Council of the
European Union

Brussels, 12 May 2022
(OR. en)

8799/22

COMPET 296
IND 146
MI 353
RC 28
RECH 221
TELECOM 194
FIN 524
CADREFIN 66

COVER NOTE

From:	Secretary-General of the European Commission, signed by Ms Martine DEPREZ, Director
date of receipt:	11 May 2022
To:	General Secretariat of the Council
No. Cion doc.:	SWD(2022) 147 final - PART 1/4
Subject:	COMMISSION STAFF WORKING DOCUMENT **A Chips Act for Europe**

Delegations will find attached document SWD(2022) 147 final - PART 1/4.

Encl.: SWD(2022) 147 final - PART 1/4

EUROPEAN
COMMISSION

Brussels, 11.5.2022
SWD(2022) 147 final

PART 1/4

COMMISSION STAFF WORKING DOCUMENT

A Chips Act for Europe

Table of Contents

Introduction 4

PART I 6

1. The Worldwide Semiconductor Manufacturing Landscape 6

  1.1 Societal Dependence on Semiconductors 6

  1.2 Global Semiconductor Value Chain 7

    1.2.1 The major segments of the value chain 7

    1.2.2 Interdependencies across the value chain 9

    1.2.3 Concentration and potential choke points within the supply chain 11

2. The Chips Crisis 13

  2.1 Unprecedented Global Semiconductor Shortages 13

  2.2 Why has the supply chain become so fragile? 13

  2.3 Factors in the Current Chip Crisis 14

  2.4 Impact of shortages 16

    2.4.1 Example: the chips shortage and its impact on the automotive industry 17

    2.4.2 Example: the chips shortage and its impact on the healthcare industry 18

    2.4.3 Example: The chip shortage and its impact on the EU space and defence 19

    2.4.4 Example: The chip shortage and its impact on industrial automation 19

    2.4.5 Example: The chip shortage and its impact on the EU energy system 19

  2.5 Impact of the Ukraine Crisis 20

3. Global Market Perspectives and where Europe is in the Market 21

  3.1 Market Perspectives - World Markets 21

  3.2 Market Position of Europe 28

  3.3 European Strengths in the Global Market that can be Built Upon 29

    3.3.1 A snapshot of the European supply chain 29

    3.3.2 Design and Manufacturing in Europe 31

    3.3.3 The Research efforts of Europe 32

4. Technology Trends and Evolving User Requirements for Key European Sectors 34

  4.1 Industrial Automation 34

  4.2 Automotive Industry 35

  4.3 Healthcare 37

  4.4 5G and 6G Communications 38

  4.5 Aerospace, Defence and Security 40

  4.6 Energy 40

5. Technology Drivers and Opportunities for the Future 42

5.1 Edge Computing 42
5.2 Artificial Intelligence 42
5.3 Increasing Security and Confidentiality Requirements 43
5.4 Environmental Sustainability 45
6. Evolution of Technology to Meet the needs in 2030 48
6.1 Greater Processing Power 48
6.2 Device Architectures Tailored for AI 49
6.3 Open-Source Hardware - RISC-V 50
6.4 EDA Tools and Ecosystem 52
6.5 More than Moore 53
6.6 Quantum Technologies 53
PART II - A Plan for Action 57
7. The Chips Act: the way forward 57
Limited innovation capacity in the ecosystem 58
Low investment in manufacturing capacity 59
Imbalance between supply and demand 60
8. The Three Pillars of the Chips Act Package 62
8.1 Pillar 1. The Chips for Europe Initiative 62
8.1.1 Introduction 62
8.1.2 Explaining further the Pillar 1 approach 62
8.1.3 Investing in a pan European virtual design platform 63
8.1.4 Investing in competence centres and skills development 64
8.1.5 Investing in new pilot lines 66
8.1.6 Investing in Advanced Technology and Engineering Capacities for quantum chips 67
8.1.7 Managing the Intellectual Property 68
8.1.8 Implementing the Chips for Europe initiative: the Chips Joint Undertaking 69
8.1.9 The role of the European Chips Infrastructure Consortium (ECIC) 70
8.1.10 The Chips Fund 71
8.1.11 Impact and benefits 72
8.2 Pillar 2. A Framework to Ensure Security of Supply 74
8.2.1 Urgency to invest in new production capabilities for the EU 74
8.2.2 Explaining further the pillar 2 approach 76
8.2.3 Impact and benefits 81
8.3 Pillar 3. Monitoring and Crisis response 86
8.3.1 Urgency for the EU to start monitoring the semiconductor supply chain 86
8.3.2 Explaining further the pillar 3 approach 87

