.5%
Rest of Memory	0.4%	TW - CN	30.1% - 23.1%

Source: JRC Elaboration on WSTS data and EC customs data.

90 In Table 4.11 Europe refers to the broader European continental market, encompassing the European Union, the United Kingdom, the Middle East, and Africa. This geographic scope is determined by the level of aggregation for which WSTS data is available. Further details on the definition and scope of Europe in the context of WSTS data can be found in the Appendix of Chapter 3.

4.3.3 Future trends

Looking ahead, the automotive semiconductor value chain is expected to undergo significant changes. One notable trend is the potential for direct connections between car manufacturers and semiconductor manufacturers, bypassing traditional distributors. This shift could streamline the supply chain, reduce costs, and improve the efficiency of semiconductor procurement. Evidence suggests that as the demand for advanced automotive technologies like electric vehicles and ADAS grows, car manufacturers are increasingly seeking closer partnerships with semiconductor companies to secure a stable supply of critical components[91]. This trend is driven by the need for more specialized and high-performance semiconductors, which are essential for the next generation of automotive innovations.

Furthermore, the 2023 European Chips Act aims to bolster Europe's semiconductor ecosystem by reducing dependencies on imports through increased local production capabilities. If successful, this initiative could enhance Europe's technological leadership and resilience in semiconductor technologies. By investing over €43 billion in public and private funds, the Act supports the development of advanced semiconductor manufacturing facilities and innovation hubs across Europe, which could lead to a more secure and autonomous supply chain. As a result, Europe might be better positioned to meet the growing demand for semiconductors in various industries, including automotive, thereby potentially reducing reliance on external suppliers.

91 McKinsey highlights the importance of semiconductor companies adapting their strategies to capture value in the evolving automotive landscape, including forming closer partnerships with car manufacturers.

Main takeaways

- European automotive semiconductor sales have increased substantially since 2020.
- The growth was driven by firstly, the increasing number of vehicles sold, secondly, the increasing complexity and capability of each vehicle, and thirdly, electric vehicles, which are gaining popularity, require a significantly higher number of semiconductors compared to their internal combustion counterparts. As a result, the semiconductor content per vehicle is expected to continue its upward trajectory.
- The automotive industry is rapidly adopting Advanced Driver Assistance Systems (ADAS) to enhance vehicle safety and driving experience, with technologies like adaptive cruise control and LIDAR sensors becoming foundational.
- There is a significant shift towards electric vehicles (EVs) and autonomous driving, with semiconductor firms playing a crucial role in this transition through AI and data analytics integration.
- The need for more specialized and high-performance semiconductors, which are essential for the next generation of automotive innovations, necessitates closer integration between car manufacturers and semiconductor firms.

Concluding remarks and next steps

The European Union (EU) has long been a significant player in the global semiconductor market, yet it faces numerous challenges and dependencies that could impact its future competitiveness. This report provides a comprehensive overview of the EU's position within the global semiconductor sector, focusing on trade dependencies, market dynamics, and the implications for key end-using sectors, particularly the automotive industry. The analysis draws mainly on data from the World Semiconductor Trade Statistics (WSTS) and the SCAN monitoring tool, offering insights into the distribution and dynamics of semiconductor shipments to Europe, as well as the structural dependencies that characterize the EU's semiconductor supply chain.

Trade Dependencies and Market Dynamics

The EU's semiconductor market is characterized by significant trade dependencies, particularly in the final product segment. The analysis reveals that the EU is heavily reliant on imports for several categories of semiconductors, including logic chips and memory chips, which are primarily sourced from Taiwan. The potential for substitutability with domestic production is particularly low for memory chips, where extra-EU imports significantly exceed exports. This dependency poses a risk to the EU's semiconductor supply chain, especially in the event of geopolitical tensions or supply chain disruptions.

The SCAN (Supply Chain Alert Notification) tool highlights that 23 out of 127 monitored semiconductor-related products are at risk of import disruptions. These products span various segments of the semiconductor supply chain, including raw materials, inputs, equipment, and final products. The EU exhibits the lowest potential for import substitution in the final products segment, where imports account for approximately 60% of total EU domestic supply.

Equipment Segment

The equipment segment is a critical part of the semiconductor supply chain, encompassing the machinery and tools used in the manufacturing of semiconductor devices. The EU holds a strong position in this segment, particularly in specialized machines used for wafer fabrication and semiconductor manufacturing. European manufacturers are global leaders in this market, contributing significantly to the EU's export capabilities.

The global equipment market for semiconductor manufacturing is dominated by North America, the EU, and Japan. The EU's strength lies in its leadership in microlithography and mask-making equipment, driven by companies like ASML. This segment accounted for 30% of the global sales of wafer fabrication equipment in 2023. The EU also has a notable presence in other equipment subsegments, such as process diagnostic equipment and deposition tools.

However, the equipment segment also faces challenges, including dependencies on imports for certain subsystems used for air, gas, and fluid management. These products are primarily sourced from Japan, China, and the US, highlighting the need for diversification and strengthening of domestic production capabilities.

Semiconductor Shipments and End-Using Sectors

The demand for semiconductors in the EU has been steadily increasing, with shipments reaching $53 billion in 2022. Notably, 2021 saw a 27% increase in shipments, compensating for the declines of 2019 and 2020, with the latter year heavily impacted by the Covid-19 crisis. WSTS forecasts a continued increase in shipments to Europe, predicting a cumulated 75% rise between 2017 and 2027. Despite this growth, Europe remains the fourth-largest market for semiconductors, with a

10.6% share of shipments in 2023, behind China (29%), the Americas (25%), and Japan and the rest of Asia. This growth is expected to continue, with a projected 75% increase in shipments between 2017 and 2027.

Semiconductor shipments are categorized by WSTS into eight types: discrete, optoelectronics, sensors, actuators (DOSA), analog, micro, logic, DRAM, SRAM, flash memory, and other memory types. European end-users receive fewer logic chips, DRAM, and flash memories than global counterparts, but more micro, DOSA, and analog semiconductors, with Japan outpacing Europe in DOSA shipments. The communication and computer manufacturing sectors are the primary consumers of logic chips and DRAM, while the European automotive and industrial sectors consume most of discrete, analog, micro, SRAM, and other memory types arriving to the market. From 2020 to 2023, shipments of analog, logic, and other memory types to Europe increased by over 40%, while DOSA and micro grew by 30%. Conversely, DRAM and flash memory shipments decreased by over 10% over the same period. The automotive sector alone accounts for 37% of semiconductor shipments to Europe.

The Automotive Sector and Semiconductor Demand

The automotive sector is a vital component of the EU's economic fabric, contributing significantly to employment and GDP. In 2023, the sector provided over 13 million jobs and accounted for approximately 6% of the EU's total employment. This industry is heavily reliant on semiconductors, which are essential for a wide range of applications in modern vehicles, from engine control units to ADAS.

