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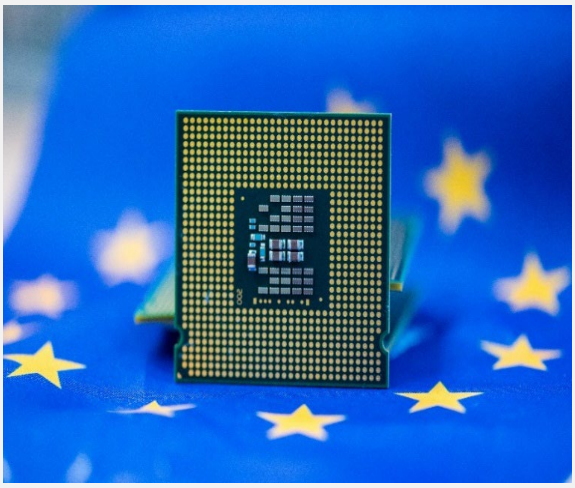

State of play future trends and vulnerabilites of the semiconductor supply chain

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Contents

Abstract

This note is focused on the supply chain of semiconductor products, the chips, increasingly at the core of the digital transformation. It identifies EU stance in the world supply chain, its dependency on non-EU products and technologies and provides a non-exhaustive overview of its vulnerabilities, discussing the challenges of listing a complete set of dependencies.

The semiconductor supply chain is highly specialized and complex with a worldwide dimension and a strong interdependency among firms. In the EU value chain, nearly 80% of input suppliers and 63% of customers to the companies in the chain are located outside the EU, defining the boundaries of EU vulnerability and its dependence on geopolitical considerations. EU dependency on foreign jurisdictions appears at different levels of the supply chain. The provision of raw materials and intermediate inputs, the dependency on water and energy are only some examples of potential sources of vulnerabilities if natural or man-made risks occur.

This study supports the activities of the European Semiconductor Expert Group, which aims at preparing the ground for the implementation of the future European Chips Act. It stems from the mapping of EU companies operating in the semiconductor supply chain undertaken at EU level, and complements the European Semiconductor value chain consultation which has been undertaken in the second half of 2022.

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This report benefited from comments and feedbacks provided by the colleagues in DG CNECT. We are also grateful to JRC colleagues for their support. In particular the Critical Raw Materials team for backing section 5.2, to A. Ciani and P. Bonnet for the analyses of trade data in section 5.2, to J.M. Rueda-Cantuche and L. Pedauga for the work on re-export (section 5.4, Appendix 3 and 4). We also thank R. Compano and two anonymous referees for their suggestions. The picture in the front page comes from https://audiovisual.ec.europa.eu/en/reportage/P-051873. As usual, all errors are ours, moreover, "the views expressed are purely those of the writer and may not in any circumstances be regarded as stating an official position of the European Commission".

1. General picture: complex, global and costly.

Incredibly interconnected and capital-intensive, the semiconductors industry is the backbone of the digital and green economy. Its key product, the chip, is a miniaturized piece of semiconductor materials designed, manufactured and packaged to perform some tailored functions. Semiconductor chips are the building blocks of digital products, from PCs and smartphones, to the infotainment and safety of cars or many other digital applications, as well as gaming consoles and domestic appliances. Over the past three decades, the world semiconductors market grew at a 7.5% compound annual growth rate, well above the 5% growth of world GDP[1]. Semiconductors have not only created innovation but also economic value. Between 1995 and 2015, Information Handling Services (his) estimated an additional $3 trillion in global GDP directly linked to semiconductors advancements and $11 trillion of indirect impact[2]. In 2022, sales of chips surpassed $675 billion worldwide, and in the coming four years, the market for chips is expected to increase by 20%, reaching $800 billion in 2026[3].

The supply chain of semiconductors is complex, global, and involves a large number of companies with a high level of interdependency. An example of the semiconductor supply chain is that of a smartphone application processor, i.e., a chip that can be considered the brain of the smartphone[4]. As many as 12 steps and commercial exchanges are needed to go from designing of the processor unit and the manufacturing of the semiconductor chips, to the packaging, before the final commercialization (Figure 1). For a single chip, the production in a manufacturing facility heavily relies on advanced design tools and intellectual properties (IP) which are likely licensed from US companies. It requires thousands of processing steps, about 300 different inputs, including raw materials and gasses most likely imported from Asia, and over 50 classes of high precision equipment tools[5] obtained predominantly from the EU, Japan and the US. In addition, large companies are likely to perform intermediate production steps in other countries so the entire production process, from the development of advanced research to the assembly and packaging, can easily entail the crossing of more than 70 international borders before a chip reaches the end customer[6]. The complexity

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[1] BCG (2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf.

[2] Information Handling Services (IHS), Moore's law impact, 2015.

[3] TechInsights, 2022. Sales refer to analog, memory, logic and discrete & optoelectronic chips.

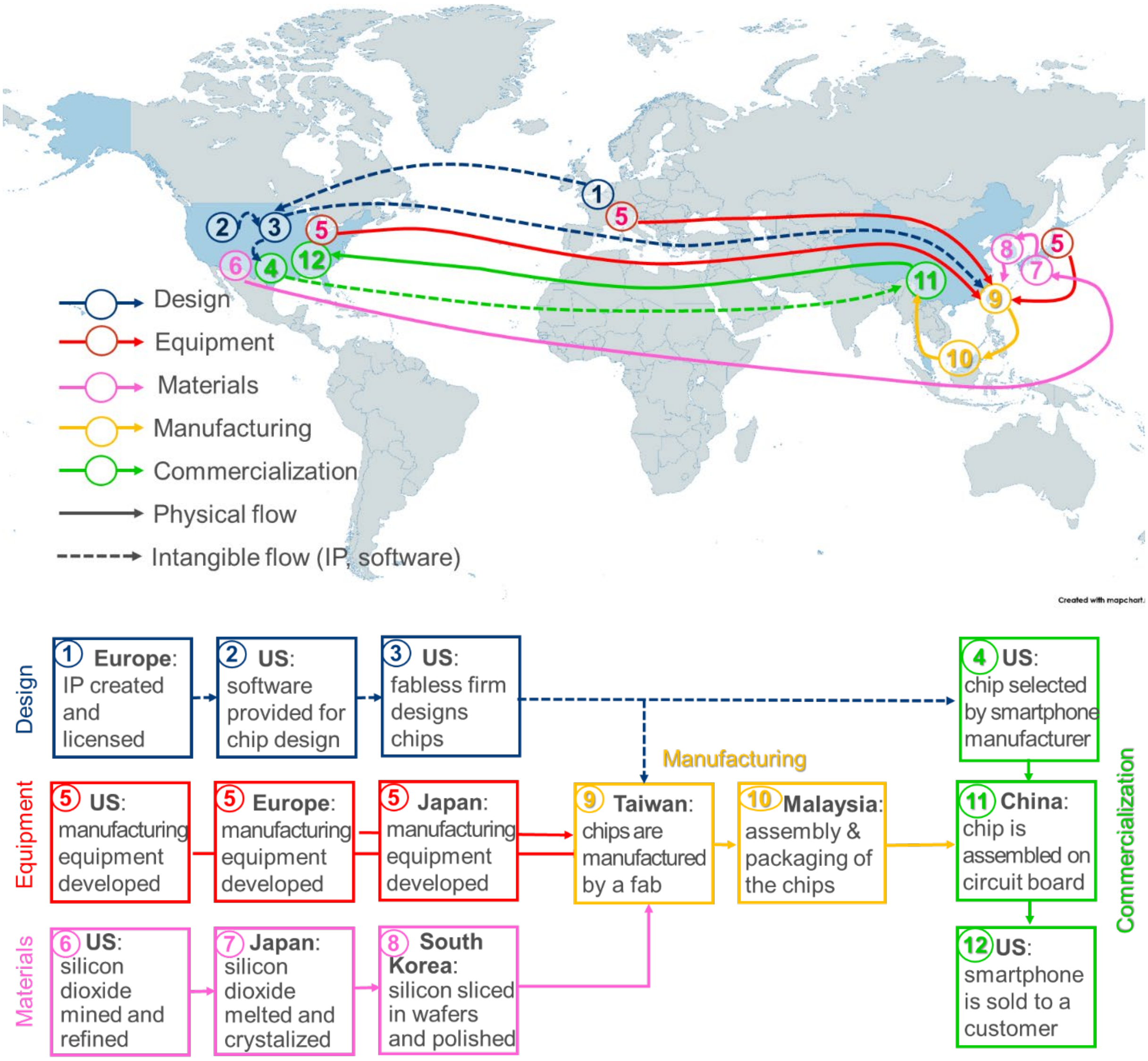
[4] Carrara, S., Bobba, S., Blagoeva, D., Alves Dias, P., Cavalli, A., Georgitzikis, K., Grohol, M., Itul, A., Kuzov, T., Latunussa, C., Lyons, L., Malano, G., Maury, T., Prior Arce, Á., Somers, J., Telsnig, T., Veeh, C., Wittmer, D., Baldassarre, B., Buesa, A., Black, C., Pennington, D., Christou, M., Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/386650, JRC132889.

[5] Each tool incorporates many technological sub-systems such as modules, lasers, mechatronics, optics and control chips (BCG, 2021).

[6] CSET (2021), https://cset.georgetown.edu/publication/sustaining-u-s-competitiveness-in-semiconductor-manufacturing/.

rapidly scales up when considering all the different semiconductor components (e.g., processor, memory, transmitter and receiver) of a product such as the smartphone provided in the example or a computer or other types of electronic devices and products requiring different types of chips (e.g., from consumer electronics, to automotive, to ICT).

Figure 1: The global journey of a smartphone application processor.



Source: JRC rearrangement from BCG (2021).

The high level of technological specialization and the large expenditures for chip manufacturing facilities and for the technological innovation have favoured economies of scale and geographical displacement. In the supply chain we observe today, the production sites are concentrated in the areas able to assure qualified workforce, funds (often public), and an ecosystem able to support the increasing complexity and R&D intensity of the more advanced productions[7] while back end operations are mostly localised in low labour cost countries for economies of scale considerations.

The recent shortage of semiconductors for the automotive industry has brought to the public attention both the strategic importance for the economy of the whole semiconductor sector and the fragility of such a globalized value chain. It has also made clear the extent of European dependency in many segments, from the production of wafers where the market leader is Japan with 56% (Europe stands at 14%) to the manufacturing of chips, dominated by the US, Taiwan and South Korea, with Europe representing a modest 7%, concentrated in mature nodes[8].

This note provides an overview of the segments of the value chain putting the EU in a wider context. The sections below will show the expected trends on chip demand and supply brought about by digitalization and the green transition and will detail some of the vulnerabilities of this value chain with a closer look to the EU position. This study supports the activities of the European Semiconductor Expert Group, which aims at preparing the ground for the implementation of the future European Chips Act. It stems from the mapping of EU companies operating in the semiconductor supply chain undertaken at EU level, and complements the European Semiconductor value chain consultation which has been undertaken in the second half of 2022.

2. Semiconductor supply chain: the segmentation and the players

Since the pioneer companies in the 1960s, the semiconductor industry structure has evolved from vertically integrated companies, performing all the production steps (e.g. Phillips in Europe), to a specialised structure where one company only operates in one or few layers of the supply chain. The layering of the supply chain and its strong specialization was favoured by the increase of technological complexity, the large R&D and capital costs needed for innovating and producing especially the smaller nodes, and the need to look for cost-saving solutions. Today no company (or even country) is vertically integrated across all stages of production. Instead, companies tend to be highly specialized in specific tasks and deeply interconnected with the other players in the global supply chain.

Signs of change in the organisation of the supply chain have been observed recently. With the Moore's law pointing to the miniaturization of chips, and the technology becoming more and more complex, in the recent years production phases (such as chip design and chip

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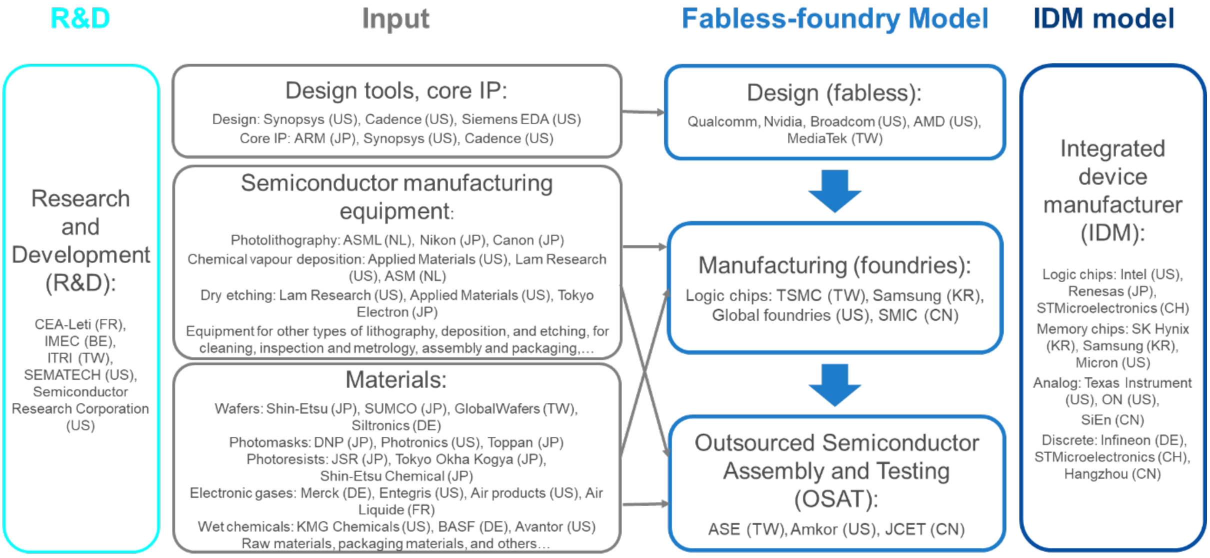
[7] Kleinhans (2021), https://www.stiftung-nv.de/sites/default/files/eu-semiconductor-manufacturing.april_.2021.pdf.

[8] See the Appendix for the definition of the node size.

assembling/testing and packaging) tend to be integrated back with production instead of being delocalized to external producers[9]. The tendency to insourcing production is accelerating after the supply chain disruptions experienced during the COVID pandemic which made chip production a national security concern.

Figure 2: Semiconductor supply chain and leader companies by segment.



Source: JRC rearrangement based on the top firms listed in CSET (2021) on 2019 market share data; top manufacturers of wafers and fabless are from Statista[10] 2023; R&D listing is based on reported R&D centres in SIA (2016).

In the current global production chain, the three main interconnected layers are: design, fabrication (or manufacturing) and the phase of testing, assembling and packaging. These technological layers can be executed by companies with different business models forming the semiconductor supply chain (Figure 2[11]).

Design refers to all the steps required to design a chip. The first is to derive a schematic model of the integrated circuit meeting the technical requirements of the chip while accounting for the electronic components specifications and their operating conditions. The

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[9] In 2015, Samsung lost Apple's order for production of iPhone application processors to TSMC, which developed the fan-out wafer-level packaging technology. Since then Samsung has increased its packaging capabilities and in 2022 it has established a Test & Package Center. Other players are also moving, TSMC plans to build a new semiconductor packaging plant in Taiwan. Intel will also invest US$7 bn and US$4.6 bn in Malaysia and Poland, respectively, to build packaging plants, and in Feb. 2023 it announced a $1.5 bn investments in Vietnam. Gartner forecast that the semiconductor packaging market is expected to grow from US$48.8 bn in 2020 to US$64.9 bn in 2025 (source: http://www.businesskorea.co.kr/news/articleView.html?idxno=88952). See also https://www.eetasia.com/the-5-leading-semiconductor-manufacturers-today/

[10] Statista: www.statista.com

[11] Fig. 2 puts together the production step with the business models of the supply chain.

schematic model (logic design) is then converted into a physical design, the integrated circuit layout, with interconnected electronic components (e.g. transistors) . Finally, validation and verification via software simulations will ensure that the physical design will operate as expected.

The design step is performed using specialized software tools known as *electronic design automation (EDA)*. EDA software (where market leaders are Synopsys, Cadence, Siemens EDA) contains a library of semiconductor devices as well as re-usable portions of designs, known as core *intellectual properties (IPs)*. EDA software may offer the possibility to simulate the physical, electrical, and thermal property of the designed circuit for validation. The IPs are usually developed by specialized companies (e.g., Arm, Synopsys, Cadence) and are incorporated in the chip design upon the granting of a license.

Fabrication is the process of converting the design in a semiconductor chip. It is performed in one or more semiconductor manufacturing facilities ("fabs" or "foundries"). The first ingredient is a wafer of silicon or other semiconductor materials (e.g., silicon carbide, gallium arsenide, indium phosphide). In the fab the wafer goes through numerous manufacturing processes (such as deposition, lithography, etching, implantation, metallization) to physically form the transistors, the other electronic devices and their metal interconnections. First, a thin film of material is deposited on the wafer to form a new layer, using a *deposition* tool. Then, after *masking* (protecting selective areas of the wafer using a photoresist film), the circuit pattern is drawn in the layer using a process called *photolithography*[12]. During the *etching* phase, the newly created pattern in the photoresist is further carved by removing the degraded film. Alternatively, in the *ion implantation* process, atoms are embedded in the created pattern. At this point, the photoresist is removed and the wafer cleaned from the residue of the process and made ready for another etching phase.

The procedure is usually repeated to add new layers, up to a dozen for most complex chips, until the desired layout is reached. 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.

These processes are referred to as "*front-end*" and carried out in one or more fabs. There are two business models for fabs: (1) fabs owned by *Integrated Device Manufacturers (IDMs)*, which manufacture chips based on their own designs; and (2) *foundries*, i.e., fabs operating independently and manufacturing chips for third-party customers.