8.3.3 Impact and benefits 91
9. Coordination and Governance of the Chips Act 93
10. Budgetary Aspects 96
10.1 Investment 96
10.2 Breakdown of Funding Components 96
11. Application of the ‘one in, one out’ approach 99
12. What success looks like 101
Glossary 102
Annex 1. Introduction to Semiconductors 108
Annex 2. Semiconductor Manufacturing Steps 110
Annex 3. Moore’s Law 112
Annex 4. FinFET and FDSOI Semiconductor Technologies 113
Annex 5. Examples of ongoing Pilot Lines in EU 117
Annex 6. Chips for Europe: Examples of impact of Pilot Lines 120

Introduction

On 8 February 2022, the European Commission proposed a comprehensive set of measures for strengthening the EU's semiconductor ecosystem, the **European Chips Act**.[1] In this package, the Commission has adopted a **Communication**, outlining the rationale and the overall strategy, a proposal for a **Regulation** for adoption by co-legislators, a proposal for **amendments** to a Council Regulation establishing the KDT Joint Undertaking, and a **Recommendation** to Member States promoting actions for monitoring and mitigating disruptions in the semiconductor supply chain.

To complement the proposed package, and as provided for in the Better Regulation rules for cases where an Impact Assessment could not be prepared due to the urgency of an initiative, this Staff Working Document (SWD) aims to explain why Europe needs to act now to address shortcomings in key chip design and manufacturing competences and facilities to ensure its resilience against supply chain disruptions. This SWD also provides additional information concerning the rationale behind the proposed measures in the 3 pillars which are the foundations of the proposal and explains further their implementation. This would not have been possible without providing a panoramic description of the characteristics of the semiconductor value chain, key market and technology trends and opportunities, given the complexity of the technological context and of the semiconductor ecosystem.

The SWD also intends to elucidate on the ongoing **crisis** and the pivotal role semiconductors have acquired in the global context. Semiconductors are indeed at the centre of **geopolitical** interests. Leading economies are keen to secure their supply in the most advanced chips with significant investments, as this increasingly conditions their capacity to act economically, industrially, militarily, being the drivers of the digital transformation.

The first part of the SWD (chapter 1) illustrates the highly complex semiconductor value chain, in which extraordinary technological advances have pushed to a high level of specialisation in a global network of deeply interdependent actors, with little flexibility leading to structural vulnerabilities and chokepoints. As consequence, the supply chain is prone to disruptions, such as the one that followed the pandemic and that is still ongoing, impacting many industries globally (as illustrated in chapter 2).

An analysis of the global semiconductors market, its main segments and future trends is outlined in Chapter 3, with a focus on the relative position of Europe. An overview of the main technology trends in key industrial sectors (chapter 4) is followed by an analysis of opportunities driven by the evolution of key technologies (chapter 5). Technological advances will be instrumental to help achieve Europe's 2030 ambitions (chapter 6), including the doubling of its production share of semiconductors, as set out in the Digital Decade targets[2], as well as the twin transition related to the electrification and digitalisation of the economy.

Against this backdrop and based on the conclusions (chapter 7) of the in-depth analysis, this SWD outlines a strategic approach, explaining the activities included in the Chips Act structured around three pillars. Chapter 8 provides further explanations on the set of measures included in these three pillars of the Chips Act:

---

[1] COM(2022) 45. Communication from the Commission: A Chips Act for Europe. 08/02/2022
COM(2022) 46. Proposal for a Regulation establishing a framework of measures for strengthening Europe's semiconductor ecosystem (Chips Act). 08/02/2022
COM(2022) 782. Commission Recommendation on a common Union toolbox to address semiconductor shortages and an EU mechanism for monitoring the semiconductor ecosystem. 08/02/2022

[2] COM(2021)118. 2030 Digital Compass: the European way for the Digital Decade. 09/03/2021

- **Pillar 1 -** The **Chips for Europe** Initiative supporting large-scale technological capacity building and innovation throughout the Union to enable the development and deployment of cutting-edge, next generation semiconductor and quantum technologies.
- **Pillar 2** aiming to create a framework to ensure **security of supply** by targeting the attraction of investments and enhanced production capacities in semiconductor manufacturing, advanced packaging, test, and assembly.
- **Pillar 3** proposing to create a coordination mechanism between the Member States and the Commission to strengthen collaboration with, and across, Member States for **Monitoring and Crisis Response**.