The demand for automotive semiconductors is influenced by the increasing number of vehicles, the complexity of electronic features, and the rise of EVs, which require a higher number of semiconductors than traditional vehicles. The global chip shortage that began in 2020 highlighted the vulnerabilities in the semiconductor supply chain and underscored the need for a more resilient and robust supply chain.

The EU automotive semiconductor market is projected to grow significantly, with sales expected to reach EUR 17 377 million by 2026. This growth is driven by the increasing complexity of vehicles, the shift towards electrification, and the development of autonomous driving technologies. The market's growth is primarily driven by the safety segment, which is projected to grow at a CAGR of 9.05%, and the power electronics segment, which is the fastest-growing segment with a CAGR of 11.1%.

The future of automotive technology is closely tied to advancements in semiconductor technology. As vehicles become more intelligent and connected, the demand for sophisticated semiconductors will continue to grow. While self-driving cars will rely heavily on advanced semiconductors for processing vast amounts of data from sensors, making real-time decisions, and ensuring safety, the broader automotive industry already requires a significant number of chips for less than fully automated systems. Autonomous driving technology has the potential to revolutionize transportation, making it safer, more efficient, and more accessible. The integration of these technologies will shape the future of mobility, leading to smarter, more sustainable vehicles. According to McKinsey, autonomous driving could generate hundreds of billions of dollars in value for the auto industry by the end of this decade. Additionally, the widespread adoption of self-driving cars could significantly reduce traffic accidents and fatalities. However, self-driving cars have so far been a disappointment, with many challenges and setbacks. It remains unclear when fully autonomous vehicles will become a reality. As the technology matures, it is plausible to expect to see more advanced features and greater integration of autonomous systems in everyday vehicles.

Next Steps

The European Union (EU) stands at a pivotal moment in the semiconductor industry, facing both significant challenges and promising opportunities. The Draghi report (Draghi, 2024) identifies several critical challenges facing the semiconductor industry in the European Union. These challenges are multifaceted and require coordinated efforts to address effectively. Here are the key challenges highlighted in the report:

1. **Global Supply Chain Dependencies**: The EU's semiconductor industry is heavily reliant on imports for critical components and raw materials. This dependency makes the supply chain vulnerable to disruptions caused by geopolitical tensions, trade restrictions, and other global events.

2. **Innovation Gap**: The report points out a significant gap in innovation within the EU compared to other leading regions like the US and Asia. This gap is attributed to difficulties in moving from research and development (R&D) to commercialization, as well as challenges in scaling new ventures across a fragmented single market with complex regulations.

3. **Financial Constraints**: The semiconductor industry requires substantial investments to maintain competitiveness. However, there is ongoing debate about the feasibility and desirability of raising such amounts, given the pressure on public finances.

4. **Regulatory Complexity**: The EU's regulatory environment is often seen as cumbersome and fragmented, which can hinder the growth and competitiveness of the semiconductor industry. The report emphasizes the need for policy coordination and simplification to create a more conducive environment for industrial growth.

5. **Talent Shortages**: The semiconductor industry requires a highly skilled workforce, but there is a growing shortage of qualified engineers and technicians in the EU. This talent gap can impede innovation and production capabilities.

6. **Supply Chain Transparency**: Improving transparency and traceability within the semiconductor supply chain is crucial for identifying and addressing potential vulnerabilities. The lack of visibility can lead to inefficiencies and difficulties in responding to disruptions.

Addressing these challenges involves strategic initiatives such as increasing domestic production capacity, investing in R&D, enhancing collaboration between industry stakeholders, and promoting sustainable practices. The Draghi report provides a roadmap for the EU to strengthen its semiconductor industry and ensure its long-term competitiveness and resilience in the global market.

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Appendix 1

Table A1.1: – Mapping of relevant product codes

Segment of the Semiconductor Supply Chain	Number of CN codes (2023) in each segment	CN codes (2023)
Raw materials for wafers	11	25051000, 25061000, 28046100, 28256000, 28259085, 28429010, 28492000, 28500020, 28539090, 81129289, 81129295
Inputs	56	28011000, 28013090, 28041000, 28042100, 28042910, 28042990, 28043000, 28044000, 28047090, 28049000, 28061000, 28070000 ,28092000, 28111100, 28111910, 28112100, 28112200, 28112930, 28121990, 28129000, 28151100, 28151200, 28152000, 28170000, 28181091, 28182000, 28230000, 28261990, 28273985, 28309085, 28332500, 28433000, 28461000, 28469090, 29319000, 37013000, 37019900, 37050090, 37079020, 37079090, 38249996, 39199020, 39201023, 39231010, 59119091, 70200005, 81129940, 81129950, 81129970, 90012000, 90019000, 90021900, 90022000, 90029000, 90121000, 90129000
Wafers	3	38180010, 38180090, 38249975
Equipment	26	84141015, 84145915, 84145925, 84145935, 84145995, 84149000, 84195020, 84195080, 84212920, 84212980, 84213915, 84213925, 84213935, 84213985, 84219910, 84219990, 84431940, 84861000, 84862000, 84864000, 84869000, 90112010, 90308200, 90308400, 90308900, 90314100
Final products	31	85365003, 85365005, 85411000, 85412100, 85412900, 85413000, 85414100, 85414900, 85415100, 85415900, 85419000, 85423111, 85423119, 85423190, 85423211, 85423219, 85423231, 85423239, 85423245, 85423255, 85423261, 85423269, 85423275, 85423290, 85423310, 85423390, 85423911, 85423919, 85423990, 85429000, 90330010

Source: JRC elaboration based on the methodology described in Section 1.1

Table A1.2: List of CN8 codes and descriptions for products at structural risk of import disruptions, based on structural indicators for the year 2023.