Assembly, Testing, and Packaging (ATP) indicate the steps of cutting a finished wafer into separate chips; assembling each chip on a frame; wiring the assembled chip to connect

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[12] First, a "photoresist" is coated on the deposited material, then a photolithography tool passes light through the "photomask" with the circuit pattern to imprint the pattern by selectively dissolving the photoresist.

it to external devices, and enclosing it in a protective case or package. Testing and assembly are typically considered “back-end” processes of the fab.

ATP can be performed following two business models: (1) as *in-house ATP services* carried out in IDMs and foundries after fabrication; and (2) by *outsourced semiconductor assembly and test (OSAT)* firms, operating for third-party customers. ATP is relatively more labour-intensive than the other segments of the chain and typically produces an added value lower than that of the design and the fabrication. For this reason, ATP facilities are typically established in developing countries with low labour cost.

Some of the major players in the semiconductor supply chain are reported in Figure 2, including also those providing inputs and carrying out R&D. Inputs consist of semiconductor materials (such as silicon) and other raw materials, specialty chemicals (e.g., photoresists) and gases (e.g. neon) for the manufacturing and the ATP steps. The raw materials used in the semiconductor manufacturing processes span a large proportion of the periodic table. Section 5 provides more details about the required raw materials and the related EU dependencies.

Fundamental and applied R&D is a key aspect for the technological advancement in semiconductors. The research in the semiconductor field (from materials, to electronic circuits, to processes, and manufacturing equipment) has also a global scale, paralleling the physical production of chips. About 36% of all Chinese scientific publications related to semiconductors are co-authored with foreign institutions. This percentage increases to 60% for publications of US institutions[13]. Additionally, the presence of organisations that bring together companies, universities and research institutions, has favoured innovation and R&D collaborations. Institutions such as IMEC in Belgium, CEA-Leti in France, Fraunhofer in Germany but also A*STAR in Singapore or Semiconductor Research Corporation (SRC) in the US have pulled funds and research efforts to create technological breakthroughs.

The high specialization of the semiconductor industry has favoured geographical sites providing qualified workforce and R&D capabilities, shaping the segmentation of the supply chain observed today (Figure 3). Along the value chain, the US-Semiconductor Industry Association (SIA)[14] counts for more than 50 regions providing 65% or more of the total global supply. For the design, the US is a leader for EDA and core IP. In the front-end wafer fabrication, Taiwan and South Korea contends the leadership, while China plays a top role in memory production. For the back-end manufacturing, the concentration of companies is still in Taiwan, China and South Korea. Instead, for the manufacturing of equipment, the US, Japan and the EU are the main players, sharing different specializations for the many types of equipment. For process chemicals (e.g., photoresists, photomask), Japan is leading the

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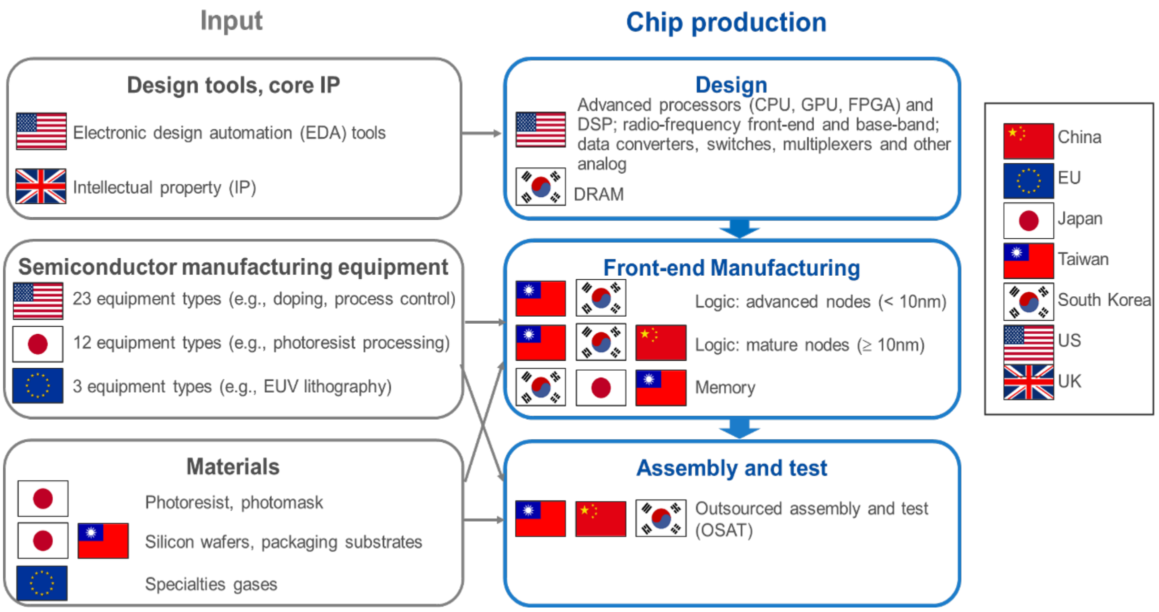
[13] BCG (2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

[14] BCG (2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf .

production, with some shares also for Taiwan and the EU. With the only exception of cobalt and platinum, China has large shares of almost all key materials including 95.7% for primary low grade gallium, 83.6% of tungsten, 82% magnesium, 64% of silicon (the most used material for wafers)[15].

Figure 3: Geographical concentration of the semiconductor supply chain: value chain activities where one region accounts for about 65% or more of the global share measured in capacity for the manufacturing, assembly and test and in revenues for the other activities



Source: JRC elaboration on BCG (2021).

2.1 The geographical imbalance of the production

The geographical imbalance of production is well known, with top players (especially for lower node size, see below) located in Taiwan and South Korea, and the US, with China rapidly advancing. Europe represents a 7%, share of total world production in 2022, down from 9% in 2009 (

Figure 4) in spite of a compound annual growth of 4% in the period between 2018 and 2022.

Altogether, the US contributes 39% of the total value added of the global semiconductors industry, while Europe (especially the Netherlands, Germany and the UK) accounts for 11%[16].

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[15] CSET (2021), https://cset.georgetown.edu/publication/sustaining-u-s-competitiveness-in-semiconductor-manufacturing/.

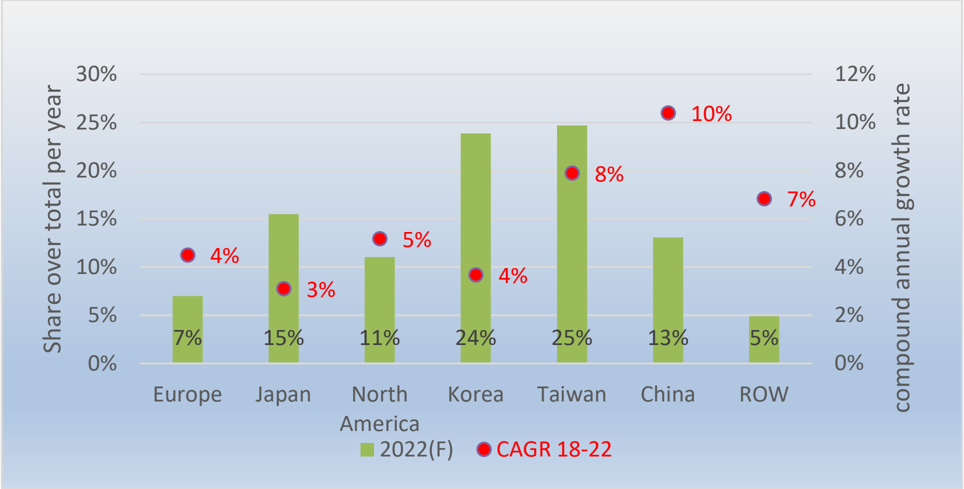
[16] CSET (2021), https://cset.georgetown.edu/publication/sustaining-u-s-competitiveness-in-semiconductor-manufacturing/.

For the Asian countries, Japan and South Korea follow with 14% and 16% respectively, preceding Taiwan with 12%. China, with a modest 6% of the global supply chain value added, is quickly developing capabilities in many segments of the value chain. Home of dominant suppliers of raw materials and traditionally strong in the back-end operations (assembly, testing and packaging), China remains highly reliant on imports of semiconductors ($300 bn a year), especially for high-end chips and frontier applications for AI, space and defence, dominated by the US, South Korean and Taiwanese companies.

The future developments, hence the balance of power across regions, will depend not only on private money invested but also and foremost on public support and on the effects of the US export control measures, harshened in October 2022 which are likely to reshape the geography of chip production.

It is clear that the global scale of this supply chain cannot be easily decoupled to achieve self-sufficiency. BCG and SIA estimate that a parallel fully self-sufficient local supply chain in each region of the world would require at least $1 tn incremental upfront investments. Europe would need an estimated upfront investment of more than $300 bn to replicate the whole supply chain. Additional annual costs as high as the profits of the whole semiconductor value chain would be necessary to maintain the self-sufficiency. Such additional investments would cause an increase in semiconductor prices estimated to range between 35% and 65%[17]. Ultimately the increased chip price would reach consumers, depress final demand, erode companies' margin, slow down R&D and most likely expel less productive companies from the market if not backed by public subsidies.

Figure 4: Market share for chip: (physical) production (in square inches of wafers) by region.



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[17] BCG (2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf .

Source: JRC elaboration on data TechInsights, Electronics and Macroeconomy Industry Forecast, accessed 08-02-2023. CAGR stands for compound annual growth rate. F indicates forecasted values.

2.2 Mutual interdependency of the Supply Chain

The worldwide dimension of the semiconductor supply chain with its concentration points requires optimized and dedicated logistics for moving materials, equipment, and products across oceans and borders[18]. Besides logistics, the removal of trade barriers and tariffs is the other important factor favouring global trade flows. Under the WTO Information Technology Agreement (ITA[19]), the import duties on a wide range of information technology products were eliminated in 1995 and the list was further expanded in 2015. Among the six main categories of goods receiving duty-free status, semiconductors and semiconductors equipment accounted for approximately one third of the export in 2017[20].

The removal of the international trade barriers and tariffs for the semiconductor products has also promoted robust trade flows of intermediate and unfinished products. The extent of the interdependencies between the different geographical regions and the increase of the global flows are reported in Table 1 and Table 2, respectively, for the integrated circuits. China (including Hong Kong) had the highest trade flows in 2021, in particular from Taiwan and ASEAN (Association of Southeast Asian Nations) countries. EU27 not only has a strong trade with China but also a CAGR of import with the same country around 19.5%. The link between trade barriers and trade flows towards specific areas has to be borne in mind when considering vulnerabilities. Any natural or man-made event that influences these trade flows will affect companies that source inputs from of sell products to these areas.

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[18] An example is the company DHL, which provides specialized shipping services specifically dedicated to the whole supply chain of semiconductors: https://www.dhl.com/global-en/home/industry-sectors/technology/technology-expertise/semiconductor-logistics.html (accessed on 20/10/2022)

[19] https://www.trade.gov/trade-guide-wto-it-agreement (accessed on 20/10/2022), the list of the signatory countries accounts for approximately 95% of world trade in IT products.

[20] See https://www.wto.org/english/res_e/booksp_e/ita20years_2017_full_e.pdf.

Table 1: Heat map of the global flows of import (in billion EUR) in 2021 relative to electronic integrated circuits and their parts

From→ To (Reporter)↓	ASEAN	China	EU27	Japan	South Korea	Taiwan	USA	TOTAL
ASEAN		34	4	7	19	27	7	97
China	122		11	24	95	175	17	445
EU27	13	5		1	1	3	3	26
Japan	3	2	1		2	12	2	21
South Korea	5	18	1	3		12	3	42
Taiwan	12	17	2	9	14		4	58
USA	21	2	2	1	2	5		32
TOTAL	176	78	21	43	133	234	37	721

Source: data taken from UN Comtrade for HS code 8542 in 2021. Data refers to import from the importer.

Table 2: Heat map of the CAGR (in percentage) for the import in the period 2017-2021 relative to electronic integrated circuits and their parts.

From→ To (Reporter)↓	ASEAN	China	EU27	Japan	South Korea	Taiwan	USA	AVG on import
ASEAN		23.2	4.7	9.6	5.4	7.1	-5.7	9.7
China	10.8		16.2	7.8	5.8	15.7	10.5	11.2
EU27	16.4	19.5		-8.9	12.0	7.6	21.1	15.1
Japan	1.9	8.1	-0.3		2.5	8.2	1.1	5.7
South Korea	3.1	17.1	14.9	1.5		8.6	-5.3	9.3
Taiwan	14.6	19.3	6.3	12.0	21.4		3.8	15.5
USA	7.3	-4.9	-5.6	-8.0	4.4	7.1		4.5
AVG on export	10.5	18.8	8.6	7.6	6.9	13.4	4.4	

Source: data taken from UN Comtrade for HS code 8542 in 2017 and 2021. Data refers to import from the importer.

> *"It would be unrealistically expensive and unproductive to attempt to replicate the global supply chain in any single country in an attempt to achieve self-sufficiency."* [21]

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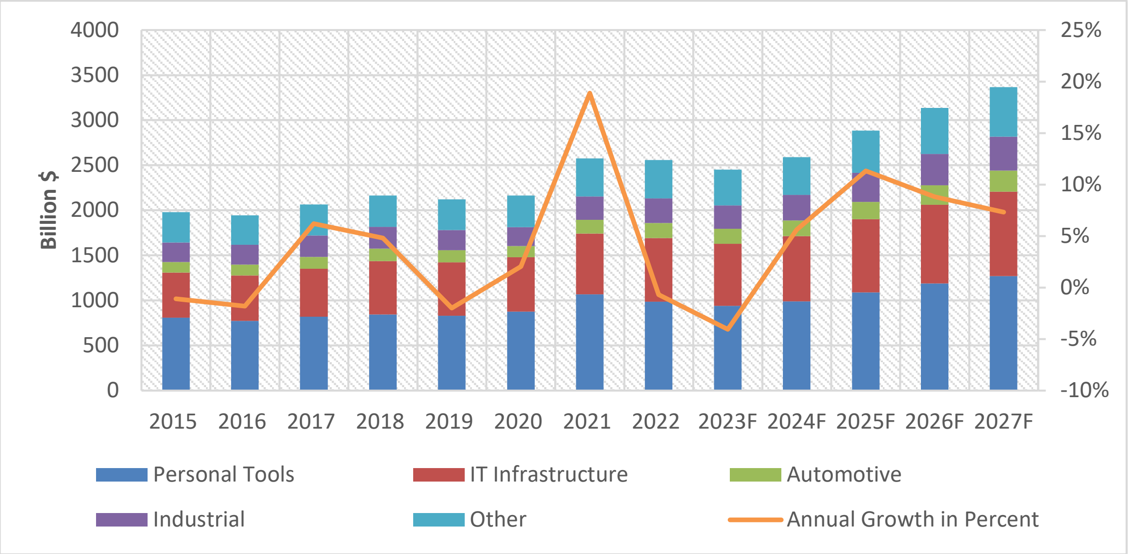
[21] BCG (2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf .

3. Demand side: global electronic sales are expected to reach $3.5tn in 2027

The digitalisation of life and business has boosted the demand of chips in the past years and will accelerate it even further, conditional to global demand outlooks and geopolitical considerations. In 2021, global electronics sales were $2.6 tn, and are expected to reach $3.5 tn in 2027 (Figure 5) despite the geopolitical tensions between US and China and the effect on inflation caused by the war in Ukraine and the soaring energy prices. “Megatrends such as working from home, the widespread application of artificial intelligence and machine learning, and rising demand for electric cars, all of these indicate that the demand for semiconductors will continue to rise as we move deeper into a digital-first society”[22].

Figure 5: Global sales of electronics by main segments.



Source: TechInsights, Electronics and Macroeconomy Industry Forecast, accessed on 08-02-2023. Annual growth stands for the annual growth of total sales for all segments. Table 3 has additional breakdowns for each segment.

According to McKinsey, 70% of the growth in the demand of semiconductor chips will be driven by three sectors: computing and data storage, automotive and wireless communication[23]. TechInsights estimates a 42% growth in electronic sales for IT Infrastructure in the period 2021-2027 (Table 3). The rapid expansion of cloud computing and the growth of data centers and supercomputing is likely to push up the demand for

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[22] Sentence attributed to Ondrej Burkacky, senior partner in McKinsey’s Munich, see https://www.newelectronics.co.uk/content/interviews/strong-chip-growth-forecast-through-to-2030/

[23] See https://www.newelectronics.co.uk/content/interviews/strong-chip-growth-forecast-through-to-2030

servers and mainframes (+59% in the period 2021-27). Data storage will continue to grow (+54% in 2027 as compared to 2021) pushed by the need to stockpile vast amounts of data, being generated nowadays mostly by videos recorded by smartphones and shared through social media applications[24]. In automotive, infotainment, autonomous driving systems, electrification of the engines and advancements in safety features will drive up electronics presence in cars with electronic sales expected to reach a +56% by 2027. The automation of the industrial production is expected to exploit AI, sensors and connectivity to improve the efficiency, rising the demand of electronics of +50% in 2027 as compared to 2021[25].

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[24] Ericsson Mobility Report, November 2022, available at: https://www.ericsson.com/4ae28d/assets/local/reports-papers/mobility-report/documents/2022/ericsson-mobility-report-november-2022.pdf (accessed on 6/12/2022)

[25] TechInsights (July 2022) expects continuing growth with silicon demand increasing at a CAGR of 5.6% as the industry expands to back the 5G extension, AI proliferation, and the growing data economy.

Table 3: Worldwide electronic sales, compound annual growth rate in various years and expected percentage growth between 2021 and 2027.