Governance and budgetary aspects are outlined in chapters 9 and 10. The SWD includes a glossary of terms and acronyms, and Annexes providing technical information in relevant aspects:

Annex 1. Introduction to Semiconductors providing some insight on the technology and different types of semiconductor devices.

Annex 2. Semiconductor Manufacturing describing the various steps of the fabrication process.

Annex 3. Moore’s Law and its central role in the fast technology evolution of the sector.

Annex 4. FinFET and FDSOI Semiconductor Technologies. A comparative analysis of the two most prominent manufacturing technologies

Annex 5. Ongoing Pilot Lines with brief description of pilot lines launched in the period 2014-2020.

Annex 6. Chips for Europe: Examples of impact of Pilot Lines and their extended geographic and community benefits.

PART I

1. The Worldwide Semiconductor Manufacturing Landscape

1.1 Societal Dependence on Semiconductors

Semiconductors are the material basis for chips[3] embedded in virtually every technology product today. Chips are miniaturised physical devices that can capture, store, process and act on data. Semiconductors are essential building blocks for digital products used in everyday activities such as work, education and entertainment, for critical applications in cars, trains, aircraft, healthcare and automation, as well as for the functioning of key infrastructures for energy, mobility, data and communications. They are also crucial for the must-win technologies of the future, such as artificial intelligence (AI), low power computing, 5G/6G communications, as well as the Internet of Things (IoT) and edge, cloud and high-performance computing platforms.

A vast range of semiconductor devices are used in sensing, communications, power management and to meet ever-increasing computational demands as AI penetrates more and more application domains[4]. These miniaturised devices determine the performance characteristics of digital systems, not only in terms of computational throughput, but also in terms of security and energy-efficiency. With an increasingly connected world, security has become a key concern and essential in critical applications such as autonomous cars, electrical grid infrastructures and banking. The importance of ever-greater energy efficiency as an essential component of meeting the goals of the digital and green transitions has been highlighted in recent EU flagship initiatives[,5,6].

All industrial ecosystems rely increasingly on semiconductor technology for their competitive edge. Top Original Equipment Manufacturers and social media companies have taken to designing their own chips in-house. The acquisition of suppliers, rivals and start-ups with semiconductor expertise has become part of a strategy for companies to enhance digital product offerings and accelerate next-generation production portfolios.

The massive investments in the world's major semiconductor-producing regions today are not just about the semiconductor industry per se, but about the enabling role of cutting-edge semiconductor technology in the competitiveness of downstream industries, in defending strategic economic interests and national security and delivering on societal challenges.

Ensuring security of supply and resilience across the full supply chain for these vital products is essential for Europe's future.

Semiconductors are at the heart of innovation and the current industrial revolution. A key enabler for the digitisation of industry and an essential element of future smart and sustainable products and services, they are critical to Europe's security and resilience of the semiconductor supply

---

[3] Also referred to as integrated circuits or ICs

[4] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 2030 Digital Compass: the European way for the Digital Decade, COM(2021) 118, 9.3.2021.

[5] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal. COM(2019) 640, 11.12.2019.

[6] A new Industrial Strategy for a globally competitive, green and digital Europe and its update of 2021 (https://ec.europa.eu/commission/presscorner/detail/en/IP_21_1884).

chain, and its economic and societal well-being.

1.2 Global Semiconductor Value Chain

1.2.1 The major segments of the value chain

The active component of a chip is a transistor - an electronically controlled switch. Since the 1960s, the business of chip production has been driven by doubling the amount of transistors in a given area of semiconductor - and hence doubling the computing power without cost - every eighteen months. Referred to as Moore's Law (see Annex 3), this trend dates from 1965 when a chip had just 64 transistors.