Segments	CN8 code	CN8 description
Raw materials for wafers	28256000	Germanium oxides and zirconium dioxide
Raw materials for wafers	81129289	Unwrought gallium; gallium powders
Inputs	28013090	Bromine
Inputs	28047090	Phosphorus (excl. red phosphorus)
Inputs	28129000	Halides and halide oxides of non-metals (excl. chlorides and chloride oxides)
Inputs	28181091	Artificial corundum, whether or not chemically defined, with < 50 % of the total weight having a particle size > 10 mm (excl. with an aluminium oxide content >= 98,5% by weight "high purity")
Inputs	28273985	Chlorides (excl. ammonium, calcium, magnesium, aluminium, iron, cobalt, nickel, tin and mercury chloride)
Inputs	37050090	Photographic plates and film, exposed and developed (excl. products made of paper, paperboard or textiles, for offset reproduction and cinematographic film and ready-to-use printing plates)
Inputs	37079020	Developers and fixers in the form of chemical preparations for photographic use, incl. unmixed products, in measured doses or put up for retail sale ready for use (excl. salts and compounds of heading 2843 to 2846)
Inputs	37079090	Preparation of chemicals for photographic uses, incl. unmixed products put up in measured portions or put up for retail sale in a form ready for use (excl. varnishes, glues, adhesives and similar preparations, sensitising emulsions, developers and fixers and salts and precious-metal compounds etc. of heading 2843 to 2846)
Inputs	38249996	Chemical products and preparations of the chemical or allied industries, incl. those consisting of mixtures of natural products, not predominantly composed of organic compounds, n.e.s.
Inputs	39199020	Self-adhesive circular polishing pads of a kind used for the manufacture of semiconductor wafers, of plastics
Inputs	59119091	Self-adhesive circular polishing pads of a kind used for the manufacture of semiconductor wafers
Inputs	81129940	Articles of germanium, n.e.s.
Inputs	81129950	Articles of niobium "columbium", n.e.s.
Equipment	84141015	Vacuum pumps of a kind used for the manufacture of semiconductors or solely or principally used for the manufacture of flat panel displays
Equipment	84145915	Fans of a kind used solely or principally for cooling microprocessors, telecommunication apparatus, automatic data processing machines or units of automatic data processing machines
Equipment	84212920	Machinery and apparatus for filtering or purifying liquids, made of fluoropolymers and with filter or purifier membrane thickness <= 140 µm (excl. those for water and other beverages, and artificial kidneys)
Final products	85411000	Diodes (excl. photosensitive or light emitting diodes "LED")
Final products	85412100	Transistors with a dissipation rate < 1 W (excl. photosensitive transistors)
Final products	85419000	Parts of diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, light emitting diodes and mounted piezoelectric crystals, n.e.s.
Final products	85423231	Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
Final products	85423261	Electronic integrated circuits as electrically erasable, programmable read-only memories "flash E^2PROMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)

Source: JRC elaboration on the SCAN dashboard for year 2023 which is based on EC customs data and PRODCOM. Extraction date: 02.09.2024.

Table A1.3: SCAN structural indicators for the CN8 products of the semiconductors supply chain at risk of import disruption – 2023

Segments	CN8 code	Total Import (*m EUR)*	Total Export (*m EUR*)	Top Source	Concentration		Substitutability		S-Risk
					Top Source Import Share	HHI Index	Im-port/Ex-port	Exposure Index	
Raw materials for wafers	**28256000**	91.00	22.76	CN	52.48%	0.328	4.00	0.65	*
Raw materials for wafers	**81129289**	7.00	5.75	CN	84.43%	0.720	1.22	0.89	**
Inputs	**28013090**	23.15	3.72	IL	51.33%	0.479	6.22	1.00	**
Inputs	**28047090**	151.66	2.13	KZ	88.37%	0.789	71.30	0.99	**
Inputs	**28129000**	31.48	26.15	US	57.09%	0.381	1.20	0.28	*
Inputs	**28181091**	108.18	32.74	CN	66.64%	0.486	3.30	0.59	*
Inputs	**28273985**	116.28	60.27	AR	60.08%	0.406	1.93	0.33	*
Inputs	**37050090**	281.34	190.80	US	88.73%	0.793	1.47	NA	*
Inputs	**37079020**	238.47	193.72	JP	78.40%	0.635	1.23	0.51	*
Inputs	**37079090**	183.30	115.87	JP	48.31%	0.416	1.58	0.54	*
Inputs	**38249996**	4 450.61	3 114.41	KR	69.62%	0.500	1.43	0.35	*
Inputs	**39199020**	23.03	9.63	US	58.97%	0.423	2.39	0.38	*
Inputs	**59119091**	10.84	2.65	US	60.34%	0.483	4.09	0.83	**
Inputs	**81129940**	4.41	3.68	CN	86.83%	0.759	1.20	0.83	**
Inputs	**81129950**	55.89	14.57	US	61.92%	0.461	3.84	0.80	**
Equipment	**84141015**	94.01	20.47	JP	56.18%	0.411	4.59	0.81	**
Equipment	**84145915**	219.21	80.49	CN	66.54%	0.457	2.72	0.89	**
Equipment	**84212920**	123.94	85.06	US	67.03%	0.483	1.46	0.62	**
Final products	**85411000**	1 295.47	823.07	CN	53.41%	0.324	1.57	0.63	*
Final products	**85412100**	344.79	260.95	CN	57.24%	0.374	1.32	0.42	*
Final products	**85419000**	222.84	144.05	CN	55.88%	0.354	1.55	0.31	*
Final products	**85423231**	74.88	13.34	TW	55.82%	0.396	5.61	0.95	*
Final products	**85423261**	205.84	64.39	TW	54.22%	0.328	3.20	0.85	*

*Source: JRC elaboration on EC customs data and PRODCOM. Extraction date: 02.09.2024. Chosen thresholds for concentration indexes are 50% for the share of the top source in extra-EU imports and 0.4 for the HHI index. For substitutability indexes, the thresholds are equal to 1 for the ratio of extra-EU imports and extra-EU exports, and to 60% for the exposure index. The exposure indicator is computed as the share of extra-EU imports in EU total supply (sum of domestic production from PRODCOM and extra-EU imports). * indicates products in medium risk for which at least one concentration index and at least one substitutability index are above the respective thresholds, ** indicates products in high risk for which all structural indicators are above the thresholds. Please refer to the Table A1.2 for the description of the CN8 codes.*

Appendix 2

Deep dives on trade dependencies in the raw materials for wafers and inputs segments

Raw materials for wafers. The aggregate results for the raw materials segment reported in Table 1.1 show the EU has rather differentiated imports and domestic capacity in this segment. The aggregate results are mainly driven by one important product in the segment, ultra-purified silicon (CN 28046100), which is the most used material to produce silicon wafers. Indeed, this product accounts for around 20% of the segment imports and almost 70% of the segment's export values in 2023, far surpassing the import and export levels of all the other products in the segment. Trade and production data indicate that the EU has significant domestic capacity for this material.[92] For instance, the EU is a net exporter, with a ratio of import/export equal to 0.10 in 2023. However, extra-EU imports are highly concentrated from the US (80%).