	16-21	***22-27***	***21-27***
	CAGR	**CAGR**	**% change**
Personal Tools	**6.7%**	**4.1%**	**21.4%**
PCs	10.8%	2.3%	11.1%
Tablets	1.5%	2.1%	9.1%
Cellular Handsets	4.9%	6.5%	36.6%
Audio/Video	3.0%	3.0%	14.8%
Other Devices	5.8%	4.6%	27.1%
IT Infrastructure	**6.0%**	**5.1%**	**41.7%**
Wireless	3.6%	5.9%	38.1%
Wired	1.6%	5.5%	36.2%
Servers& Mainframes	12.2%	6.2%	59.4%
Storage	6.2%	6.4%	53.9%
Peripherals	4.1%	-0.5%	2.7%
Other	2.5%	3.2%	27.2%
Automotive	4.6%	6.2%	55.7%
Industrial	3.5%	5.5%	49.6%
Other	5.1%	4.9%	37.2%
TOTAL	**5.8%**	**4.8%**	**34.2%**

Source: TechInsights, Electronics and Macroeconomy Industry Forecast, accessed 08-02-2023.

Starting from the demand of electronic devices, it is possible to quantify the demand for semiconductor chips. However, there is not a unique way to define demand. If one measures the demand of chips in terms of the number of chips sold to the final industrial users i.e. the electronic device makers, then US-based companies would drive one third of the global demand[26] (Table 4) followed by China with 26%, while Europe stands at a modest 10% .

However, the electronic device makers often do not manufacture their devices in the same country where the company is headquartered or registered. Rather, part of the production process is typically taking place in different countries. In this case, China would take the lion's

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[26] According to BCG (2021), US-based companies have a 45% market share for large PCs and information and communication infrastructure including data centers and network equipment, and 30% market share in smartphones and industrial equipment.

share of global demand, absorbing more than one third of all the manufactured chips worldwide, followed by the US and Taiwan. Finally, if demand is measured in terms of the location of consumers or end users that buy the electronic devices containing chips, then the relative shares change again. In this case, Europe accounts for 20% of the chip sales not far from the US (25%) and China (24%).

Table 4: Global semiconductors sales by geographic area, 2019 (%).

	DEMAND (%)		
	Headquarter of the electronic device maker	Where the device is manufactured/assembled (end users)	Location of consumers
US	33	19	25
China	26	35	24
Taiwan	9	15	1
S.Korea	11	12	2
Japan	10	9	6
Europe	10	10	20
Other	1	0	22

Source: rearranged data from BCG (2021). China refers to mainland China.

The difference between these three measures is an indication of the different location of company headquarters, manufacturers and end users of electronic devices. The data highlights that in Europe, **a large share of electronics purchased by European consumers are actually manufactured or assembled elsewhere** (most likely in China which is the destination of 35% of global chip sales), **by electronic device makers located outside the EU** (most likely in the US which hosts 33% of the headquarters).

The mismatch between demand and supply in Europe is clear. According to TechInsights data, in 2019, Europe produced about 7% of all semiconductors vis à vis a demand going from 10% to 20%, depending on the definition.

This is confirmed by trade data[27]. The EU is a net importer of diodes, transistors, and similar semiconductor devices, which includes the less advanced semiconductor technology, with a trade deficit close to €6 bn in 2020. China is the leading partner to the EU with more than 30% of total EU import of these products starting from 2007 onwards (growing to over 50% in 2019 and 2020) reflecting the role of China in the production of less advanced chips and in back-end.

The EU is also a net importer of electronic integrated circuits such as processors, memories, and amplifiers, including the most advanced chips employed by the consumer electronics, the automotive, and the space industry. The EU trade deficit in this category has consolidated

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[27] Ciani (2022) , https://joint-research-centre.ec.europa.eu/system/files/2022-04/JRC129035.pdf.

around €6 bn from 2016 onwards. Taiwan is the leading exporter of integrated circuits to the EU, accounting on average, for around 20% of EU imports in the period 2017-2020.

The gap between EU supply and demand is not likely to change any time soon, with global demand expected to grow yearly at 4.8% between 2022 and 2027 (Table 3) and with EU production rising yearly at 4% in the last five years (

Figure 4). This mismatch is likely to be even larger as EU production is mainly on mature nodes, precisely those needed to fuel the green transition e.g. in automotive, which is expected to increase its chip demand substantially in the next years.

4. Supply side: global chip sales are expected to exceed $800 billion in 2026

The supply chain is highly specialized and diversified for the different types of chips. Indeed, there is a variety of chips that are employed in many different electronic devices for diverse markets, and are manufactured using different semiconductor technologies. Chips can be divided in three groups depending on the type of functions performed (Table 5).

Logic semiconductor devices (also referred to as digital) are based on binary logic (0 and 1), e.g., the presence or the absence of a voltage. They are the fundamental building blocks for computing (e.g. CPUs), but also for digital signal processors, field programmable gate arrays (FPGAs), graphics processing units (GPUs), application specific integrated circuits (ASIC), and other connectivity products.

Logic chip design is concentrated in the United States with South Korea, Europe, Japan, Taiwan, and China each having much smaller market shares. Instead, the production of logic chips is concentrated in East Asia and especially in Taiwan, for both legacy and—especially—leading-edge nodes. Only TSMC (Taiwan) and Samsung (South Korea) have commercial logic chips at the leading edge (5 nm and below).

Memory devices are used to store information and can be found in computers, smartphones and electronic devices. Two are the most common types of memories:

- **DRAM**[28] memory is volatile and used to temporary store information. It is used in PC, servers and smartphones. An increasing need of DRAM for automobile applications such as for advanced driver-assistance systems is expected in the near future.
- **NAND**[29], the most common type of flash memory, is capable of permanently storing information. Examples of NAND memories are the solid state drives (SSDs) used in laptop hard drives.

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[28] DRAM stands for Dynamic Random Access Memory.

[29] NAND stays for “NOT AND”, which is the type of logic operation used by the memory building block (“logic gate”) for writing and reading data bits.

Memory chip design is mostly done in South Korea, and the United States, followed by other East Asia countries (e.g., Taiwan for DRAM and Japan for NAND). Memory chip production is concentrated in East Asia. The DRAM production is dominated by South Korea. Instead, NAND production is more distributed in East Asia (Japan, South Korea, and China). Part of the reason for the concentration in East Asia is that memory chips are easier to produce than logic chips so their production has been shifted to countries assuring a competitive advantage.

Discrete, Analog, and Optoelectronic devices (DAO). DAO includes a variety of different chips. Discrete devices are designed to perform a single electrical function (e.g. a single transistor in a package). Analog devices handle analog signals (e.g., a digital-to-analog signal converter)[30]. Optoelectronic devices handle the light, to produce or receive optical signals (e.g., the image sensors of the cameras)[31].

The production of discrete, optoelectronics, and sensors is concentrated in East Asia. However, most of these devices are using legacy technology and thus, substitutes are typically available in Japan and Europe, which are also major discrete and optoelectronics producers[32]. The production of analog chips is spread worldwide, with Europe and the US sharing the market with East Asia.

A summary of the different types of chip with their main designers and manufacturers is provided in Table 5. Among the top players, the EU is competitive only in the DAO segment, with Infineon, Bosch and Osram, whereas for logic chips, Europe is playing a minor role with STMicroelectronics and NXP.

The sale of the different chip types (logic, memory and DAO) has increased steadily in the last years with a CAGR of about 4% in produced units in the period 2015-2020 (Figure 6), leading to a CAGR in sales (i.e., total monetary value) of about 5% for logic and DAO and 9.3% for memory (Figure 7). Interesting, DAO with 85% of all the semiconductors units produced worldwide, only represents 44% of the sales in dollars during the period 2015-2020. This is an indication of the lower price of mature technologies included in the DAO, or alternatively of the higher prices (hence margins) of more advanced technology related to small node sizes in logic and memory chips.

For the coming years, total sales are expected to exceed $800 bn in 2026 (up from $585 bn in 2021) with DAO growing at a CAGR of 7.2% in the period 2021-26 (Figure 7) and representing again the bulk of semiconductor production forecasted in 2026. Sales of

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[30] Analog semiconductor devices handle real-world signals, which are inherently analog (i.e., continuously varying signals like the electrical current or the voltage). Their essential function is to process analog signal when the signal at either input, output or both is analog. They can be used for a variety of applications such as signal conversion (e.g., digital-to-analog or analog-to-digital conversion), signal filtering, amplification, or comparison, power management (e.g., convert, control and distributed DC power, or AC to DC power conversion).

[31] Optoelectronic devices can be found in the image sensors of the cameras, lasers, optical receivers etc.

[32] CSET (2022), https://cset.georgetown.edu/publication/sustaining-u-s-competitiveness-in-semiconductor-manufacturing/.

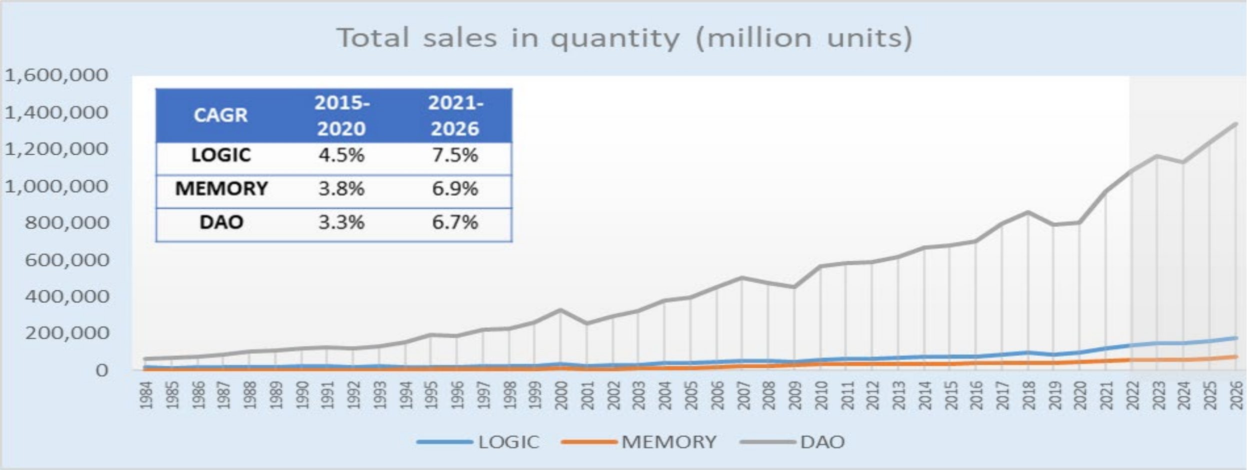
memory and logic are forecasted to grow at a CAGR of 6.8% each in the period 2021-2026, and are expected to represent respectively 4.5% and 10.8% of total unit produced worldwide.

Table 5: Types of chips with their main designers and manufacturers.

	Logic	Memory	DAO
Examples	CPU, GPU, FPGA, ASIC, etc.	DRAM, NAND	Analog: digital-to-analog or analog-to-digital conversion, amplification, power conversion, etc. Optoelectronics: image sensors of the cameras, lasers, optical receivers, etc.
Main designers	Intel (U.S.), AMD (U.S.), Nvidia (U.S.), Xilinx (U.S.)	Only IDMs: **DRAM:** Samsung (South Korea), SK Hynix (South Korea), Micron (U.S.) **NAND**: Samsung (South Korea), Toshiba (Japan), Western Digital (U.S.), Micron (U.S.), Intel (U.S.), SK Hynix (South Korea)	
Main manufac-turers	**Foundry**: TSMC (Taiwan), Samsung (South Korea), Global Foundries (US), SMIC (China) **IDM:** Intel (US), Renesas (Japan), STMicrolectronics (Switzerland), NXP (US/Netherlands)		**Discrete**: Infineon (Germany), STMicroelectronics (Switzerland), Hangzhou (China), Onsemi (U.S.), Mitsubishi (Japan) **Analog**: Texas Instrument (U.S.), Osemi (U.S.), SiEn (China), ASMC (China), Bosch (Germany), STMicroelectronics (Switzerland), TowerJazz (Japan) **Optoelectronics:** Sony (Japan), Nichia (Japan), Samsung (South Korea), Osram (Germany),

Source: JRC elaboration. See also CSET (2021).

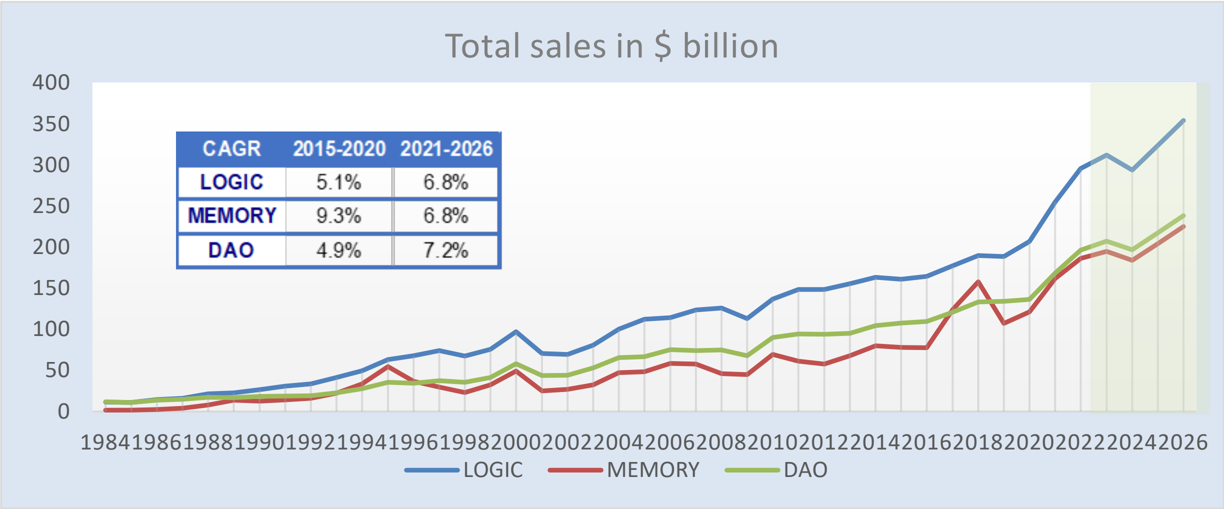
Figure 6: Yearly trend of the world sales of semiconductors in number of units.



CAGR	2015-2020	2021-2026
LOGIC	4.5%	7.5%
MEMORY	3.8%	6.9%
DAO	3.3%	6.7%

Source: TechInsights Inc., accessed in July 2022. DAO stands for discrete, analog and optoelectronics.

Figure 7: Yearly trend of the world sales of semiconductors in billions of dollars.



CAGR	2015-2020	2021-2026
LOGIC	5.1%	6.8%
MEMORY	9.3%	6.8%
DAO	4.9%	7.2%

Source: TechInsights Inc., accessed in July 2022. DAO stands for discrete, analog and optoelectronics.

4.1 No chip left behind

Each technological segment (e.g., automotive, consumer electronics) and each electronic device requires a mix of chips each one with peculiar specifications. Fast operations in computers need small and fast processors equipped, most likely, with the latest technological nodes associated to the smallest transistor size[33]. They also need memory to store data and interfaces to assure connectivity (DAO). The proportion of different types of chips is approximately, 64% logic, 18% memory and 18% DAO. Any shortage, delay, or disruption in

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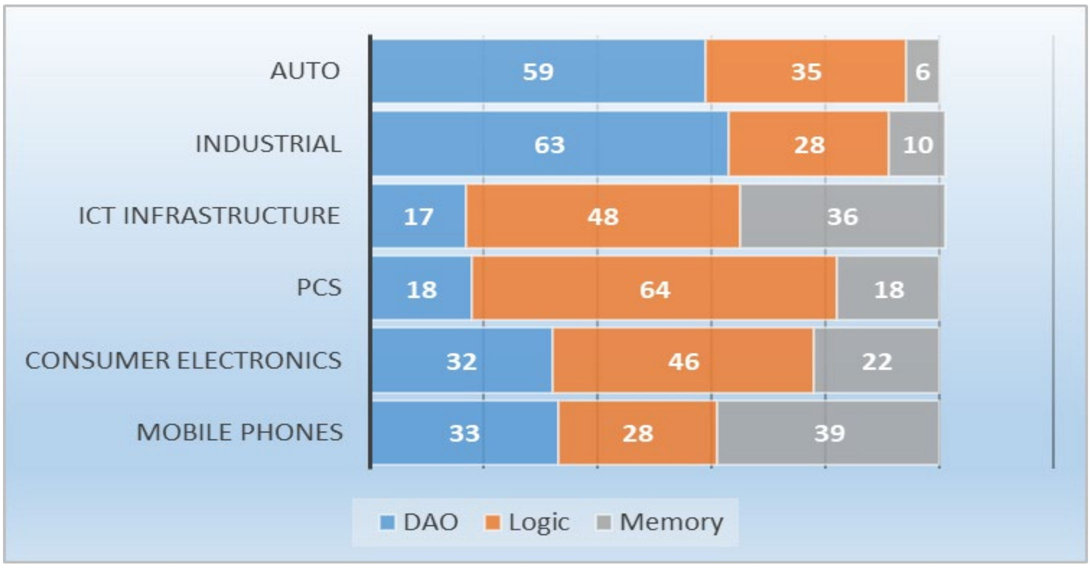
[33] See the Appendix for the definition of the node size.