The business is characterised by rapid technological change fuelled by constant research and development (R&D) at all stages of the value chain : from the **software** and intellectual property (**IP**)[7] that support the process of chip **design**, to the **materials** (wafers & chemicals) and **equipment** that support the processes of **fabrication**, and subsequent **assembly, test and packaging** of the chip.

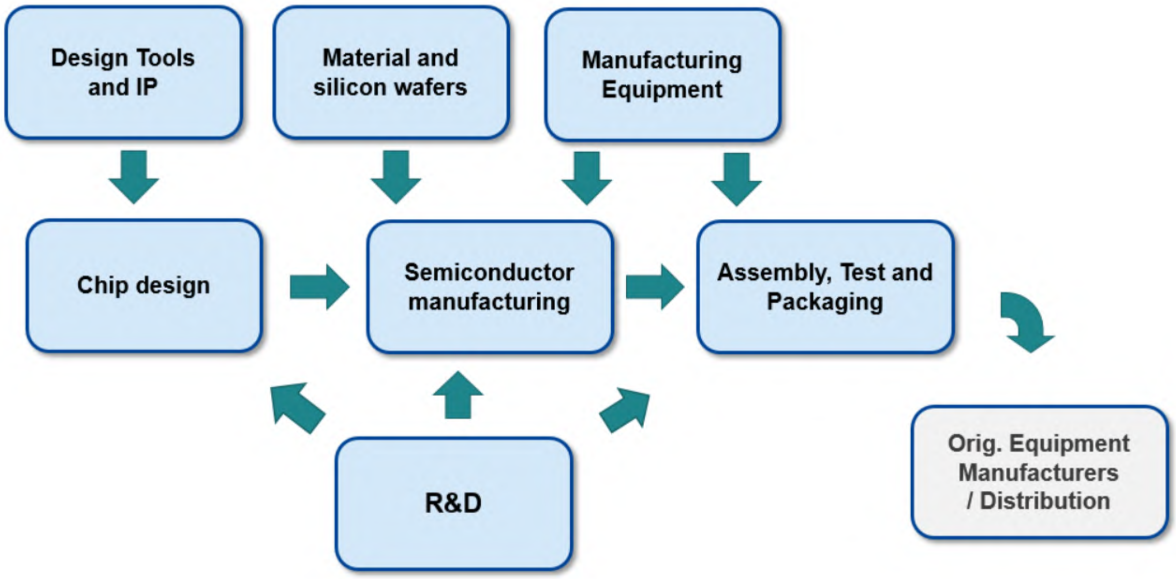


Figure 1. The semiconductor value chain

The process of chip **design** depends on specialised software tools or electronic design automation **(EDA) tools** provided by companies such as Cadence Design Systems, Synopsis and Mentor Graphics/Siemens. The EDA market is dominated by US companies with 70% of global sales. These tools use Intellectual Property blocks **(IP blocks)** from third-party IP vendors such as ARM (UK) or Imagination Technologies (UK) as parts of new designs.

Chemicals[8], specialty gases[9], minerals and high-purity materials are important for many of the process steps in semiconductor fabrication (e.g., patterning, deposition, etching, polishing) and for

---

[7] Because of the complexity of designing chips with millions or even billions of transistors, chip designers license intellectual property or IP blocks (basic functional building blocks).

[8] Boron, Phosphorus, Germanium, Indium, Gallium, etc.

equipment operation, facility cleaning and packaging. Chip manufacturing requires nearly 500 specialised process chemicals; this number is rising as semiconductors become more complex. Key suppliers are Shin-Etsu Chemicals, Sumitomo Chemicals, Mitsui Chemicals (Japan), BASF, Linde, Merck KGaA, Air Liquide (EU), Taiwan Specialty Chemicals Corporation, and in Dow/DuPont (US). The demand for raw materials within the industry is expected to rise by more than a third in the next four years.

Silicon wafers serve as the substrate material and undergo a variety of complex process steps before being diced and packaged as chips. Depending of the production processes and input material used, there are different types of silicon wafers, with features and performance characteristics suitable for different end use chips. Japan's Shin-Etsu and Sumco are the world's largest silicon wafer makers respectively, followed by Taiwan's GlobalWafers, Germany's Siltronic, Korea's SK Siltron and France's Soitec.