Two codes associated to the raw materials segment are found to be at risk of import disruption: “Germanium and zirconium oxides” (CN 28256000) and “Unwrought[93] gallium; gallium powders” (CN 81129289).[94] Interestingly, Gallium and Germanium have fuelled the political debate due to concerns over potential shortages of these semiconductor materials, which are critical for the production of certain advanced chips, as well as certain optical and military devices.[95] Both trade codes appear in the list of products affected by the recent introduction of new export restrictions on Gallium and Germanium by the Chinese government in August 2023.[96]

Unfortunately, for the product "Germanium and zirconium oxides" (CN 28256000), it is difficult to provide a more detailed assessment of potential risk from the trade perspective, as this product code is a composite product group including materials related to both zirconium and germanium oxides. The data availability does not allow for the retrieval of specific export or production data on germanium oxides.[97]

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92 More specifically, ultra-purified silicon (CN 28046100) is the result of processing and refining silica to obtain a high-purity metalloid. The EU also has domestic capacity for the mining and extraction phase of this material. For example, for the extraction product "Silica sands and quartz sands, whether or not colored" (CN 25051000), the EU27 shows aggregate extra-EU exports larger than imports and very low exposure indicator. Another useful source of information on statistics related to silica is the RMIS dashboard, which confirms that the EU is among the top global producers of silica sands (see https://rmis.jrc.ec.europa.eu/rmp/Silica).

93 Unwrought means that the mineral has not undergone significant processing.

94 A third code corresponding to Germanium, “unwrought” Germanium (CN 81129295), is also monitored in SCAN but has not been identified as being at risk of import disruption in 2023, owing to the relatively good levels of domestic capacity within the EU. EU imports of unwrought Germanium amounted to EUR 2.9 million in 2023, while exports reached EUR 12.1 million. However, it's important to note that assessing potential risks related to this Germanium-related product is very difficult, as the product code CN 81129295 does not refer to the extraction phase, for which the EU might have high dependencies on resource-rich third countries such as China, but rather to a processed material. In the EU, there is a important company in the market for recycling and processing Germanium: Umicore. Information on Germanium natural reserves is limited, but some useful information is contained in the RMIS dashboard for Germanium: https://rmis.jrc.ec.europa.eu/rmp/Germanium.

95 https://www.ft.com/content/9cd56880-4360-4e11-8c22-e810d3787e88

96 https://m.mofcom.gov.cn/article/zwgk/gkzcfb/202307/20230703419666.shtml

97 However, it could be useful to have a look at aggregate statistics and information contained in the RMIS dashboard for Germanium: https://rmis.jrc.ec.europa.eu/rmp/Germanium.

In the EU, imports of unwrought gallium were EUR 7 million in 2023 (Table A1.3).[98] The imports of this product are primarily sourced from China (84%). The indicators of substitutability potential, such as the ratio of imports to exports and the exposure index, are above the respective thresholds, indicating a limited EU capability to substitute extra-EU imports of this product with EU domestic production. Moreover, the product unwrought gallium shows a very high index of import concentration (HHI equal to 0.7) and, therefore, is classified as being at high risk of import disruption according to SCAN, as all four structural indicators exceed the respective thresholds.

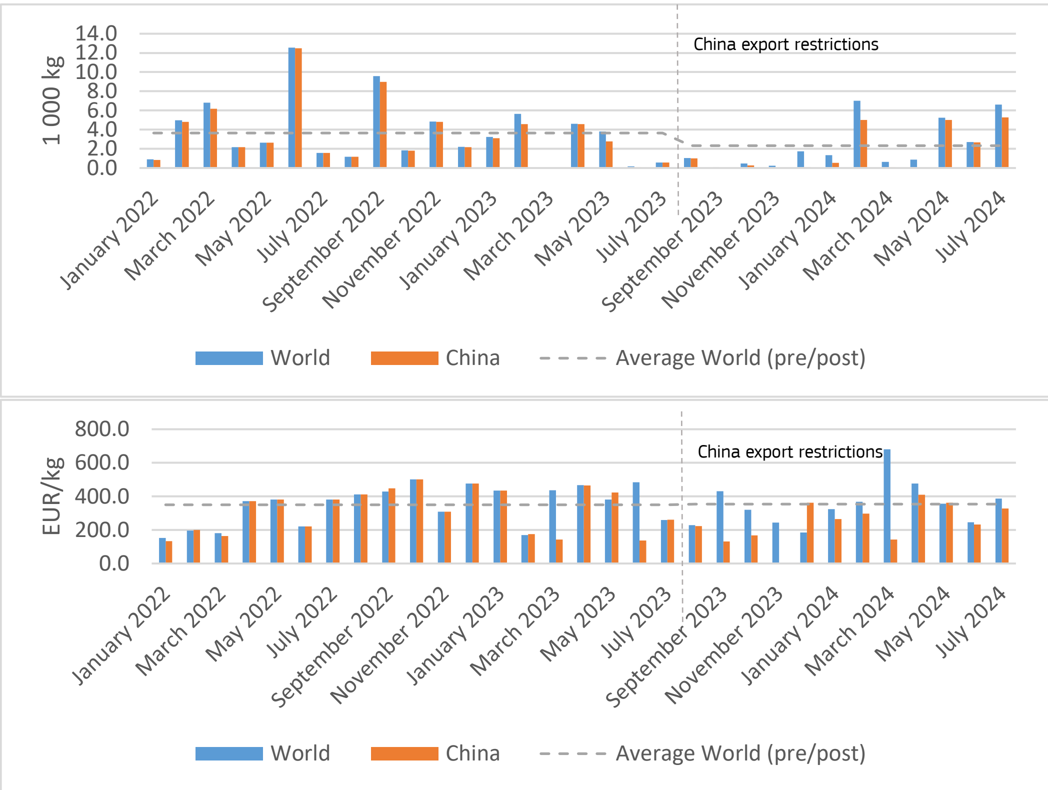
The appendix provides evidence on monthly imported quantities and unit values[99] to assess whether the Chinese export restrictions had affected the recent trade flows of this good to the EU. Import flows from China have experienced a marked slowdown in the months following the introduction of the policy in the second semester of 2023 (Figure A2.1), but have rebounded during the last available quarter to import levels that are similar to those preceding the restriction. One possible explanation could be the short-run uncertainty caused by the restrictions and administrative delays for importers and exporters to comply with China's new export licensing program.

All in all, evidence from monthly import quantities and unit values suggests that, on average, imports of these products have continued flowing from China to Europe despite the introduction of the policy. However, the situation should be regularly monitored to assess any limited or more disruptive signals of distress in EU import flows for these products.

98 Relatively small levels of imports do not necessarily imply low relevance of the product, as this material may be used only in small quantities or destined for niche industrial applications. Only a technical assessment could confirm whether this material is crucial for sensitive technologies, even if traded in small amounts.

99 Following the trade literature, import prices are proxied by unit values, which correspond to the ratio of the value and the quantity of the traded products.