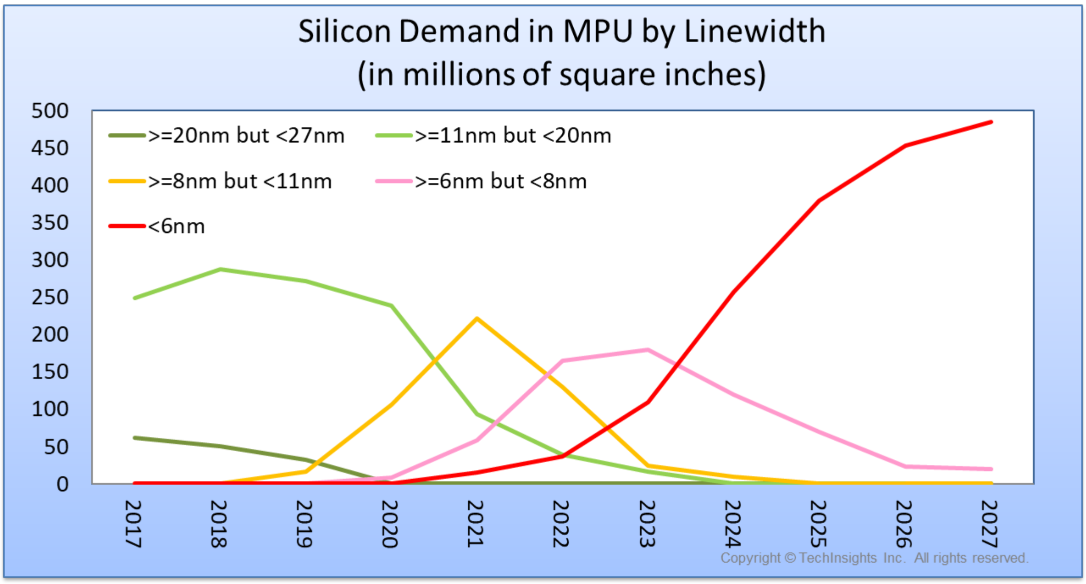
the supply chain of a single type of chip will ultimately impact the entire production. The requirement of different chip types happens also in automotive and other industrial segments: more than half of the chips used there are DAO and only about 30% are logic. For other segments (i.e., mobile phones, consumer electronics and ICT) the percentages varies according to the application (Figure 8) but the result does not change. Each electronic device uses (and will use) different types of chips, not necessarily all leading edge. **Any shortage in mature nodes is therefore likely to also impact products using leading edge technology**. This should be taken into account when public authorities decide to subsidise production.

Figure 8: Global semiconductors sales by allocation market, 2019 (%).

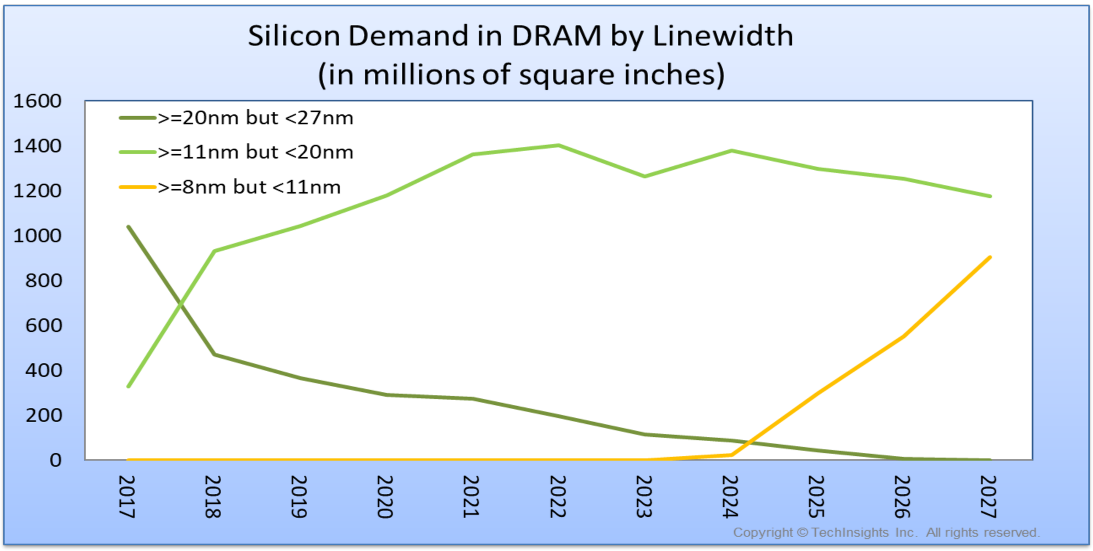


Source: JRC rearrangement from BCG (2021), DAO= discrete, analog, optoelectronics and sensors. ICT Infrastructure includes data centers and communication networks.

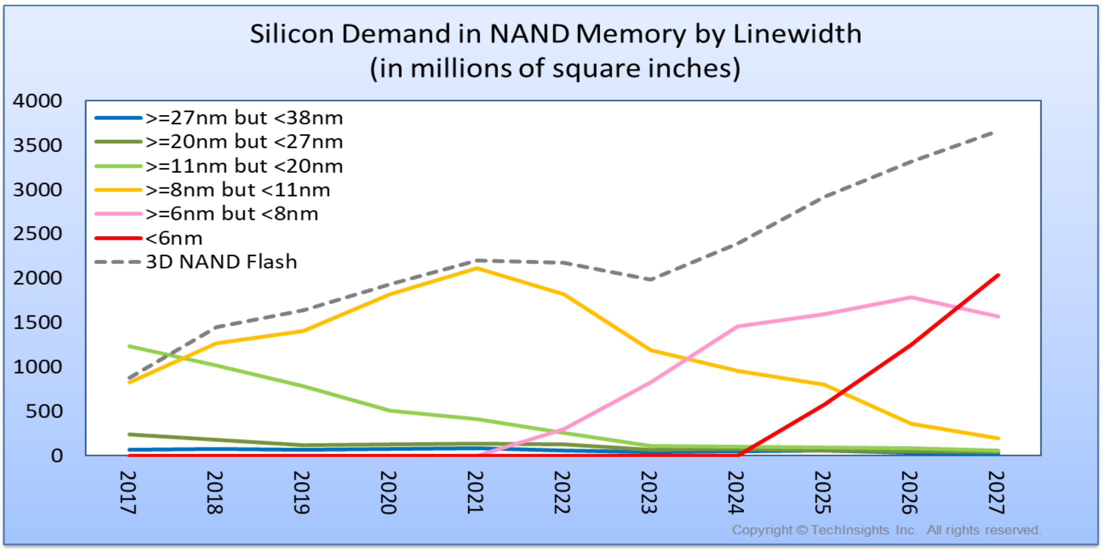
Figure 9: Silicon demands in millions of square inches for the different node size



(a) Silicon demand for logic chips for microprocessors (MPU)



(b) Silicon demand for memory chips of type DRAM (i.e., volatile memory)



(c) Silicon demand for memory chips of type NAND flash (i.e., non-volatile memory)

Source: TechInsights , accessed in November 2022.

The coexistence of mature and advanced technologies can also be seen looking at the evolution of "leading edge" node size[34] for logic, memory and DAO components and the corresponding silicon demand. Currently, logic chips are manufactured at a mix of different node sizes, from the smallest one below 5 nm which will become the leading edge in few years, up to the bigger ones at 27 nm for the microprocessors (MPU, Figure 9.a) and even bigger for other types of logic chips.

The forecasted evolution for the MPU chips (Figure 9.a) shows an exponential increase of the most advanced technological nodes (and the disappearance of the other ones) as a result of technological innovation according to Moore's law. The logic chips used in other devices, such as in microcontrollers and digital signal processors (not shown) will instead feature a mix of different and less advanced node sizes.

Within memories, DRAM (volatile type of memories used in PC and smartphone) is currently using node sizes between 11 and 20 nm (Figure 9.b), but sub-10 nm node size is expected to ramp up quickly. However, for NAND memories (non-volatile memory used in solid state drives and USB drives), the trend of node size scaling (Figure 9.c) is being replaced with the trend of stacking more layers to form 3D memory cells, enabling higher memory density.

The chips in the DAO (discrete, analog, and optoelectronics) group, which include transistor with higher node size and different semiconductor types, may not improve sufficiently in performance or cost-effectiveness when using smaller nodes; or they may use other types of semiconductors (e.g., different from silicon) for which a smaller miniaturization is not yet

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[34] See Appendix 1 for a discussion of the leading edge for each chip type.

available or possible. For those type of chips, production at more mature node-size will still be the case in the coming years.

Chip manufacturing needs (and will need in the coming years) to cover a wide range of nodes from the smallest ones below 5 nm used mainly for logic and memory to the legacy nodes at 180 nm and above for DAO. More importantly, the technological innovation, intended as the ability to miniaturize chips, is (and will likely be) different across the three types of chips. Consequently, **the concept of "leading edge" technology should be tailored to the type of chip and application**[35].

As shown in Figure 9, the leading edge for some logic chips (e.g., MPU) is at 5 nm or less; but for other applications it can lag behind[36]. For memory chips, the leading edge is typically just behind the one for logic, whereas for DAO chips, it is dependent on the application and the semiconductor material[37].

4.2 A capital intensive and subsidized value chain

Each segment of the semiconductor industry is highly capital-intensive. Design activities account for 65% of the total industry R&D (about $90 bn in 2019 according to SIA). The total development cost of a new front edge chip (SoC) could well exceed $1 bn, while a new chip manufactured in mature nodes or derived from the re-use of existing designs would cost between $20 m and $200 m to develop[38].

In the manufacturing segment, state-of-the-art fabs require highly advanced technological facilities (or "clean rooms") with an extreme level of cleanliness[39], thermal control and complex equipment for chip production[40]. The capital expenditure (capex) of a standard capacity fab for the production of advanced analog chips costs about $5 bn while a fab for advanced logic and memory could easily ramp up to $20 bn, including building, equipment

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[35] ZVEI (2021), https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2021/November/Halbleiterindustrie_fuer_Deutschland_und_Europa/Semiconductor-Strategy-for-Germany-and-Europe.pdf

[36] e.g. 16-40 nm are sufficient for microprocessors and microcontrollers used in automotive.

[37] e.g., for optical sensor cells the leading edge is at 130 or 350 nm, for GaAs and GaN HEMT is less than 100 nm, for light emitting devices made of compound semiconductors it is 2000 nm.

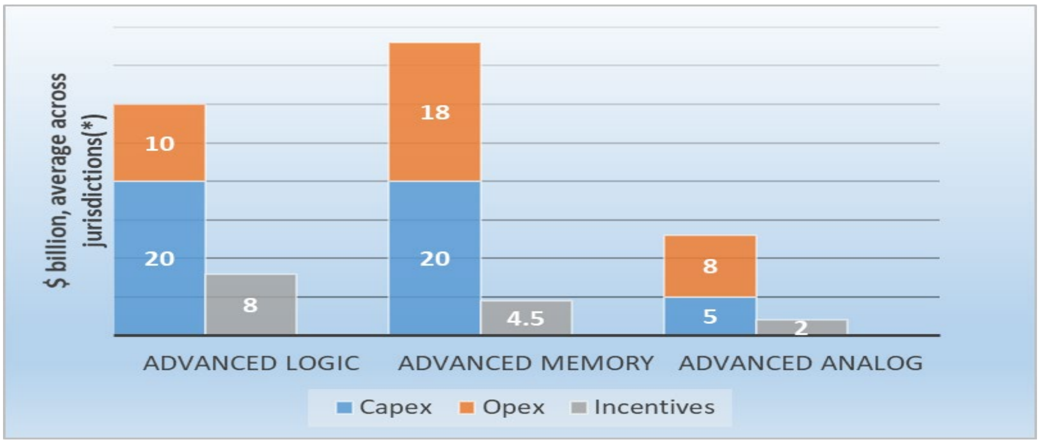
[38] BCG (2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf .

[39] The cleanliness level of the clean rooms is expressed as a function of the number of particles of 0.5 micron or bigger for cubic meter of air. The outdoor air in a typical urban area contains 35 million particles of 0.5 micron or bigger for cubic meter. The top class of clean rooms have absolutely zero particles of that size and very limited number of particles of smaller size.

[40] To produce frontier chips at 7 nanometres and below, advanced lithography equipment such as those using EUV (extreme ultra-violet) technology are needed. One single EUV machine can cost $150 m.

and land. For comparison purpose, the estimated cost of a next-generation aircraft carrier is around $13 bn and a new nuclear power plant goes from $4 bn to $8 bn[41].

Figure 10: Estimated Total Cost of Ownership (TCO) for a new fab over ten years.



Source: JRC elaboration based on data from BCG (2020), average across jurisdictions. Capex includes capital expenditure (upfront land, construction, and equipment); Opex refers to ten years of operating expenses (labour utilities, material taxes). (*) Jurisdictions are US, Japan, South Korea, Taiwan, China, Singapore and Germany.

In addition, the operating expenses (Opex) of the fabs are also significant. The total cost of a new fab over a period of ten years is reported in Figure 10 for different types of chips.

Similarly, the back-end requires significant investment for specialized equipment and facilities (13% of the total industry capex, estimated at $110 bn in 2019) but it is typically less capital intensive than the front-end fabrication.

Given the high capital investment, government incentive may reduce the up-front capital expenditures and may help supporting some Opex. The level of government incentives varies across jurisdictions. For instance, the total cost of a new fab for advanced logic in the US has been estimated approximately 22% higher than that in some Asian countries and 37% higher than in China, where up to 70% of the gap is due to the lower government incentives (Figure 11). Similar figures have been estimated for advanced memory or advanced logic fabs. A state of the art fab in the US is respectively 34% and 32% more expensive than in China and the largest part of this difference is due to public subsidies.

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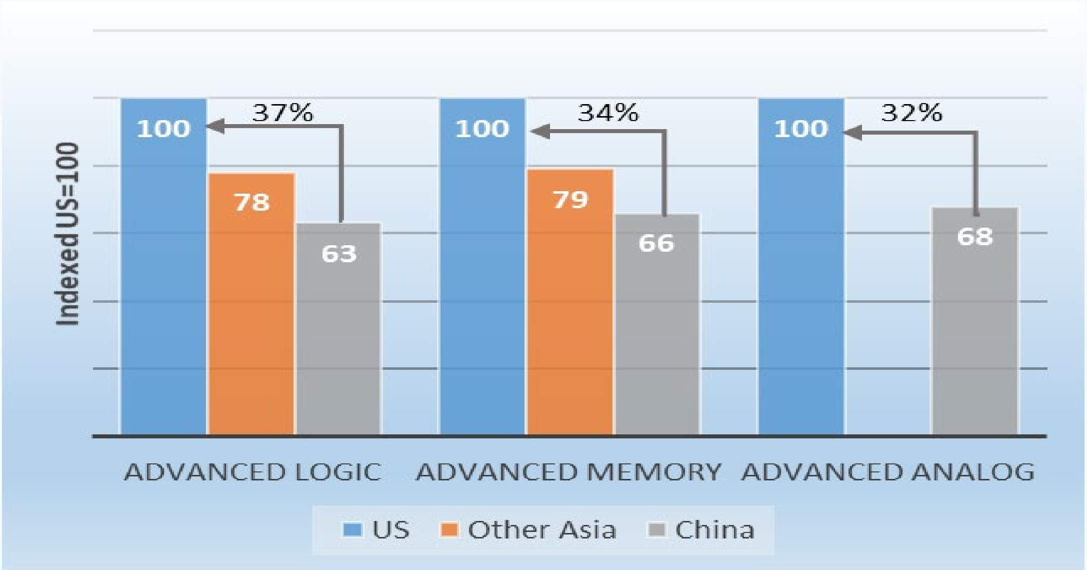
[41] BCG (2020), https://www.semiconductors.org/wp-content/uploads/2020/09/Government-Incentives-and-US-Competitiveness-in-Semiconductor-Manufacturing-Sep-2020.pdf

Figure 11: Estimated total cost of ownership of a new state of the art fab in different regions (US=100).



Source: JRC elaboration based on data from BCG (2020).

All countries involved are mobilising funds to support the semiconductor value chain. In 2021, South Korea announced a ten-year $450 bn investment to strengthen its semiconductor industry[42]. In Nov. 2022, Japan announced a $500 m investment to manufacture advanced chips[43]. At the same time, Taiwan proposed larger tax breaks for technology companies carrying out R&D in the semiconductor field and supported TSMC to build new factories in the United States and Japan[44]. In December 2022, Reuters reported[45] Chinese investments of 1 trillion Yuan (approx. $143 bn) over a five-year period to support domestic chip production as a response to the US sanctions[46]. In August 2022, the United States passed a landmark act to provide $52.7 bn in grants for US semiconductor production and research with additional tax credits for chip plants estimated to be worth $24 bn[47]. The EU Chips' Act proposal will mobilise until 2030 more than €43 bn of public and private investments to boost research and investments in semiconductors[48].

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[42] See https://spectrum.ieee.org/south-koreas-450billion-investment-latest-in-chip-making-push#toggle-gdpr

[43] See https://www.reuters.com/technology/japan-invest-up-500-mln-new-advanced-chip-development-company-2022-11-11/

[44] See https://www.reuters.com/technology/chip-giant-taiwan-eyes-bigger-tax-breaks-tech-rd-retain-competitive-edge-2022-11-17/

[45] https://www.reuters.com/technology/china-plans-over-143-bln-push-boost-domestic-chips-compete-with-us-sources-2022-12-13/

[46] https://edition.cnn.com/2022/10/31/tech/us-sanctions-chips-china-xi-tech-ambitions-intl-hnk/index.html

[47] https://www.mckinsey.com/industries/public-and-social-sector/our-insights/the-chips-and-science-act-heres-whats-in-it

[48] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en

Private investments were also rising in the last years. To keep up with the increased demand and backed by public support, in the last 3 years top world IDM and fabs have budgeted nearly $425 bn in capital expenditures to expand their production[49]. Over 60% of this capex was planned by the top 3 companies, the Taiwanese TSMC, the South Korean Samsung and the US based Intel (Figure 12). For comparison purpose, the top 8 hyperscale fabless - among them Amazon, Google, Meta, Alibaba, and Tencent - have invested over $393 bn in the period 2020Q1-2022Q3, that is 64% higher than the capital investment of the three preceding years (2017-19).