Figure A2.1: EU import quantities and unit values of unwrought gallium



Source: JRC elaboration on EC customs data (extraction 02.09.2024). "Unwrought gallium; gallium powders" corresponds to CN 81129289

Inputs. Thanks to the presence of leading EU suppliers and companies[100], the EU is relatively well-placed in the global market for electronic gases and wet chemicals, which are key inputs to produce semiconductors. In the SCAN monitoring, product categories related to electronic gases such as Nitrogen, Oxygen, Hydrogen, Argon, Neon, Krypton and Xenon[101], which are used in various semiconductor manufacturing processes, do not show warning levels in structural indicators for the year 2023. This is in general true for both import concentration and substitutability potential with

100 Linde (Germany), Air Liquide (France), BASF (Germany) are listed as major companies for electronic gases and chemicals in CSET (2021). Linde and Air Liquide have also been indicated as key suppliers of electronic specialty gases by respondents to the US survey on the assessment of the status of the microelectronics industrial base in the united states: https://www.bis.doc.gov/index.php/other-areas/office-of-technology-evaluation-ote/industrial-base-assessments

101 Neon, Krypton and Xenon are aggregated under the same CN code (280429990). Concerns regarding the supply of these rare gases and potential disruptions to supply chains have arisen following the Russian aggression in Ukraine, as both Russia and Ukraine are major suppliers of these rare gases. However, significant disruptions have been prevented. Reports from sources such as the Economist highlight investments in recycling these materials by companies and supplier diversification as factors that have strengthened the supply chain (see https://www.economist.com/finance-and-economics/2023/03/30/how-rare-gas-supply-adapted-to-russias-war). In the SCAN dashboard for 2023, imports of these rare gases are quite diversified, primarily sourced from Ukraine (29%), the US (25%), and China (22%). The HHI index is rather low at 0.2. Furthermore, there is domestic capacity for this product within the EU (with an exposure index of 0.18), suggesting that EU companies have some ability to diversify imports away from Russia to some extent.

domestic production,[102] confirming the strong position of EU companies in this market. The EU also shows a relatively high degree of import differentiation and high levels of substitutability with domestic production for key wet chemicals used in etching, such as Hydrogen chloride, Sulphuric acid, Hydrogen fluoride, Hydrogen bromide, Sodium Hydroxide and Potassium Hydroxide.

However, the evidence reported in Table A1.3 shows that there are potential foreign dependencies affecting other input products, potentially related to front-end manufacturing processes, such as Bromine (CN 28013090), Phosphorus (CN 28047090) Halides (CN 28129000), Artificial Corundum (CN 28181091), Chlorides (CN 28273985), or “Chemical products and preparations of the chemical or allied industries n.e.s.” (CN 38249996). All of these products are identified as being at risk of import disruption according to the SCAN structural indicators for the year 2023.

Two products, Bromine (CN 28013090) and Phosphorus (CN 28047090), have all structural indicators above the thresholds, with imports concentrated in Israel (51%) and Kazakhstan (88%) respectively, and very low levels in substitutability indicators. The products related to Halides (CN 28129000), Artificial Corundum (CN 28181091), Chlorides (CN 28273985), and “Chemical products and preparations of the chemical or allied industries n.e.s.” (CN 38249996) all have the substitutability indicator imports over exports above one, with imports concentrated from the following geographies: the US for Halides (CN 28129000) (57%), China for Artificial Corundum (CN 28181091) (67%), and Argentina for Chlorides (CN 28273985) (60%).

The CN code 3824996, "Chemical products and preparations of the chemical or allied industries n.e.s.," is an aggregate product category containing various chemical products and materials, including Indium Tin Oxide, which could be potentially relevant for specific semiconductor applications but is also used in many other electronics applications. One point of caution is that this product group accounts for a large portion of extra-EU imports within the segment (approximately 40%), and thus, it could be one product driving the overall segment results in terms of both structural indicators and the share of imports from products at risk within the segment. This product is mainly imported from South Korea (70%). The evidence on these products should be then complemented by industry and technical experts in semiconductor chemical processes assessing the extent to which these materials could be considered critical and strategic for the industry.

The EU also exhibits some degree of dependency for products related to photoresist materials and chemicals (CN 37079020[103] and CN 37079090[104]), with imports highly concentrated in Japan, and

102 The only exception is the product Helium (CN 28042910), which, although not classified as being at risk of import disruption, is still characterized by concentration indexes close to the thresholds and relatively low levels of substitutability potential with domestic capacity.

103 CN description “Developers and fixers in the form of chemical preparations for photographic use, incl. unmixed products, in measured doses or put up for retail sale ready for use (excl. salts and compounds of heading 2843 to 2846)”

104 CN description “Preparation of chemicals for photographic uses, incl. unmixed products put up in measured portions or put up for retail sale in a form ready for use (excl. varnishes, glues, adhesives and similar preparations, sensitising emulsions, developers and fixers and salts and precious-metal compounds etc. of heading 2843 to 2846)”

for one product related to photomasks (CN 37050090[105]), with imports highly concentrated in the US. The EU is a net importer in all these three products (ratio imports/exports above one).[106]

Two products related to Chemical Mechanical Planarization pads (CN 39199020, CN 59119091) also exhibit highly concentrated imports in the US. These two products also show low levels of import substitutability, with imports of product CN 39199020 more than doubling exports and imports of CN 59119091 at approximately four times the level of exports. Finally, other products with structural indicators above the thresholds are products related to wrought germanium (CN 81129940) and niobium (CN 81129950), with imports highly concentrated in China and the US, respectively, and relatively low levels of domestic production.

105 CN description "Photographic plates and film, exposed and developed (excl. products made of paper, paperboard or textiles, for offset reproduction and cinematographic film and ready-to-use printing plates)"

106 The exposure indexes for the products CN 37079020 and CN 37079090 are instead below the threshold, suggesting that there is some degree of EU domestic production for these products. Production data for CN 37050090 is instead not available in Prodcom.

Appendix 3

Table A3.1: List of CN8 product codes and descriptions related to the equipment segment