In the EU, Infineon and STMicroelectronics represented only 3% of the world capex of top players in 2022, but their investment grew at a compound annual growth (CAGR) of 21% between 2015 and 2022. In the same period, only Chinese top companies' investments grew more every year (28%). A positive outlook for Europe comes for the announced investments of the German-based Infineon (€5 bn to expand its 300 mm manufacturing capacity in the coming years[50]) and Bosch (€3 bn by 2026[51]), and the French/Italian STMicroelectronics[52] (€730 m new silicon carbide wafer factory in Italy[53]).

The EU can be also attractive for foreign investors encouraged by geopolitical considerations and state aid packages[54]. In 2022 Intel announced plans to invest €80 bn in the EU over the next decade[55]. The US-based Global Foundries has announced in October 2022 a partnership with STMicroelectronics for the development of a new 300 mm semiconductor manufacturing facility in France, and has plans to expand its site in Germany[56]. Asian investments instead remain weak. In September 2021, the European Commissioner Thierry Breton embarked on a 'Tech & Chips Tour' in Japan and South Korea to strengthen cooperation and trade relations[57]. In January 2023 the Taiwan's Industrial Technology Research Institute signed a cooperation agreement with the Lithuanian company Teltonika[58] to build semiconductor

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[49] TechInsights data TI TCI Graphics retrieved on February 2023. The year 2022 is forecasted.

[50] https://www.eetimes.eu/infineon-to-invest-e5b-in-dresden-300-mm-fab/

[51] https://www.electronicsweekly.com/news/business/bosch-to-invest-e3bn-in-semiconductor-expansion-2022-07/

[52] STMicroelectronics is a French-Italian joint venture, registered in the Netherlands and headquartered in Switzerland.

[53] https://www.semiconductor-today.com/news_items/2022/oct/st-051022.shtml

[54] See Semiconducotrs in Europe: the return of industrial policy. Institut Montaigne, March 2022.

[55] The real amount of the investment is however uncertain, given the disappointing revenue results in 2022Q4 (-34% on a year-on-year basis), and the negative outlook for 2023Q1 as consumers are expected to pull back on computer spending, https://www.intel.com/content/www/us/en/newsroom/news/eu-news-2022-release.html#gs.qy6pqo

[56] https://www.reuters.com/technology/stmicroelectronics-globalfoundries-confirm-major-new-france-investment-2022-07-11/

[57] https://aeneas-office.org/2021/09/30/eu-tech-and-chips-asia/

[58] https://evertiq.com/design/53178

technology capabilities in the country, with an investment of €14 m and TSMC is in talks with Germany to open its first EU plant targeted to the car industry[59].

Yet, in 2022 the downturn in the global demand of tech products has pushed back investment plans of many companies, including TSMC[60], SK Hynix and Micron. In January 2023, Samsung reported its lowest quarterly profit since 2014. With memory chip prices falling by double-digit percentages in 2022 and US export restrictions to China bringing uncertainty, semiconductor capital spending is forecasted to shrink globally.

TechInsights predicts a 17% world capex drop in 2023, the largest decline since the global financial crisis. The reduction hits mostly DRAM and NAND memory products with $19.6 bn and $19.9 bn respectively in 2023 (it was $29.8 bn and $26.8 bn in 2022). In 2023, the largest share of top players' capex, $83.6 bn, will be invested in advanced logic and foundry (down from $91.6 bn in 2022), while DAO will collect $17.8 bn, down from $18.5 bn in 2022 (Figure 13). These diminished private incentives for creating new capacity could imply the need of additional public support to compensate. China and the US seem to move in this direction.

The increased public and private investments for re-shoring the production come at a cost, as for decades this value chain has been outsourced for cost-efficiency. Any measures for mitigating the dependencies and the risk of supply chain disruption may cause excessive capacity built-up, lower technological innovations, and higher consumer costs. If incentives are given to set up new production plants, then they must be accompanied by other long-term measures to avoid or compensate market saturation, price drop and economic difficulties of companies.

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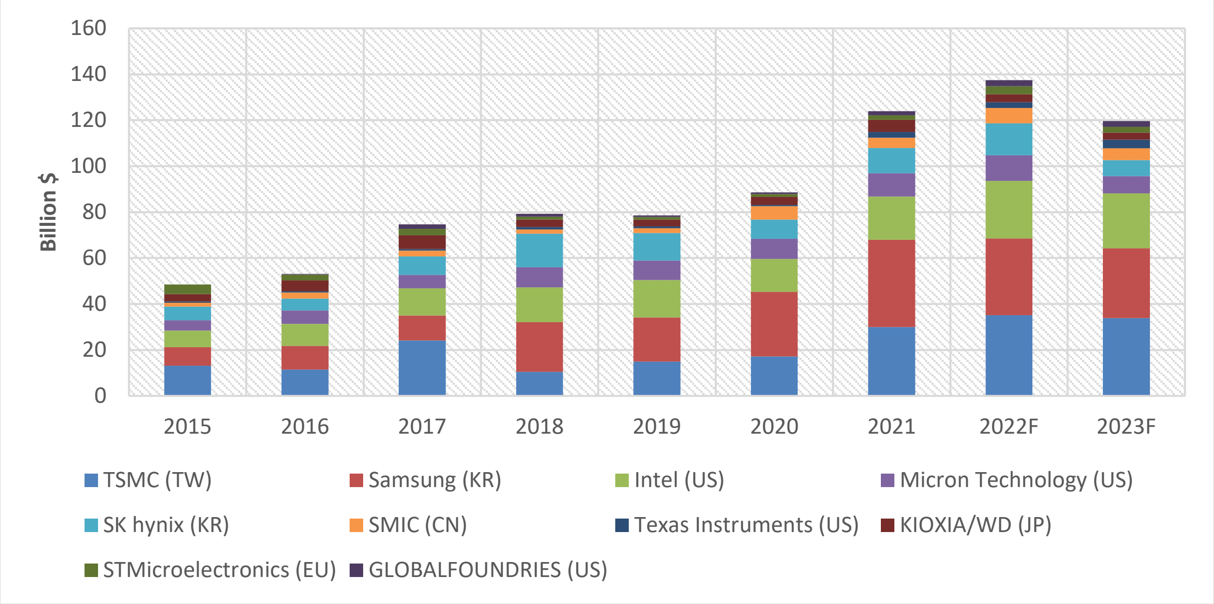
[59] https://www.politico.eu/article/taiwan-chips-semiconductor-tsmc-plan-for-europe-exposes-germanys-precarious-position-on-asia/

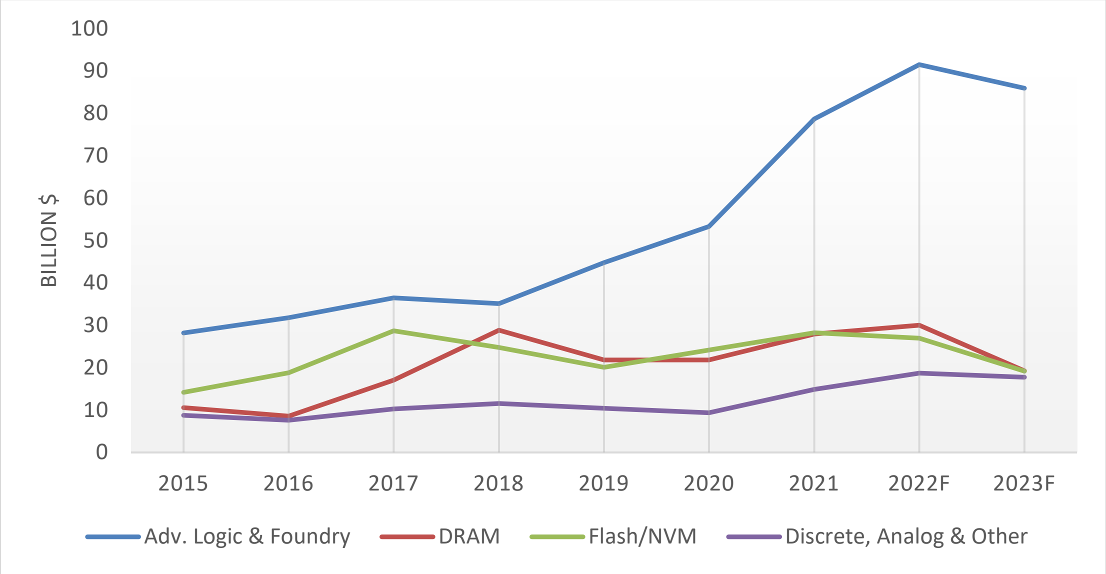
[60] https://www.reuters.com/technology/tsmc-q4-profit-up-78-beats-market-expectations-2023-01-12/

Figure 12: Capital expenditures of top 12 IDMs and foundries.



Source: TechInsights Inc. data, accessed 08/02/2023. F indicates a forecasted value.

Figure 13: Capital expenditures by type of chip.



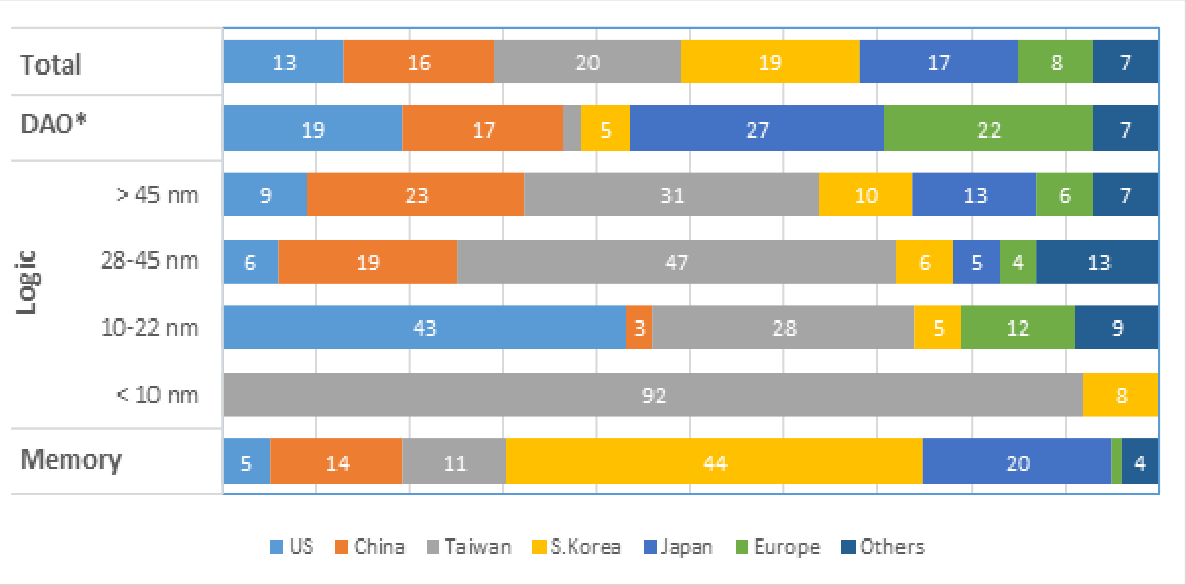
Source: JRC elaborated from TechInsights Inc. data, accessed 08/02/2023. F indicates a forecasted value.

5. Vulnerabilities and dependencies

The global dimension of supply and demand and the complexity of the chip production which requires numerous processing steps and a variety of materials and intermediate goods, expose the semiconductors value chain to natural or man-made risks and disasters.

The complexity of semiconductors supply chain makes it difficult, if not impossible, to assess the extent of the EU dependency on foreign jurisdictions in detail for any type of technology and goods, hence the EU vulnerability to the different types of risks. Any monitoring of vulnerabilities should therefore strike a balance between the breadth of knowledge of technologies, processes and actors, and the amount of available/accessible data, often coming from commercial sources and therefore covering only partially and imperfectly the different aspects to monitor. One should bear in mind that any assessment done by an external body could never approach the (often confidential) information possessed by companies[61].

Figure 14: Overview of key global players for semiconductor manufacturing (Wafer fabrication capacity). Detail by country (%) and chip type.



Source: BCG x SIA (Semiconductor Industry Association), 2021 – Strengthening the global semiconductor supply chain in an uncertain era. DAO stands for discrete, analog and optoelectronics[62.]

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[61] See Kleinhans, Hesse and Denkena, 2022, for a comprehensive discussion.

[62] Data on the figure are based on company headquarters and not on production plant. Data on plants could dramatically change the picture. For example the two main South Korean players in the memory business have production plants in China. According to the FT, SK Hynix's Wuxi plant in eastern China accounts for nearly half of its Dram memory chip production, while Samsung's plant in Xian takes up about 40 per cent

Dependencies and market concentration conditions are not homogeneous across the different types of semiconductor materials and chips, thereby creating bottlenecks in the supply of certain types of chips. While the overall picture appears rather diversified, with production shared among many players, Figure 14 reveals a quasi-monopolistic situation with strong dependencies for certain types of chips. A striking example is the small-scale logic chips (size lower than 10 nm), for which Taiwan accounts for 92% of global production. Taiwan also plays a prominent role in the production of logic chips in the 28-45 nm and >45 nm scales, alongside, China (at 23%)**,** counting together for two thirds of global production and leaving only about one third to other players. Clearly, the dominance of a single country in any segment of the semiconductor market exposes the EU (and the rest of the world) to potential vulnerabilities. Geopolitical factors and environmental factors, such as the severe drought that hit Taiwan in 2021 contributed to the current global chip shortage, which can further magnify these vulnerabilities and cause disruptions.

Dependencies and potential vulnerabilities can occur not only in the chip production, but also in the equipment production segment (Table 6). The EU, with the Dutch ASML[63], is the world leader in lithography, and particularly in the extreme ultraviolet lithography (EUV) technology necessary to produce the most advanced chips. However, the EU relies on other jurisdictions for other equipment and related products, e.g. mask exposure equipment are imported from Japan, or Ion implanters from the US. The EU is critically dependent for equipment related to testing as well as etching and cleaning tools. Disruptions on any of these technologies/components constitute an element of vulnerability for EU companies and the entire value chain. The sections below focus the attention on four sources of dependencies/vulnerabilities: water and energy, raw materials, intermediate inputs including the need to look at re-export data and geopolitics.

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of its NAND flash memory output (https://www.ft.com/content/c285a4f2-de0a-4370-88e3-7bbc32f8c314) .

[63] See the Appendix 2 for more details.

Table 6: Overview of key global players for manufacturing equipment by country and technology.

Equipment	Market share, 2021							Total sales	
	North America	**Taiwan**	**South Korea**	**Japan**	**EU**	**China**	**RoW**	2021, $bn	CAGR 2017-21
Total equipment	**41.6%**	**0.4%**	**4.0%**	**29.4%**	**19.2%**	**1.9%**	**3.6%**	**104.1**	**15%**
Wafer Fabrication Equipment	44.9%	0.1%	3.2%	27.8%	21.4%	1.6%	1.2%	89.0	16%
Microlithography and Mask Making Eqpt	*0.6%*	-	*0.4%*	*25.1%*	*73.4%*	*0.4%*	*0.1%*	*21.6*	*20.0%*
Resist Processing Eqpt	*0.3%*	-	*2.3%*	*94.4%*	*1.9%*	*1.0%*	-	*3.6*	*17.0%*
Optical Exposure Eqpt	*0.4%*	-	*0.0%*	*7.8%*	*91.4%*	*0.3%*	-	*17.2*	*20.8%*
Direct Write Systems	-	-	-	*67.3%*	*32.7%*	-	-	*0.04*	*5.0%*
Mask Exposure Eqpt	*5.9%*	-	-	*83.3%*	*10.8%*	-	-	*0.8*	*18.2%*
CMP Equipment (*)	*68.7%*	-	*1.3%*	*28.5%*	-	*1.5%*	-	*2.8*	*12.0%*
Ion Implanters	*93.2%*	*1.0%*		*5.2%*	-	*0.6%*	-	*2.0*	*11.4%*
Deposition & Related Tools	*59.7%*	-	*5.2%*	*24.1%*	*7.6%*	*2.1%*	*1.3%*	*23.5*	*14.6%*
Etching & Cleaning Tools	*54.3%*	-	*4.7%*	*37.4%*	*0.6%*	*2.4%*	*0.5%*	*25.7*	*14.6%*
Process Diagnostic Equipment	*71.4%*	-	*0.7%*	*13.1%*	*8.0%*	*1.2%*	*5.6%*	*11.0*	*18.2%*
Other Equipment (**)	*8.6%*	-	*7.4%*	*70.1%*	*11.9%*	-	*2.0%*	*2.3*	*4.6%*
Test and Related Systems	35.4%	2.6%	10.8%	43.3%	0.9%	4.2%	2.8%	8.6	13%
Assembly Equipment	5.1%	0.8%	6.1%	34.0%	13.6%	2.9%	37.5%	6.5	9%

(*) Chemical-Mechanical Planarization.

(**) Wafer Manufacturing Eqpt, Automated Handling Systems, Reticle Repair Systems, Wafer Marking Systems.

Note: the market share for assembly corresponding to the ROW is almost entirely attributable to Singapore.

Source: JRC elaboration on TechInsights (data, accessed 08/02/2023). CAGR stands for compound annual growth rate.

Nearly 80% of input suppliers and 63% of customers to the companies in the EU supply chain are located outside the EU[64].

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[64] JRC elaboration on Factset data.