CN8 code	CN8 description
84141015	Vacuum pumps of a kind used for the manufacture of semiconductors or solely or principally used for the manufacture of flat panel displays
84145915	Fans of a kind used solely or principally for cooling microprocessors, telecommunication apparatus, automatic data processing machines or units of automatic data processing machines
84145925	Axial fans (excl. table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W, and fans for cooling IT equipment of 8414 59 15)
84145935	Centrifugal fans (excl. table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W, and fans for cooling IT equipment of 8414 59 15)
84145995	Fans (excl. table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W, axial and centrifugal fans, and fans for cooling IT equipment of 8414 59 15)
84149000	Parts of: air or vacuum pumps, air or other gas compressors, fans and ventilating or recycling hoods incorporating a fan, and gas-tight biological safety cabinets, n.e.s.
84195020	Heat exchange units made of fluoropolymers and with inlet and outlet tube bores with inside diameters measuring <=3 cm
84195080	Heat-exchange units (excl. those used with boilers and those made of fluoropolymers with inlet and outlet tube bores with inside diam-eters measuring <=3 cm)
84212920	Machinery and apparatus for filtering or purifying liquids, made of fluoropolymers and with filter or purifier membrane thickness <= 140 µm (excl. those for water and other beverages, and artificial kidneys)
84212980	Machinery and apparatus for filtering or purifying liquids (excl. such machinery and apparatus for water and other beverages, oil or petrol filters for internal combustion engines, artificial kidneys, and those made of fluoropolymers with filter or purifier membrane thickness <= 140 µm)
84213915	Machinery and apparatus for filtering or purifying gases, with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm
84213925	Machinery and apparatus for filtering or purifying air (excl. intake air filters for internal combustion engines, and those with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm)
84213935	Machinery and apparatus for filtering or purifying gases other than air by a catalytic process (excl. those with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm, and catalytic converters for exhaust gases from internal combustion engines)
84213985	Machinery and apparatus for filtering or purifying gases other than air (excl. isotope separators, those using a catalytic process, those with stainless steel housing and with inlet and outlet tube bores with inside diameters <= 1,3 cm, and particulate filters for exhaust gases from internal combustion engines)
84219910	Parts of machinery and apparatus of subheadings 84212920 or 84213915, n.e.s.
84219990	Parts of machinery and apparatus for filtering or purifying liquids or gases, n.e.s.
84431940	Printing machinery for use in the production of semiconductors
84861000	Machines and apparatus for the manufacture of boules or wafers
84862000	Machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits
84864000	Machines and apparatus specified in Note 11 C to chapter 84
84869000	Parts and accessories for machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays, and for machines and apparatus specified in note 11 C to chapter 84, n.e.s.
90112010	Photomicrographic optical microscopes fitted with equipment specifically designed for the handling and transport of semiconductor wafers or reticles (excl. stereoscopic microscopes)
90308200	Instruments and apparatus for measuring or checking semiconductor wafers or devices, incl. integrated circuits
90308400	Instruments and apparatus for measuring or checking electrical quantities, with recording device (excl. appliances specially designed for telecommunications, multimeters, oscilloscopes and oscillographs, and apparatus for measuring or checking semiconductor wafers or devices)
90308900	Instruments and apparatus for measuring or checking electrical quantities, without recording device, n.e.s.
90314100	Optical instruments and appliances for inspecting semiconductor wafers or devices or for inspecting photomasks or reticles used in manufacturing semiconductor devices

Source: JRC elaboration based on the official CN 2023 descriptions

Appendix 4

Table A4.1–Mapping of the WSTS classification to CN codes for ICs final products

WSTS Classification	CN8	CN8 Definition
DOSA	85411000	Diodes (excl. photosensitive or light emitting diodes "LED")
DOSA	85412100	Transistors with a dissipation rate < 1 W (excl. photosensitive transistors)
DOSA	85412900	Transistors with a dissipation rate >= 1 W (excl. photosensitive transistors)
DOSA	85419000	Parts of diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, light emitting diodes and mounted piezoelectric crystals, n.e.s.
DOSA	85413000	Thyristors, diacs and triacs (excl. photosensitive semiconductor devices)
DOSA	85414900	Photosensitive semiconductor devices (excl. photovoltaic generators and cells)
Analog	85415100	Semiconductor-based transducers (excl. photosensitive)
DOSA	85414100	Light emitting diodes "LED"
Other	85415900	Semiconductor devices, n.e.s.
Logic (incl. micro)	85423111	Electronic multi-component integrated circuits "MCOs" as processors and controllers as specified in note 12 (b) (4) to chapter 85, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits
Logic (incl. micro)	85423119	Electronic integrated circuits as processors and controllers, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits in the form of multichip integrated circuits consisting of two or more interconnected monolithic integrated circuits as specified in note 12 (b) (3) to chapter 85
Logic (incl. micro)	85423190	Electronic integrated circuits as processors and controllers, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits (excl. in the form of multichip or multi-component integrated circuits)
Rest of Memory	85423211	Electronic multi-component integrated circuits "MCOs" as memories as specified in note 12 (b) (4) to chapter 85
Rest of Memory	85423219	Electronic integrated circuits as memories in the form of multichip integrated circuits consisting of two or more interconnected monolithic integrated circuits as specified in note 12 (b) (3) to chapter 85
DRAM	85423231	Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
DRAM	85423239	Electronic integrated circuits as dynamic random-access memories "D-RAMs", with a storage capacity of > 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
SRAM	85423245	Electronic integrated circuits as static random access memories "static RAMs", incl. cache random-access memories "cache-RAMs" (excl. in the form of multichip or multi-component integrated circuits)
Rest of Memory	85423255	Electronic integrated circuits as UV erasable, programmable read-only memories "EPROMs" (excl. in the form of multichip or multi-component integrated circuits)
Flash Memory Chips	85423261	Electronic integrated circuits as electrically erasable, programmable read-only memories "flash EÂ²PROMs", with a storage capacity of <= 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
Flash Memory Chips	85423269	Electronic integrated circuits as electrically erasable, programmable read-only memories "flash EÂ²PROMs", with a storage capacity of > 512 Mbit (excl. in the form of multichip or multi-component integrated circuits)
Rest of Memory	85423275	Electronic integrated circuits as electrically erasable, programmable read-only memories "E2PROMs" (excl. flash EÂ²PROMs and in the form of multichip or multi-component integrated circuits)
DRAM	85423290	Memories in multicombinational forms such as stack D-RAMs and modules (excl. in the form of multichip or multi-component integrated circuits, and D-RAMs, S-Rams, cache-RAMs, EPROMs and flash EÂ²PROMs)
Analog	85423310	Electronic multi-component integrated circuits "MCOs" as amplifiers as specified in note 12 (b) (4) to chapter 85
Analog	85423390	Electronic integrated circuits as amplifiers (excl. multi-component integrated circuits)
DOSA	85423911	Electronic multi-component integrated circuits "MCOs" as specified in note 12 (b) (4) to chapter 85 (excl. such as processors, controllers, memories and amplifiers)
Other	85423919	Electronic integrated circuits in the form of multichip integrated circuits consisting of two or more interconnected monolithic integrated circuits as specified in note 12 (b) (3) to chapter 85 (excl. such as processors, controllers, memories and amplifiers)
Other	85423990	Electronic integrated circuits (excl. in the form of multichip or multi-component integrated circuits and such as processors, controllers, memories and amplifiers)

WSTS Classification	CN8	CN8 Definition
Other	85429000	Parts of electronic integrated circuits, n.e.s.
DOSA	85365003	Electronic AC switches consisting of optically coupled input and output circuits "insulated thyristor AC switches" (excl. relays and automatic circuit breakers)
Logic (incl. micro)	85365005	Electronic switches, incl. temperature protected electronic switches, consisting of a transistor and a logic chip "chip-on-chip technology" (excl. relays and automatic circuit breakers)
DOSA	90330010	Light-emitting diode "LED" backlight modules, which are lighting sources that consist of one or more LEDs, and one or more connectors and are mounted on a printed circuit or other similar substrate, and other passive components, whether or not combined with optical components or protective diodes, and used as backlight illumination for liquid crystal displays "LCDs" of apparatus of Ch 90

Source: JRC elaboration based on the official CN 2023 descriptions

Appendix 5

Definitions for semiconductor categories

- DOSA (Discrete, Optoelectronics, Sensors, Actuators) – Diodes, Small Signal Transistors, Power Transistors, Rectifiers, Thyristors, all other discretes, optoeletronics, sensors and actuators.
- Analog – Amplifiers/Comparators, Interface, Power Management, Signal Conversion, Application specific analog.
- Micro - MPU (microprocessor units), MCU (microcontroller units), DSP (digital signal processors).
- Logic - Digital Bipolar, General Purpose Logic, Gate Array, Std cell and fied prog logic, Display Drivers, Touch Screen Controller, Special Purpose Logic.
- DRAM – Dynamic Random Access Memories.
- SRAM - Static Random Access Memories.
- Flash Memory – Flash Memory.
- Rest of Memory – Rest of Memory.

Definitions for End Using Sectors

- Consumer - TV, Video, Audio, White Goods, Other Consumer like cameras, Games, Smart Watches, Fitness Monitors, etc.
- Automotive - Entertainment and Information, Power Train and All Other Automotive Applications.
- Computer & Office - Personal Computers, Office Equipment and Peripherals, Handheld and All Other Computer Equipment.
- Industrial & Instrument - Power Supply, IC Card, All Other Industrial like Test, Control and Measuring Equipment.
- Communications - Wireless Handset, Networking and Remote Access, Other Communications like Base Stations, Broadcasting Equipment, etc.
- Government - Military, Aerospace.

Definitions for Geographies

- Americas: United States of America and its possessions (including Puerto Rico), Canada, Mexico, Brazil and rest of Latin America (all other countries in Central and South America).
- Europe: Continental Europe including Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Monaco, Netherlands, Norway, Poland, Portugal, Romania, Russia, San Marino, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom (including its possessions, e.g. Cayman Islands), Vatican City; Africa, the Middle East including Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen and following other countries assigned to the region: Afghanistan, Armenia, Azerbaijan, Georgia, Kyrgyzstan, Kazakhstan, Turkmenistan, Uzbekistan.
- Japan

- China: People's Republic of China (including Hong Kong and Macau).
- Asia Pacific/All Other: All other Asia (including, without limitation, Korea (south and north), Republic of China (Taiwan), Singapore, Malaysia, Thailand, Indonesia and all other Asia), Australia and New Zealand. All other Asia includes countries such as Cambodia, Vietnam, Philippines, India, Pakistan, Myanmar and others.

Appendix 6

Functionalities of Non-Electric Vehicles (Non-EVs) that require semiconductors:

1. **Engine and Power Management:**
   - **Engine Control Units (ECUs):** ECUs use semiconductors to process data from sensors to control fuel injection, ignition timing, and air-fuel mixture. This optimizes engine performance, enhances fuel efficiency, and reduces emissions. By adjusting these parameters in real-time, ECUs ensure the engine operates at peak efficiency. This precise control is essential for meeting environmental regulations and improving vehicle performance.
   - **Transmission Control:** Semiconductors in transmission control units (TCUs) manage gear shifts, ensuring smooth and efficient power delivery from the engine to the wheels. They process data from various sensors to determine the optimal timing for gear changes. This results in a more responsive and fuel-efficient driving experience. TCUs also help protect the transmission from damage by preventing improper gear shifts.
   - **Power Conversion and Battery Management:** Semiconductors in power converters adjust voltage levels from the alternator to suit various vehicle components, ensuring systems like infotainment, lights, and sensors receive appropriate power. Efficient power conversion is crucial for maintaining overall energy efficiency. In non-electric vehicles, semiconductors also manage the car's 12V battery, ensuring it is charged properly and efficiently. Proper battery management is essential for reliable vehicle operation.
2. **Safety and Driver Assistance Systems:**
   - **Advanced Driver Assistance Systems (ADAS):** ADAS relies on semiconductors to process data from cameras, radar, and lidar sensors. These systems enable features like adaptive cruise control, lane-keeping assist, and automatic emergency braking. By providing real-time analysis and response, ADAS helps prevent accidents and reduce the severity of collisions. The integration of these systems is a step towards fully autonomous driving.
   - **Airbag Systems:** Semiconductors control the deployment of airbags, ensuring they activate at the right moment during a collision to protect passengers. They process data from impact sensors to determine the severity of a crash. This allows the system to deploy airbags with the appropriate force. Proper airbag deployment is crucial for minimizing injuries during accidents.
   - **Electric Power Steering (EPS):** Semiconductors in EPS control units process data from various sensors (like torque sensors and speed sensors) to determine the necessary steering assistance. This ensures that the steering is responsive and requires less effort from the driver. EPS systems enhance manoeuvrability, especially at low speeds and during parking. They also contribute to overall vehicle safety by improving steering precision.
   - **Proximity Sensors:** These sensors use semiconductors to detect obstacles around the vehicle, assisting with parking and preventing collisions. They provide real-time feedback to the driver, enhancing situational awareness and safety. Proximity sensors are particularly useful in tight parking spaces and crowded environments. The accuracy and reliability of these sensors depend on the advanced processing capabilities of semiconductors.
3. **Navigation, Entertainment, and Connectivity:**

- **Navigation Systems:** Semiconductors power GPS modules and processors that provide real-time navigation, traffic updates, and route planning. These systems enhance the driving experience by offering accurate and timely information. Advanced navigation systems can also integrate with other vehicle systems, such as ADAS, to provide additional safety features. The continuous improvement of semiconductor technology leads to more reliable and user-friendly navigation solutions.
- **Entertainment Systems:** Semiconductors enable high-quality audio and video playback, Bluetooth connectivity, and integration with smartphones and other devices. They process data from various sources to provide a seamless entertainment experience. This includes features like hands-free calling and streaming music. Advanced entertainment systems enhance the overall driving experience.

4. **Lighting and Body Electronics:**
   - **LED Headlights and Interior Lighting:** Semiconductors control the brightness and direction of LED headlights, providing better illumination and energy efficiency compared to traditional halogen bulbs. They enable adaptive lighting systems that adjust to driving conditions and oncoming traffic. Semiconductors also manage the ambient and functional lighting inside the vehicle, enhancing the overall driving experience. Proper interior lighting contributes to comfort and convenience.
   - **Climate Control and Power Windows/Seats:** Semiconductors in climate control systems regulate the temperature, airflow, and humidity inside the vehicle. They provide a comfortable environment for passengers by adjusting settings based on real-time data from environmental sensors. Semiconductors control the operation of power windows and seats, providing convenience and comfort to passengers. Proper control of these systems enhances the overall user experience.