5.1 Water and energy use

Fabrication of chips uses a significant amount of water and energy to operate and companies surveyed in the recent EC Consultation expressed a concern for water and energy consumption.[65] Water is necessary for the cooling, heating and ventilation processes. Large quantities of water are also purified from bacteria, particles, organic, and inorganic sources of contamination and used to clean the wafers during the manufacturing process. Approximately, it takes about 1.5 litres to make 1 litre of ultrapure water. However, the more advanced the node process is, the higher the water consumption is and the purer the ultrapure water should be. The amount of water required per square centimetre of memory chip can reach 21 litres (Table 7), which implies about 15,000 litres for a 300 mm wafer.

Table 7: Water and energy use in a fab to produce a square cm of wafer.

Chip type	Approximate technology Year	Technology node [nm]	Water use in fab [litres per cm^2 of wafer]	Energy use in fab [kWh per cm^2 of wafer]
Logic	From 2012	5-22	7.8	2.12
Memory	From 2016	10-22	20.96	34.93

Source: data Frost (2019)[66].

Considering the high production scale of some foundries (reaching tens of thousands of wafers per month), the request of fresh water can quickly skyrocket, unless saving and recycling water measures are put in place. As an example, TSMC in the Sustainability Report[67] indicates a consumption of water of about 200,000 tons per day in 2021 in their Taiwanese sites, notwithstanding an extraordinary recycling rate of process water reaching 85%. With an average production of 14.2 million of 300 mm wafers, water consumption is about 5,830 litres per wafer or 8.25 litres per square cm.

A similar issue exists for the energy required in fabs (Table 7), e.g., for running the equipment, heating during the fabrication processes, forcing ventilation and maintaining a thigh temperature control. In 2021, a large company like TSMC reached an energy consumption of

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[65] Rosati, N., Bonnet, P., Ciani, A., Duch Brown, N., Miguez, S. and Zaurino, E., The EC consultation on the semiconductors' value chain, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/609020, JRC133892.

[66] Frost (2019), https://www.sciencedirect.com/science/article/pii/S2212371719300150 .

[67] TSMC (2021), https://esg.tsmc.com/download/file/2021_sustainabilityReport/english/e-all.pdf .

19.2 TWh for producing 14.2 million of 300 mm wafers, corresponding to about 1352 kWh per wafer or 1.9 kWh per squared cm of wafer.

Although the needs for power and water to produce wafers have decreased during the years thanks to the implementation of strategies for energy reduction or water re-use, the requirements are still high and growing with the semiconductor product demand. Moreover, the power and water provisioning are critical factors which expose foundries to risks of production reduction or disruption in the case of natural hazards or human-triggered causes. Droughts exacerbated by global warming effects, energy supply shortages triggered by geopolitical tensions, excessive energy demand, or increasing costs of water and energy, are events that already happened. In 2018, for example, a 40 minutes power outage at Samsung's Pyeongtaek chip plant caused a cut-off in the power supply and in the clean room vacuum for about 20 minutes. The products in the line and in the deposition process were ruined, wasting about 30,000-60,000 NAND memories and causing an estimated damage of $43 m[68].

5.2 Dependency on raw materials

Chip manufacturing requires huge quantities of unique materials and chemicals[69] provided by specialised vendors for each stage of the manufacturing process[70]. Raw materials in the semiconductors industry spans the entire periodic table[71] and range in price and availability from abundant silicon to expensive rare earth elements.

Once extracted, raw materials must undergo a complex process of purification to be used in industrial applications. The chemical purity of the semiconductor material is, in fact, paramount to their effective operation[72]. For example the widely used Silicon requires refining to a minimum purity of 99.9999% for its use in solar cells and 99.9999999% for use in integrated circuits[73]. Besides natural disasters, shortages of raw materials principally stem from two reasons: profits and geopolitics. The market for semiconductor materials is forecast to reach a value of more than $70 bn by the end of 2025 growing at a CAGR of 4.3% between

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[68] https://www.reuters.com/article/us-samsung-elec-plant-idUSKBN1Z01K3 .

[69] More than 400 chemical products are used in semiconductor plants, most of them are industrial secrets (https://www.perkinelmer.com/it/libraries/app-raw-material-identification-in-the-semiconductor-industry).

[70] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions - A Chips Act for Europe, 2022, link: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0045

[71] Zvei (2021), https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2021/November/Halbleiterindustrie_fuer_Deutschland_und_Europa/Semiconductor-Strategy-for-Germany-and-Europe.pdf

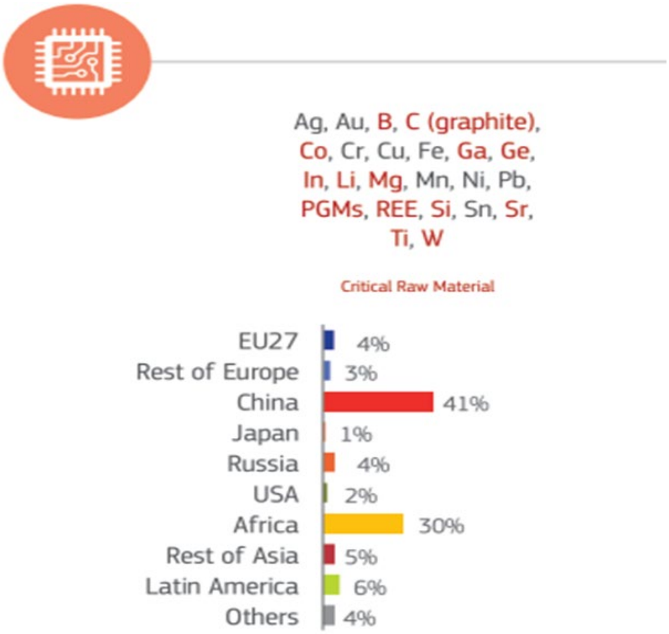
[72] L. Podmore, "How Do We Recycle Semiconductors?", https://www.azom.com/article.aspx?ArticleID=21424

[73] Safe transport and storage of these materials are crucial elements of the supply chain for computer and electronics manufacturers, see https://klingecorp.com/blog/how-to-transport-materials-for-computer-chips-and-processors/

2018 and 2025[74]. Companies extracting and refining semiconductor materials might be hesitant to increase the production ahead of a fast growing demand with the objective of keeping the prices and increasing their margins.

Geopolitical tensions also play a key role in critical raw material supply, with the trade tensions sparkling between China and the US and fostering growing concerns in Europe[75]. China provides about 41% of the raw materials needed for digital technologies (Figure 15) and indirectly controls part of the African supply[76] as well.

Figure 15: Digital technologies: an overview of key players along the supply chain (assessed for raw materials only).



Source: EC - Critical Raw Materials for Strategic Technologies and Sectors in the EU - a Foresight Study, 2020.

Recently the Russia-Ukraine conflict has increased the fear of disruptions in the raw material provision to the EU[77]. Russia is one of the main global exporters of metals, rare gasses and natural gas. For example, as much as 43% of the global mining of Palladium comes from

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[74] International Roadmap for Devices and Systems, 2020, https://irds.ieee.org/topics/semiconductor-materials

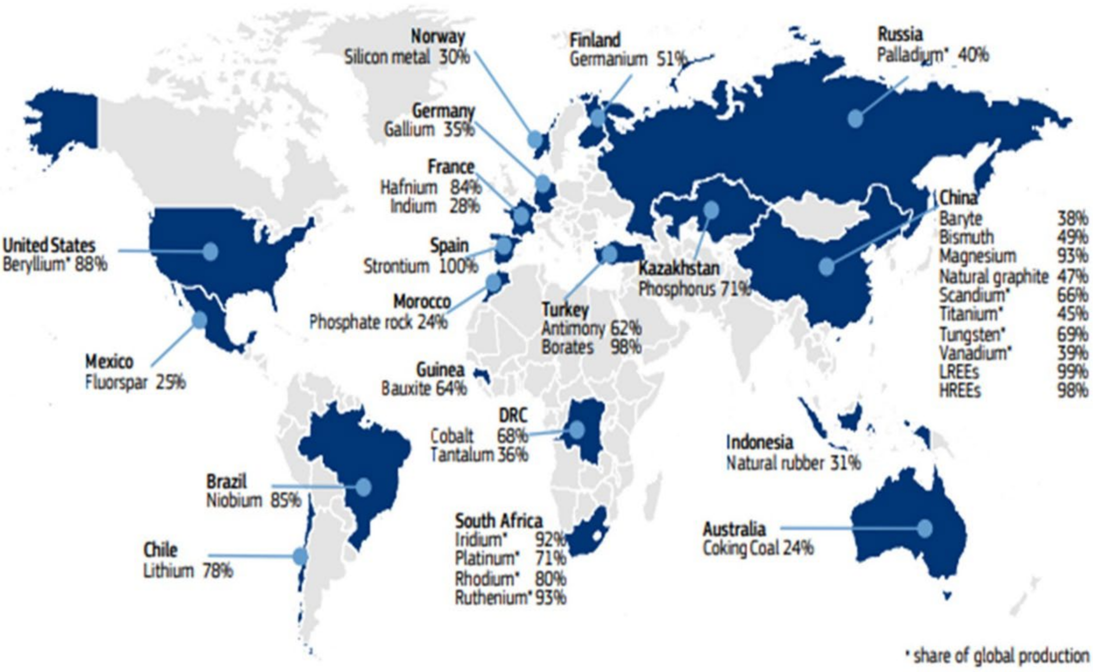
[75] For a comprehensive discussion, see Teer and Bertolini, 2022.

[76] For instance, as much as 68% of the world production of Cobalt comes from the Democratic Republic of Congo. However, the majority of mines are owned by Chinese state-owned companies and the refinement process is done in China.

[77] See for example https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7528, and https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/738219/EPRS_BRI(2022)738219_EN.pdf

Russia (Figure 16)[78]. Among rare gasses, the trade of Russian fluorocarbon, and in particular C_2F_6 used for etching and cleaning applications, is subject to sanctions due to the war[79]. Neon, critical for the lasers used to make chips, is an additional example of disruption due to vulnerability. TECHCET estimates that 40%-50% of the world's semiconductor grade neon comes from two companies in Ukraine[80], Ingas based in Mariupol and Cryoin based in Odessa. Both companies purify the Neon gas produced by Russian steel industries, but as result of the Russian invasion of Ukraine, both have shuttered their operations[81], creating problems to the main chip producers[82].

Figure 16: Current EU reliance in relation to raw or processed critical materials (2020 data).



Source: JRC 2020, "Critical Raw Materials Assessment and JRC Raw Materials Information System" rmis.jrc.ec.europa.eu HREEs=heavy rare earth elements, LREEs=Light rare earth elements. The figure shows either the share of country in global production or, when the information is available, the main country the EU is sourcing from (e.g. 35% of the gallium used in the EU comes from Germany that refine raw gallium coming from China that has 98% of the world production).

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[78] This metal is used in semiconductors manufacturing for improving adhesion of multilayer metallization structures in wafers.

[79] https://www.gasworld.com/story/shortages-of-specialty-gases-chemicals-needed-for-chip-expansions/

[80] https://www.semiconductor-digest.com/u-s-chip-expansions-squeezed-by-shortages-of-specialty-materials/

[81] See https://www.reuters.com/technology/exclusive-ukraine-halts-half-worlds-neon-output-chips-clouding-outlook-2022-03-11/

[82] https://asia.nikkei.com/Business/Tech/Semiconductors/TSMC-to-secure-neon-in-Taiwan-after-Ukraine-shock-for-chip-sector

5.3 Dependency on intermediate inputs

To measure EU actual dependency on raw materials and especially on intermediate products used in the supply chain of semiconductors one could look at trade data. Table 8 shows EU dependency on foreign (non-EU) imports for a basket of 74 products (at 8 digits of the HS classification[83]) grouped according to their use in the value chain. The group of products considered is only a sample of all the goods, raw materials and gasses used in the value chain, but it already gives an idea of the potential vulnerabilities[84].

Results show that the EU depends on import of chips for 63.7% of its needs (Table 8). China and Taiwan are the main trade partners. In particular, over 88.6% of the EU needs of photosensitive semiconductor devices, including photovoltaic cells, are covered by imports from China, as well as 34% of light emitting diodes[85] (Table 9). For flash memory cards or flash electronic storage cards the EU dependency on foreign imports reaches 96% where over one third come from South Korea. The EU dependency on memory DRAMs is over 99%. The main trade partner is Taiwan which covers between 46% and 58% of EU needs, depending on the storage capacity of memory components. Unexpected players also emerge. The EU depends on Thailand for 20% of its needs of produced semiconductor media for the recording of sound, on Malaysia and Philippines (25% and 18% respectively) for its need of certain types of multi-component integrated circuits (MCOs), while the EU dependency on the US is marginal in this segment and limited to amplifiers (Table 9).

Over half of the doped silicon (in the form of wafers or cylinders) as well as other doped chemical elements and compounds (in the form of wafers) come from foreign import, principally from Japan that covers between 18% and 21% of EU needs for these materials (Table 9). In the intermediate goods for wafer production the EU depends on 39.5% of its needs from foreign jurisdictions, mainly Japan, the US and China. Japan and Singapore are the main trade partners for inputs related to foundries (chip manufacturing) where the EU rely on foreing import for 34.7% of its needs. The EU dependency for raw materials is 28.9%, at least for the limited set of products considered. Among the products, half of the imported germanium comes from China and 40% of azides and silicides come from India (Table 9).

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[83] See https://www.trade.gov/harmonized-system-hs-codes. These 72 products are derived from the basket of 42 products at 6 HS digits mentioned in OECD, 2019.

[84] This set of goods is not specific to the semiconductors as the same good could be part of other value chains. We are also fully aware that the 72 products considered and not the only ones used in the semiconductor value chain.

[85] Cards incorporating one or more electronic integrated circuits.

Table 8: EU dependency on non-EU imported products in the selected segments of the semiconductors value chain, 2021.

Segment of the production chain	Ratio import/export	EU dependency (%)
Selected raw materials	0.27	28.9
Equipment	0.25	24.2
Intermediate goods used as input for wafer production	0.32	39.5
Silicon in form of wafers	0.71	55.2
Intermediate goods used as input for foundries	0.35	34.7
Chips	0.75	63.7

Source: JRC elaboration on a basket of 74 products associated to the semiconductors value chain according to OECD, 2019. Raw data from Comext and Prodcom 2021. EU dependency is calculated, for each product, as the ratio between imports and the sum of imports and internal production, taking then the median across products as a measure of central tendency.

To secure sustainable chip supply, the third pillar of the Chips Act provides emergency measures for crisis situations. This includes exports bans on EU products. The ratio between import and exports of the same product can help in gauging if an export ban could be sufficient to palliate EU needs in case of shocks. It is clear that each product has specific features and is usually tailor made for the client, so its use for other clients or for slightly different purposes requires a complex adaptation.

However, with this disclaimer in mind, the ratio between imports and exports indicates the possibilities for the system in case of shocks to satisfy internal demand by diverting exports. A ratio above 1 indicates that internal demand could be fully covered by re-addressing exports, while a ratio below 1, points to a dependency on foreign imports, even in case of closed borders. It is clear from Table 8, where all ratio imports/exports are below 1, that any ban on exports would not be sufficient to cover EU needs. The **dependency on foreign imports is particularly acute for raw materials and intermediate products used by EU companies**.

Table 9: EU dependency on non-EU inports for selected products used in the semiconductors value chain, 2021.

			2021		
Segment	HS code	Product	EU dependency on foreign imports (%)	top importer in the EU	Share of top importer in tot EU imports (%)
Raw Materials					
	28256000	Germanium oxides and zirconium dioxide	63	CN	32
	28500060	Azides, silicides, whether or not chemically defined	76	IN	40
	28500090	Borides, whether or not chemically defined	86	UK	41
Intermediate goods used in equipment production					
	84145915	Fans of a kind used solely or principally for cooling microprocessor	84	CN	48
	84863000	Machines and apparatus for the manufacture of flat panel displays	100	KR	40
Intermediate goods used as input for wafer production					
	37013000	Photographic plates	61	JP	50
	81129930	Articles of niobium "columbium" or rhenium	89	US	64
Silicon&chemicals used for wafers					
	38180010	Silicon doped for use in electronics, in the form of discs, wafers	55	JP	34
	38180090	Chemical elements and compounds doped in the form of discs, wafers	57	JP	21
Intermediate goods used as input for foundries					
	90012000	Sheets and plates of polarising material	81	JP	42
	90314100	Optical instruments and appliances for inspecting semiconductor wafers	75	SG	29
	90019000	Lenses, prisms, mirrors and other optical elements	70	CN	20
Chips					
	85235910	Semiconductor media, unrecorded, for the recording of sound	98	TH	20

	85235110	flash memory cards or flash electronic storage cards, unrecorded	96	KR	31
	85235190	flash memory cards or flash electronic storage cards, recorded	93	TW	18
	85235990	Semiconductor media, recorded	98	JP	40
	85414010	Light-emitting diodes, incl. laser diodes	83	CN	34
	85414090	Photosensitive semiconductor devices, incl. photovoltaic cells	88	CN	78
	85423190	Electronic integrated circuits as processors and controllers	83	MY	22
	85423231	D-RAMs", with a storage capacity of <= 512 Mbit	99	TW	58
	85423239	D-RAMs, with a storage capacity of > 512 Mbit	99	TW	46
	85423245	static RAMs, incl. cache random-access memories	100	TW	30
	85423261	flash E2PROMs, with a storage capacity of <= 512 Mbit	87	TW	36
	85423269	flash E2PROMs, with a storage capacity of > 512 Mbit	87	JP	18
	85423275	E2PROMs (excl. flash E2PROMs)	73	CN	18
	85423290	Other stack D-RAMs	83	TW	23
	85423310	MCOs (amplifiers)	83	MY	25

Source: JRC elaboration on a basket of 74 products associated to the semiconductors value chain according to OECD, 2019. Raw data come from Comext and Prodcom 2021. Product labelling has been abbreviated for space reasons.

5.4 Behind trade data, the role of re-export

Most of the information available on dependencies in raw materials or intermediate inputs are based on trade statistics, which measure the volume (and value) of trade between two jurisdictions. However, often trade goods are exported and re-exported many times before they finally land in the destination country. This implies that direct trade flows are somehow unable to fully capture vulnerabilities and one should account for the round tripping via third jurisdictions (re-export) to fully assess the extent of EU dependency.

For example, 11% of all Platinum imported in the EU comes directly from Russia, but the dependency on Russia rises to 33% when considering that some Russian Platinum is channelled into the EU via other jurisdictions (Table 10). The same happens for phosphorous, where the dependency on Kazakhstan goes from the formal 30% to 60% when indirect trade is considered.

When re-export is considered, the vulnerability concerns not only the material's primary producer who could monopolise the market directly and/or indirectly via re-export, but it also involves all the jurisdictions (and the carriers) in the trip that brings the material to Europe.

Table 10: Relevance of re-exports for chip production.

Position in the supply chain	**Product**	**Apparent dependency***	**EU dependency incl. through re-exports***	**Producing country**
Raw	Platinum	11%	33%	Russia
Raw	Platinum	7%	27%	United States
Raw	Platinum	5%	14%	Switzerland
Raw	Phosphorous	30%	60%	Kazakhstan
Raw	Fluorspar	30%	44%	Mexico
Raw	Fluorspar	11%	16%	South Africa
Input	Other chemicals	10%	24%	United States
Input	Optical material	2%	14%	Switzerland
Input	Micro-Parts	24%	47%	United States
Equipment	Parts for machines	22%	44%	United States
Equipment	Parts for machines	1%	8%	Taiwan
Equipment	Devices purify gasses	1%	22%	North Macedonia
Equipment	Devices purify liquids	11%	15%	Japan
Output	Electronic IC	0%	5%	Taiwan
Output	Electronic IC	5%	8%	Philippines
Output	Other IC	0%	9%	Taiwan
Output	Other IC	5%	8%	United States
Output	Photosensitive dev.	33%	37%	China

(*) share of extra-EU imports (%). Source: JRC elaboration on Figato database[86] (2022). For additional details on the products see Table 11 in the Appendix.

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[86] https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/figaro

5.5 Geopolitical concerns, the US-China relationship

Geopolitical considerations have a profound influence in shaping the semiconductors value chain. The disruption of the semiconductors supply chain has made clear the need to indigenize the main production steps to accomplish economic and national security objectives. In October 2022, the US administration rolled out a set of restrictions on the use and sales of advanced US technology to China in the attempt to prevent or delay the Chinese development and production of advanced chip applications. Besides the US companies and talents, the restrictions extend to the worldwide semiconductor supply chain, cutting off *de facto* the Chinese market to all the companies using US technology, wherever located in the world[87]. The pressure on *like-minded* countries to follow suit induced Japan and the Netherlands (leaders of equipment supply) to join the US in restricting the exportation of chip manufacturing tools to China in January 2023[88].

The Chinese aspirations to bring back the island of Taiwan[89] to the *Greater China* have alarmed the US further[90], worsening their relationships. A Chinese invasion of Taiwan would imply controlling chip giants like MediaTech, UMC and especially TSMC, the world's largest chip foundry, and almost the only company supplying leading edge chips to the world's largest technology firms, most of them US based. An invasion of Taiwan would enable China to control the most advanced chip ecosystem in the world, which is exactly in line with the aspiration of the Chinese President Xi Jinping to bring China to the front edge of technological progress[91].

For the time being, the Chinese response to the US restriction has been an acceleration of the transition from a market-based innovation system to security-based national innovation planning[92]. A massive fiscal incentive package, worth over $143 bn, has been announced by the Chinese government in December 2022 with the aim of creating a domestic semiconductors ecosystem[93]. This stimulus package will likely be managed by a myriad of state-controlled local, province and national funds that can interfere with company decisions. At the same time, there is a renewed emphasis on attracting foreign investments (and talents) and establishing economic links with other countries[94], while the strict control of Chinese outbound investments never stopped in the attempt to regulate the outflow of

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[87] See https://carnegieendowment.org/2022/10/27/biden-s-unprecedented-semiconductor-bet-pub-88270

[88] See https://www.ft.com/content/baa27f42-0557-4377-839b-a4f4524cfa20

[89] https://thediplomat.com/2022/08/chinas-new-white-paper-lays-out-vision-for-post-reunification-taiwan/

[90] https://www.reuters.com/world/biden-says-us-forces-would-defend-taiwan-event-chinese-invasion-2022-09-18/

[91] https://www.cnbc.com/2022/10/14/china-communist-party-congress-2022-xi-jinpings-tech-policy-in-focus.html

[92] https://thediplomat.com/2023/03/the-future-of-the-china-us-chip-war/

[93] See https://www.reuters.com/technology/china-plans-over-143-bln-push-boost-domestic-chips-compete-with-us-sources-2022-12-13/

[94] See https://www.cnbc.com/2023/03/03/china-is-rolling-out-the-red-carpet-to-attract-foreign-executives.html

national currency and direct outbound investments towards a list of sectors pre-defined by the government[95]. On the 3rd of July 2023, China established new measures for export control of Germanium and Gallium starting from the 1st of August 2023, in an attempt to protect its market and counter-react to the other export control restrictions.

How US actions and Chinese response will affect the structure of the value chain and the strategic decisions on location and production of main actors in Japan, South Korea and Europe it is yet to be seen but will undoubtedly shape dependencies in the near future.

6. Conclusions

Semiconductors are not just related to computers and smartphones. They are embedded in our cars, industrial machineries, home appliances, as well as satellites and advanced military devices. Chips pervade our life and will be more and more necessary for our green and digital transition. The chip content in electronic devices is currently at 24% (it was 14% in the 1990s) but is expected to increase to 26% by 2027[96]. Chip sales were 0.07% of the world GDP in the late 1960s, 0.24% in late 1980s, and 0.38% of the world GDP currently, and it is clear that they will also continue to rise[97].

"*The fate of nations has turned on their ability to harness computer power*" says the Economic historian Chris Miller[98]. Security of supply chain has therefore become a national security matter where geopolitical considerations play a key role.

This note described the semiconductors value chain and tried to give a taste of its complexity and interconnectivity with particular attention to the EU part of the chain. This is part of a more comprehensive exercise which includes the mapping of EU companies operating in the semiconductors value chain and the construction of a set of indicators able to display the vulnerabilities and the dependencies on non EU players/markets.

The identification of EU semiconductor supply chain and its vulnerabilities is a difficult task for the technological complexity, the interdependencies among firms and the global dimension of this industry. If an in-depth approach based on detailed data is not feasible as too data-demanding or too complex to handle, an approach based on aggregated data at the sector level is not enough either, lacking the sufficient explanatory power when trying to

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[95] Blanchette (2021): https://www.hinrichfoundation.com/research/wp/us-china/china-inc-to-ccp-inc/.

[96] TechInsights data, Diffusion rates of worldwide chip making markets, accessed 08/02/23, calculated as share of chip sales over sales of electronics.

[97] TechInsights data, diffusion rates of worldwide chip making markets, accessed 08/02/23, calculated as world sales of chips in $bn over worldwide GDP ($bn) at Purchasing Power Parity Exchange Rate as reported by the International Monetary Fund (IMF). 0.38% refers to the estimated value inn 2022.

[98] Miller (2022), author of the best-seller book "Chip War: The Fight for the World's Most Critical Technology", Scribner, 2022.

derive dependencies and vulnerabilities. An intermediate approach is therefore needed. The level of depth at which the analysis can be done is heavily constrained by the granularity of the information at hand and the necessity to combine data coming from very different sources.

Vulnerabilities in the supply chain of semiconductors can come from different sources and affect different players. A large share of electronics purchased by European consumers are manufactured or assembled elsewhere - most likely in China which is the destination of 35% of global chip sales - by electronic device makers located most likely in US which hosts 33% of the chip producers' headquarters. With global demand expected to grow yearly at 4.8% (between 2022 and 2027) and with EU production rising yearly at 4% in the last five years, the gap between EU supply and demand is likely to widen especially on the most advanced chips needed to sustain the green transition where the EU is completely dependent on Taiwan.

The companies in the value chain are highly dependent on capital investments to keep the pace of demand and technological advancements. In the last 3 years since the start of the pandemic in 2020, top IDM and fabs at the global level budgeted nearly $425 bn in capital expenditures to expand their production. Over 60% of this capex is planned by the top 3 companies (the Taiwanese TSMC, the South Korean Samsung and the US based Intel), whereas the EU with Infineon and STMicroelectronics accounts for only the 3% of the world capex of top IDMs. Capital is also needed to help small companies bring their products to the market and gain market share.

Geopolitical tensions play a key role in all segments of the value chain, from critical raw materials supply, to design tools, to production and shipment of materials, as well as equipment and chips. Geopolitics is likely to influence the localization of production and the relationship among companies, potentially changing the dependencies we observe today. A careful analysis of the current and prospected changes is therefore necessary to anticipate future vulnerabilities.

Geopolitical considerations and the need to reshore part of the production to avoid supply chain disruptions has pushed governments (including the EU) to provide incentives to set up new production plants. However, more production today, could lead to market inefficiencies tomorrow. Therefore these incentives should be accompanied by other long-term measures to avoid market saturation, price drop and ultimately economic difficulties for companies.

An additional vulnerability comes from the pace of technological advancement. EU capabilities are in the more mature chip technologies for chips related to larger node size, with Infineon, NXP, and STMicroelectronics among the world's leaders in sensors and power electronics design and manufacturing[99]. The only exceptions are the production or lithographic equipment (DUV and EUV by ASML) and the Intel fab in Ireland which will soon

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[99] Montaigne (2022), https://www.institutmontaigne.org/ressources/pdfs/publications/europe-new-geopolitics-technology-1.pdf .

start the production of the Intel 4 process technology at 7 nm[100]. Although each semiconductor technology and type of chip has its own innovation pace, the highest R&D effort and leading technological breakthrough are placed in the smallest node size. The manufacturing of logic and memory chips using the smallest nodes is concentrated in East Asia (Taiwan and South Korea), whereas their design is done in the US.

The EU needs to mobilise expertise in the design and manufacturing of the most advanced chips for each application, leveraging on the connection with the research institutes to develop the know-how and offer small scale manufacturing facilities to all companies (especially smaller ones) for developing and testing their products[101]. An example is the relationship between the Belgian IMEC and the Dutch ASML.[102] At the same time each electronic device uses (and will use) different type of chips, not necessarily all leading edge. Any shortage in mature nodes is therefore likely to impact also products using leading edge technology. This implies that no chip is to be left behind if the objective is to assure a healthy and functioning EU semiconductor ecosystem.

Other vulnerabilities also hamper the EU chip industry. Dependency on raw materials principally, but also on intermediate inputs. Involved countries should collectively make an effort and jointly address the dependencies with a forward mind-set and sustainable perspectives.

Given that complete autonomy cannot be reached due to economic and technological considerations, the EU needs to decide the level of dependency it can afford and influence the preferred alliances and partnerships. To do so a coherent set of measures to attain feasible objectives in the short, medium and long run should be put in place by the EU jointly with each member state involved. This process should involve the companies and all the stakeholders (e.g. universities with research facilities and R&D centers) in this ecosystem. This requires building a political consensus to promote industrial development beyond national borders, but also requires acting together vis à vis to the challenges that will come.

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[100] https://www.intel.com/content/www/us/en/newsroom/news/ireland-milestone-fab-34.html#gs.s3i3qq

[101] This is the *pilot line* model, backed by the EU chips Act (Pillar 1) and aimed at reducing the gap from the lab to the fab for the new technologies. By opening these pilot lines, SME and startup could have easier and faster access to foundry services for these novel (and potentially also for older) technologies (e.g., via multi-project wafer (MPW) runs).

[102] Reported in Appendix 2.

7. References

BCG (2020): BCG and SIA, “Government Incentives and US Competitiveness in Semiconductor Manufacturing”, report, September 2020, available at: https://www.semiconductors.org/wp-content/uploads/2020/09/Government-Incentives-and-US-Competitiveness-in-Semiconductor-Manufacturing-Sep-2020.pdf (accessed on 09/03/2023).

BCG (2021): Varas, A., Varadarajan, R., Goodrich, J., & Yinug, F, “Strengthening the global semiconductor supply chain in an uncertain era,” Boston Consulting Group and Semiconductor Industry Association, April, 35, 2021, available at: https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf (accessed on 09/03/2023).

Blanchette (2021): J. Blanchette, “From "China Inc." to "CCP Inc.": A new paradigm for Chinese state capitalism”, available at: https://www.hinrichfoundation.com/research/wp/us-china/china-inc-to-ccp-inc/ (accessed on 09/03/2023).

Ciani (2022): Ciani, A., Nardo, M., “The position of the EU in the semiconductor value chain: evidence on trade, foreign acquisitions, and ownership,” European Commission, Ispra, 2022, JRC129035, https://joint-research-centre.ec.europa.eu/system/files/2022-04/JRC129035.pdf (accessed on 09/03/2023).

CSET (2021): Khan, Saif M., Alexander Mann, and Dahlia Peterson, “The semiconductor supply chain: Assessing national competitiveness,” *Center for Security and Emerging Technology*, 2021, available at: https://cset.georgetown.edu/publication/sustaining-u-s-competitiveness-in-semiconductor-manufacturing/ (accessed on 09/03/2023).

CSET (2022): Hunt, Will, “Sustaining US Competitiveness in Semiconductor Manufacturing,” Center for Security and Emerging Technology, brief, 2022, available at: https://cset.georgetown.edu/publication/sustaining-u-s-competitiveness-in-semiconductor-manufacturing/ (accessed on 09/03/2023).

Eurostat (2019), EU inter-country supply, use and input-output tables — Full international and global accounts for research in input-output analysis (FIGARO). ISABELLE REMOND-TIEDREZ AND JOSE M. RUEDA-CANTUCHE (ED.) https://ec.europa.eu/eurostat/documents/3888793/10109187/KS-TC-19-002-EN-N.pdf

Frost (2019): Frost, Kali, and Inez Hua, “Quantifying spatiotemporal impacts of the interaction of water scarcity and water use by the global semiconductor manufacturing industry,” Water Resources and Industry, vol. 22, no. 100115, 2019, available at https://www.sciencedirect.com/science/article/pii/S2212371719300150/ (accessed on 09/03/2023).

Kleinhans (2021): Kleinhans J-P., “The lack of semiconductor manufacturing in Europe,” Stiftung Neue Verantwortung, 2021, https://www.stiftung-nv.de/sites/default/files/eu-semiconductor-manufacturing.april_.2021.pdf (accessed on 09/03/2022).

Kleinhans (2022): Kleinhans J-P., Hess J., Denkena W., “Governments’ role in the global semiconductor value chain #1, 2 and 3,” Stiftung Neue Verantwortung, 2022, https://www.stiftung-nv.de/de/publication/eca-monitoring; https://www.stiftung-nv.de/de/publikation/eca-mapping; https://www.stiftung-nv.de/de/publikation/eca-toolbox (accessed on 09/03/2023)

IRDS (2020): International Roadmap for Devices and Systems, 2020, https://irds.ieee.org/topics/semiconductor-materials

ITA (2017): World Trade Organization, “20 Years of the Information Technology Agreement. Boosting Trade, Innovation and Digital Connectivity,” 2017, available at: https://www.wto.org/english/res_e/booksp_e/ita20years_2017_full_e.pdf (accessed on 09/03/2023)

Martins Ferreira P., (2018), QDR methodology: understanding trade flows in the EU, https://cros-legacy.ec.europa.eu/content/qdr-methodology-understanding-trade-flows-eu-pedro-martins-ferreira_en

Miller (2022): J. Miller, “*Chip War: The Fight for the World’s Most Critical Technology*,” Scribner, 2022.

Montaigne (2022): Institut Montaigne, “Semiconductors in Europe: the return of industrial policy,” Policy paper, March 2022, available at: https://www.institutmontaigne.org/ressources/pdfs/publications/europe-new-geopolitics-technology-1.pdf (accessed on 09/03/2023).

SIA (2016): SIA and Nathan Associates, “Beyond borders; the global semiconductor value chain,” 2016, available at: https://www.semiconductors.org/wp-content/uploads/2018/06/SIA-Beyond-Borders-Report-FINAL-June-7.pdf (accessed on 12/05/2023).

OECD (2019): OECD, “Measuring distortions in international markets: The semiconductor value chain,” OECD Trade Policy Papers, No. 234, 2019, OECD Publishing, Paris, available at: https://www.oecd-ilibrary.org/trade/measuring-distortions-in-international-markets_8fe4491d-en (accessed on 09/03/2023)

TSMC (2021): Sustainability report, 2021, available at: https://esg.tsmc.com/download/file/2021_sustainabilityReport/english/e-all.pdf (accessed on 09/03/2023).

ZVEI (2021): Electro and Digital Industry Association, “Semiconductor Strategy for Germany and Europe,” 2021, available at: https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2021/November/Halbleiterindustrie_fuer_Deutschland_und_Europa/Semiconductor-Strategy-for-Germany-and-Europe.pdf (accessed on 09/03/2023).