Additional functionalities of Electric Vehicles (EVs) that require semiconductors

1. **Battery and Thermal Management:**
   - **Battery Management Systems (BMS):** BMS are critical in electric vehicles (EVs) and hybrids, ensuring the battery operates within safe parameters. They continuously monitor the state of charge, health, and temperature of the battery cells. By balancing the charge across all cells, BMS maximizes the battery's lifespan and performance. This management is crucial for preventing overcharging, overheating, and deep discharging.
   - **Thermal Management:** Semiconductors in thermal management systems help maintain optimal battery temperature, preventing overheating and ensuring efficient operation. They process data from temperature sensors to regulate cooling and heating systems. This helps extend the battery's lifespan and improve performance. Proper thermal management is essential for the reliability and safety of EV batteries.
2. **Electric and Hybrid Vehicle Systems:**
   - **Inverters and Converters:** These components use semiconductors to manage the flow of electricity between the battery and the electric motor. They convert DC to AC and vice versa as needed, ensuring efficient power transfer. Inverters and converters are crucial for the performance and efficiency of electric and hybrid vehicles. Their reliability and efficiency directly impact the vehicle's range and overall energy consumption.
   - **Onboard Chargers:** Semiconductors in onboard chargers convert AC power from the grid to DC power for the battery, enabling efficient and safe charging. They

manage the voltage and current levels to ensure proper charging. This helps prevent overcharging and extends the battery's lifespan. Advanced onboard chargers contribute to the convenience and reliability of EV charging.

3. **Charging Systems:**

   - **Charging Process Control:** Semiconductors in charging systems control the charging process, ensuring safe and efficient energy transfer from the charging station to the vehicle's battery. They manage the voltage and current levels to prevent overcharging and overheating. Advanced charging systems can also communicate with the grid to optimize charging times and costs. The development of fast and reliable charging solutions is essential for the widespread adoption of electric vehicles.
   - **Wireless Charging:** Semiconductors enable wireless charging technology, allowing EVs to charge without physical connectors, enhancing convenience. They process data from charging pads to ensure proper alignment and efficient energy transfer. This helps reduce wear and tear on charging connectors. Wireless charging systems contribute to the overall convenience and user experience of EVs.

4. **Electric Motor Control:**

   - **Motor Operation Management:** Semiconductors manage the operation of electric motors, ensuring smooth acceleration and efficient energy use. They process data from various sensors to control the motor's speed and torque. This results in a more responsive and enjoyable driving experience. Proper motor control is essential for the performance and efficiency of electric vehicles.
   - **Regenerative Braking Systems:** Semiconductors control regenerative braking systems, which recover energy during braking. This recovered energy is then stored in the battery, enhancing the overall efficiency of the vehicle. They process data from braking sensors to optimize energy recovery. Regenerative braking systems contribute to the extended range and efficiency of EVs.

Appendix 7

Various types of semiconductors used by the Automotive Sector

- **Discrete:**

Discrete semiconductors, such as transistors, diodes, and thyristors, switch and control high currents and voltages in power management systems, ensuring efficient power distribution. In motor control applications, they regulate electric motors, enhancing vehicle performance and efficiency. They are used in safety systems for functions like braking and stability control. Discrete components also manage the power supply to headlights and taillights in lighting systems and protect against overcharging and overheating in battery management systems.

- **Optoelectronics:**

Optoelectronic components, including LEDs, photodiodes, and laser diodes, are used in automotive lighting and sensing systems. LED headlights and taillights offer improved energy efficiency and longer lifespan compared to traditional bulbs. Photodiodes are used in sensors for ADAS, detecting light and converting it into electrical signals. Laser diodes are employed in lidar systems, providing high-resolution mapping and object detection for autonomous driving. Optoelectronics are also used in interior lighting systems, infotainment displays, and communication systems.

- **Sensors & Actuators:**

Sensors and actuators monitor and control various vehicle functions. Position sensors track components like the throttle and steering wheel, ensuring precise control. Proximity sensors aid in parking and collision avoidance. Temperature and pressure sensors monitor engine and environmental conditions. Actuators convert electrical signals into physical actions, such as opening valves or adjusting mirrors. In ADAS, sensors provide data for features like lane-keeping assist and adaptive cruise control. Actuators are used in systems like electronic power steering (EPS).

- **Logic:**

Logic semiconductors, including microcontrollers, DSPs, and ASICs, manage engine functions, infotainment systems, and body controls. Microcontrollers process data from sensors and execute commands. DSPs handle complex computations for tasks like speech recognition and image processing. ASICs are custom designed for specific functions, such as ADAS algorithms and image processing. Logic components are also used in vehicle-to-everything (V2X) communication systems, engine control units (ECUs), and transmission control units (TCUs).

- **Memory:**

Memory semiconductors store and retrieve data for various automotive systems. Volatile memory (RAM) provides temporary storage for data being processed. Non-volatile memory (Flash, EEPROM) retains data even when the vehicle is powered off, storing information for ECUs, infotainment systems, and ADAS. Memory components are also used in navigation systems, infotainment systems, and diagnostic systems.

- **Analog Integrated Circuits (IC):**

Analog ICs process continuous signals, converting and amplifying them for various applications. In automotive systems, analog ICs regulate voltage and current in power management. They are also employed in audio systems to amplify sound signals, in sensor interfaces to convert sensor signals into digital data, in fuel injection systems to control fuel delivery, in climate control systems to regulate temperature and airflow, and in battery management systems to monitor and balance battery cells.

- **Micro:**

Microcontrollers and microprocessors are the central processing units of many automotive electronic systems. They integrate memory, a CPU, and peripheral interfaces into a single chip, handling multiple tasks simultaneously. In engine management systems, microcontrollers optimize fuel injection and ignition timing. Infotainment systems rely on microprocessors for audio and video playback, navigation, and connectivity features. Body control modules use microcontrollers to operate power windows, locks, and lighting systems. Microprocessors are also used in ADAS and EV powertrains to control motor functions and energy management.

Additional Semiconductors in Electric Vehicles (EVs)

Electric vehicles (EVs) have additional semiconductor requirements due to their reliance on electric powertrains. Power semiconductors, such as insulated-gate bipolar transistors (IGBTs) and metal-oxide-semiconductor field-effect transistors (MOSFETs), manage the high power levels in EVs. These components are used in inverters to convert DC from the battery to AC for the motor, and in on-board chargers to manage battery charging. Wide-bandgap semiconductors, like silicon carbide (SiC) and gallium nitride (GaN), offer higher efficiency and performance, making them ideal for EV applications. EVs also require advanced battery management systems (BMS) to monitor and balance the charge of battery cells, ensuring safety and longevity.

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