8. Acronyms

AI	Artificial Intelligence
ASIC	Application specific integrated circuits
ATP	Assembly, testing and packaging
CAGR	Compound annual growth rate
CAPEX	Capital expenditure
CPU	Central processing unit
DRAM	Dynamic Random Access Memory
DUV	Deep ultra-violet
EUV	Extreme ultra-violet
FET	Field effect transistor
FPGA	Field programmable gate arrays
GPU	Graphics processing units
IC	Integrated circuit
ICT	Information and communication technology
MCO	Multi-component
MEMS	Microelectromechanical systems
MPU	Microprocessor unit
NAND	Not AND
SSD	Solid state disk
OPEX	Operating expenditure
nm	nanometres

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Appendix

1. Transistor gate length and node name

The critical characteristic of a transistor is typically considered the gate length (i.e., the length of the transistor gate). The smaller it is, the higher the number of transistors that can be integrated in a chip. The increased integration density has been following the trend predicted by Moore's law in late 1960s: a doubling of the number of transistors in a fixed-size die every 18 months.

To each gate length, a node name usually corresponds. In the early days (from 1960 to 1990), the node name coincided with the gate length and the pitch (i.e., the distance between two identical characteristics on the chip). Afterwards, half pitch started to be used and since then gate length was equivalent to half-pitch node size. Up to 28 nm (nanometres), the name and gate length were still matching.

Below 28 nm, the number of nanometres (i.e. the node name) are no longer related to a specific feature size nor is a meaningful and measurable quantity related to transistor density on the wafer[103]. A new node name is introduced by the foundries when a new process with smaller features, stricter tolerances, and higher integration density is developed. To reduce the misalignment between physical properties and node names, International Roadmap for Devices and Systems (IRDS) proposed a different labelling based on historical definition, but so far it has not found acceptance by the companies for naming their commercial products. Keeping the misalignment in mind, the historical trend of the nodes in the main foundries is shown in Figure 17.

Currently, to keep up with the Moore's law, both new transistor designs (e.g., from the finFET to the gate-all-around FET and in future, forksheet or 3D complementary FET) and new processes and equipment are required (e.g., EUV lithography) for achieving the required accuracy. With the miniaturization of chips, the design and manufacturing costs are skyrocketing. According to IBS[104], the design cost for a 3 nm chip is $650 m, compared to $436.3 m for a 5 nm device, and $222.3 m for 7 nm.

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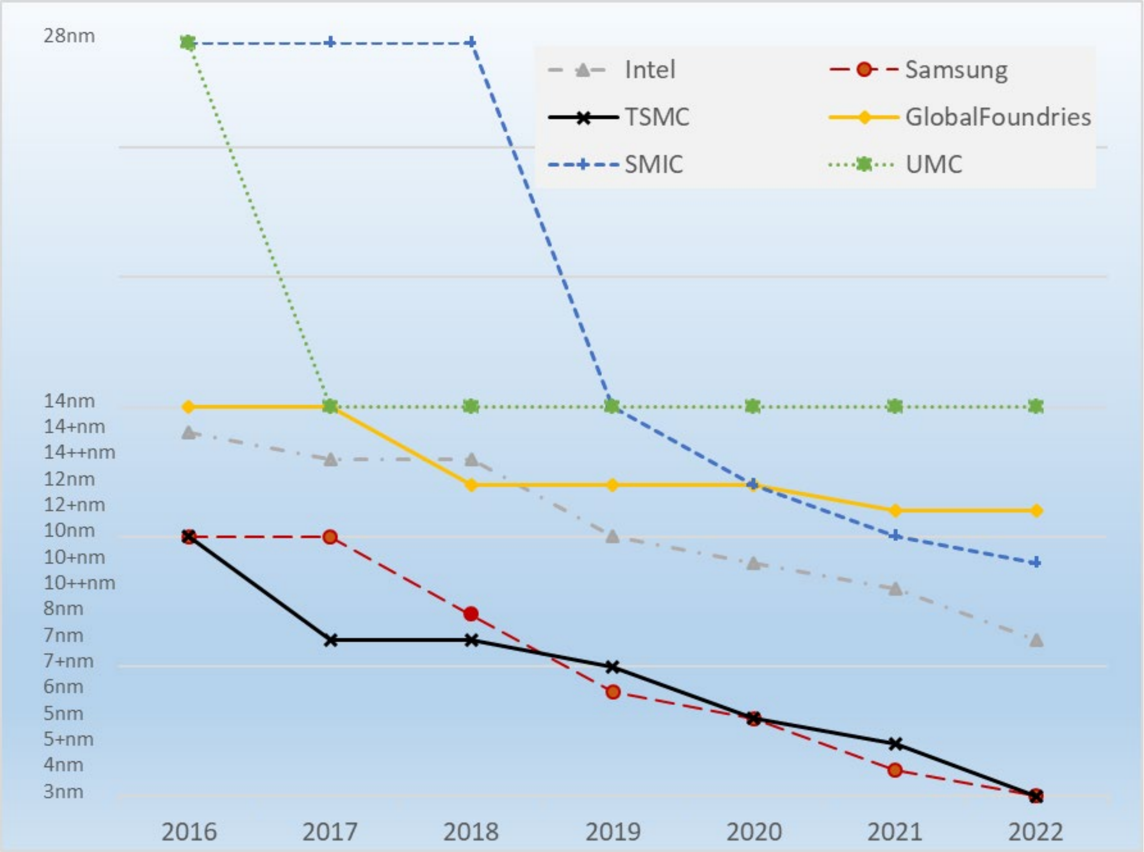
[103] IRDS, (2020), https://irds.ieee.org/topics/semiconductor-materials (last accessed 7/7/2023)

[104] https://semiengineering.com/making-chips-at-3nm-and-beyond/ (last accessed 7/7/2023)

Figure 17: Leading-edge processes in the main foundries from 2016.



Source: data from companies, conference reports, and IC Insights 2021[105]*. Intel and Global foundries are US based, Samsung is from South Korea, TSMC and UMC are located in Taiwan, SMIC is Chinese.*

2. Production of equipment: the ASML case

ASML, a company headquartered in the Netherlands, is one of the top producers of tools for lithography, i.e., the process that uses light to print patterns on semiconductor wafers. Since the introduction of extreme ultraviolet (EUV) lithography by ASML in 2010, this company practically dominates the global market in the EUV lithography and is a leader for deep ultra-violet (DUV) over Canon and Nikon (Figure 18).

EUV technology is essential for node size 5 nm and below. As of today, only few fabs (notably TSMC in Taiwan and Samsung in South Korea) have the capability of producing such a small node size, but the yearly demand for EUV systems is expected to double by 2026 (Figure 19) due to both the expansion of current capacity and the creation of new fabs. EUV technology

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[105] See https://semiwiki.com/forum/index.php?threads/revenue-per-wafer-climbs-as-demand-surges-for-5nm-7nm-ic-processes.13843/

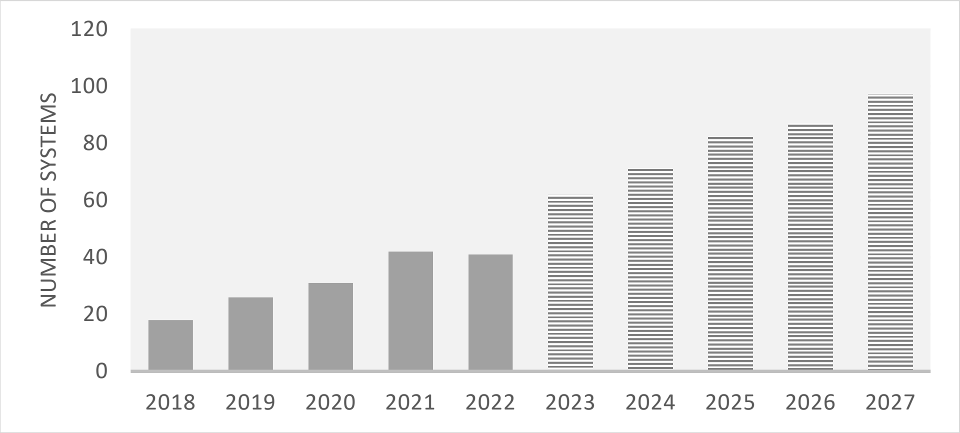
is very expensive as each EUV tool can easily cost up to $170 m. Altogether lithography alone consumes approximately 35% of the cost of a 3 nm process node[106].

Figure 18: Number of lithography systems shipped by the main manufacturers, 2022 .

Company	**Total Units**	**i-line**	**DUV**			**EUV**
			248nm	**193nm**		
				dry	**wet**	
ASML	335	41	140	28	85	41
Canon	180	129	51			
Nikon	57	32	6	11	8	
Total	572	202	197	39	93	41

Source: TechInsights, Steppers & Scanners by Shipment History and Forecast (2017 - 2027), accessed in February 2023. Data refer to the shipments of scanners and steppers in units, all applications[107].

Figure 19: Demand trend for EUV systems.



Source: TechInsights, Steppers & Scanners by Shipment History and Forecast (2017 - 2027), accessed in February 2023.

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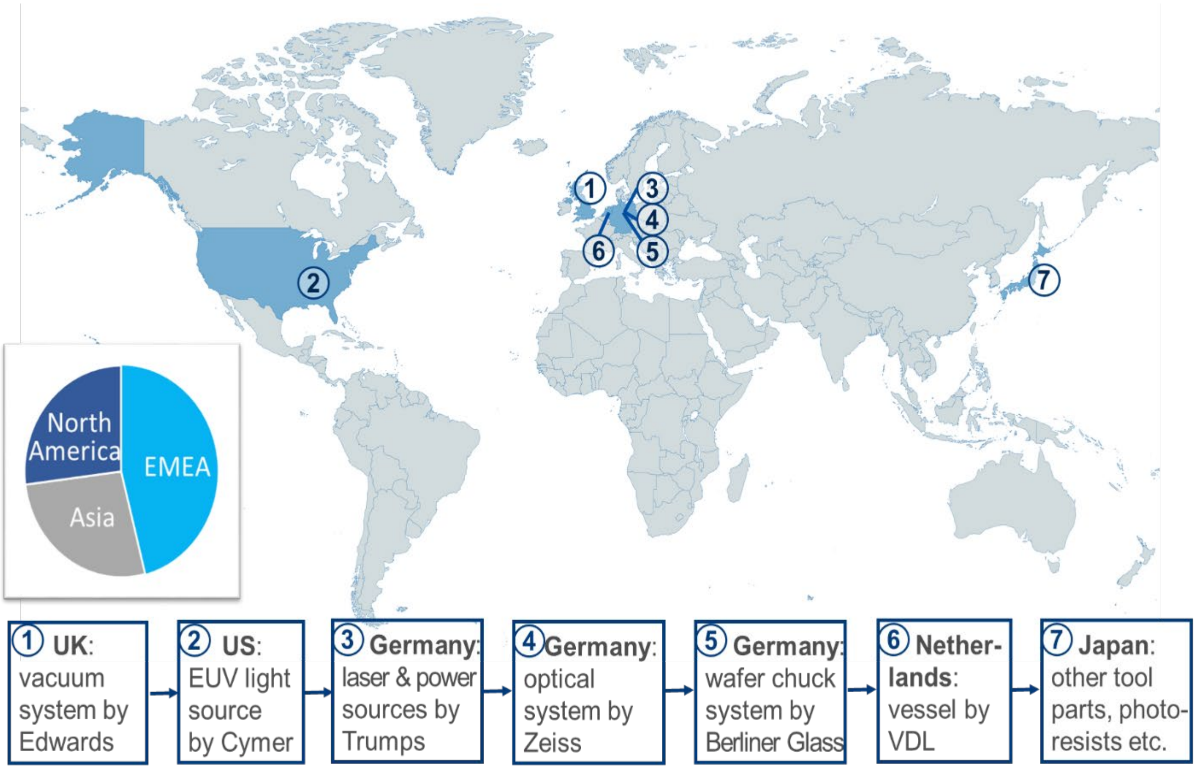
[106] See Patel, Cozma and Ahmad, EUV Requirements Halved? Applied Materials' Sculpta Redefines Lithography And Patterning Market. Semianalysis, March 2023.

[107] The DUV tools use either light source at 193 nm (based on argon fluoride, ArF) or 248 nm (based on krypton fluoride, KrF) with resolution as low as 80 nm. The ArF DUV includes ArF immersion systems – referred to as "wet"- with minimum resolution of 38 nm or "dry" ArF systems with minimum resolution of 57 nm. The i-tool steppers are tools used for resolution of 350 nm and above as well as for packaging.

The supply chain of ASML for the EUV lithographic tools contains about 100,000 parts provided by over 5,000 suppliers spread across the globe (Figure 20)[108]. The critical components are:

- EUV light sources provide by Cymer (a subsidiary of ASML in Japan), and Gigaphoton (subsidiary of Komatsu in Japan);
- precise system of mirrors provided by Zeiss (Germany);
- lasers and power sources provided by Trumpf (Germany);
- masks for EUV provided by mainly Toppan (Japan) and Veeco (US).

Figure 20: The supply chain of ASML for EUV lithography.



Source: JRC arrangement from BCG (2021).

A key role in the development of EUV technology was provided by **IMEC,** a world-leading research and innovation centre in nanoelectronics and digital technologies that brings together the most important researchers and companies in each research area. Headquartered in Belgium, IMEC has now R&D groups distributed across the globe: in several Flemish universities, in the Netherlands, Taiwan and the USA, with offices in China, India and Japan as well.

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[108] BCG (2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf.

ASML has been collaborating with IMEC on advanced lithography processes for many years. The partnership provided ASML with early feedback from IMEC members, speeding up the testing and re-calibration of the equipment, and reducing the time to market for the new products. IMEC is now an international innovation hub in nanoelectronics, semiconductors and other digital technologies.

3. Re-export

Table 11. Additional details for products in Table 10.

Product	HS code	Description
Platinum	711011	Platinum, unwrought or in powder form
Platinum	711011	Platinum, unwrought or in powder form
Platinum	711011	Platinum, unwrought or in powder form
Phophorous	280470	Phophorous
Fluorspar	252922	Fluorspar containing by weight > 97% calcium fluoride
Fluorspar	252922	Fluorspar containing by weight > 97% calcium fluoride
Other chemicals	381800	Chemical elements and compounds doped for use in electronics
Optical material	900190	Lenses, prisms, mirrors and other optical elements, of any material, unmounted
Micro-Parts	901290	Other parts and accessories for electron microscopes, proton microscopes and diffraction apparatus
Parts for machines	848690	Parts and accessories for machines and apparatus
Parts for machines	848690	Parts and accessories for machines and apparatus
Devices purify gasses	842139	Other machinery and apparatus for filtering or purifying gases
Devices purify liquids	842129	Other machinery and apparatus for filtering or purifying liquids
Electronic IC	854231	Electronic integrated circuits as processors and controllers
Electronic IC	854231	Electronic integrated circuits as processors and controllers
Other IC	854239	Other electronic integrated circuits
Other IC	854239	Other electronic integrated circuits
Photosensitive dev.	854140	Photosensitive semiconductor devices

4. FIGARO HS trade database

Raw merchandise trade statistics (UN Comtrade/EU Comext) are typically used to evaluate dependencies and vulnerabilities of strategic products. They have a high level of detail (6-8 digit) and can provide very recent trade flow datasets. However, raw trade statistics as such suffer from various **caveats** that may influence the geographical distribution of trade and therefore, the assessment of vulnerabilities and dependences. Following Eurostat (2019) and Martins-Ferreira (2018), these are the following:

- **Non-allocated trade**: one reason for non-allocated trade (and trade asymmetries) is confidentiality; for example, when one country reports its trade with a partner as confidential while the trade partner reports a (non-confidential) value for the same transaction. An alternative reason for non-allocated trade may arise when one EU Member State fails to record its trading partner and hence reports the partner as 'country and territory not specified'. Both of these examples are part of a more general case: whenever one of the two trade partners is unable to fully specify a transaction there will be a trade asymmetry. Therefore, Eurostat (2019) implemented a methodology to allocate the non-allocated trade to products/partners and reduce the trade asymmetries.

- Notwithstanding the progress that has been made in this respect and with ad-hoc bilateral workshops between EU Member States organised by Eurostat, **trade asymmetries** still exist which makes it hard for practitioners and researchers to build macroeconomic models or accurately assess economic dependences and vulnerabilities between countries. Therefore, Eurostat has developed a consolidating methodology (adopted by the OECD) to reduce the asymmetries and estimate one single trade flow for each bilateral transaction. Note however that imports have to be converted previously from CIF to FOB in order to compare exports (imports) and mirror exports (imports) in the same valuation before consolidating the corresponding bilateral trade flows.

- Besides, EU Member States may declare imports/exports for customs or tax purposes without having acquired ownership of the goods concerned, in other words, they declare quasi-transit trade (e.g. trucks crossing Germany from the Netherlands to Slovakia). Alternatively, they can also declare re-exports, when the goods pass through a country that provides just a distribution service (e.g. wholesale). While relevant for physical trade flows, **quasi-transit trade and re-exports** distort the (production-based) geographical distribution of trade among Member States and that may be economically relevant. With this purpose, Eurostat (2019) developed the QDR methodology that breaks down a global consolidated view of bilateral merchandise trade into quasi-transit trade, domestic exports and re-exports at HS6 digit level.

In this respect, Eurostat and the JRC have been making an effort during the last five years to consolidate a global balanced view of merchandise trade flows for the compilation of the Eurostat's global inter-country input-output tables (FIGARO tables – 2010-2020), which address all those caveats and thus provide an improved geographical distribution of global bilateral trade flows in goods. By doing so, the FIGARO HS trade database (FiGARO stands for Full International and Global Accounts for research in input-Output Analysis) identifies separately domestic exports, re-exports and quasi-transit trade. For re-exports, it is therefore possible to compare the bilateral trade view from the consignment (re-exporter) vs. origin (producer) perspectives in order to assess the relevance of re-exports vs. measuring vulnerabilities and dependences with just exclusively raw trade statistics.

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