Specialist vendors provide more than 50 different types of sophisticated **equipment** for each step in the chip fabrication process. Among them are lithography tools which determine the process node[10] size at which a semiconductor fabrication plant (fab) can produce, metrology and inspection equipment to confirm the yield over various stages of the process, different advanced automation and process control systems used for direct equipment control, automated transportation of materials and real-time dispatching of lots. Key suppliers include ASML (NL), Applied Materials (US), Tokyo Electron (JP), Lam Research (US), KLA Tencor (US) ASM-I (NL). The supply of certain pieces of equipment is extremely concentrated: for example, ASML holds a worldwide market share above 80% in the supply of lithography equipment, with a peak of 100% in the Extreme ultra-violet (EUV) lithography equipment.[11]

Annex 1 provides an introduction to the semiconductor technology and the different types of semiconductor devices.

Fabrication facilities, or front-end manufacturing[12], equipped with the most modern process technologies can enable transistors to be patterned onto the wafer to a precision of 5 nanometres (nm) or below and chips to be produced with 10s of billions transistors. The cost of building such a fab can be up to EUR 20 billion, while designing and developing such complex chips can be in the range of EUR 1 billion.

The volume required for cost-effective manufacturing is so high that many companies outsource production of their design to contract manufacturing companies that specialise in operating foundries for third parties. TSMC (TW), Samsung (KR), UMC (TW), SMIC (CN) and Global Foundries (US)

---

[9] Neon, Argon, Ammonia, Helium, Chlorine, etc.

[10] In semiconductor manufacturing, the process technology (or process node) has traditionally been correlated with the transistor dimension. It is measured in nanometres: 1nm or 1 nanometre = 1 billionth of a meter. **Smaller process nodes produce smaller transistors, which are faster in terms of computational throughput and more power efficient**. The smallest node in production today is 5 nm. The numbers are not related to physical features any more, but express the level of density of transistors for marketing purposes.

[11] Moody's, December 2020 (https://www.asml.com/-/media/asml/files/investors/shareholders/bonds-credit-rating/2020-12-17_asml_co_moodys.pdf)

[12] The fabrication of semiconductors is usually divided in two main phases. Front-end manufacturing refers to the wafer fabrication which includes processes such as photo-masking, etching, diffusion, ionic implantation, metal deposition, passivation (all of which are repeated many times), then backlap, and wafer probing. In back-end manufacturing, the wafer is cut, assembled, packed into different packages and tested; it is often called Assembly, Testing and Packaging (ATP).

are the major foundry companies[13]; however only TSMC and Samsung are currently able to offer front-end manufacturing at 5 nm and below.

This has transformed the business dramatically. Previously such business was predominantly featured by Integrated Device Manufacturers (IDMs) who design their own chips and have their own facilities for fabrication and assembly. Today many companies run their businesses based on “fabless” or “fab-lite” models whereby they outsource all or some of their fabrication to foundries. Fabless design accounts for around 40% of global chip revenues with Qualcomm, Nvidia, Broadcom (US), MediaTek (TW) and AMD (US) as market leaders.

IDMs such as Intel (US), Micron (US), NXP (NL), Texas Instruments (US), STMicroelectronics (FR/IT) and Infineon (DE) perform front-end manufacturing in-house. These companies operate semiconductor wafer fabrication facilities, with typical volumes of 50,000-100,000 wafers per month[14]. Strictly speaking, IDMs also make use of third-party foundries, in particular for more advanced chips.

Annex 2 describes in detail the semiconductor fabrication process.

Back-end manufacturing includes the packaging of chips into a form that ensures reliability and enables connectivity with other circuit components. Each individual chip in the wafer is tested before the wafer is sliced into individual dies. The dies that pass the wafer test are packaged, and the packaged chips undergo a full functional and performance test. This is done in-house by semiconductor IDMs or via OSATs (Outsourced Semiconductor Assembly and Test)[15].

Figure 2 illustrates how revenues are distributed across the various segments across the value chain together with the levels of R&D and CAPEX spending as a percentage of revenues. Noteworthy is that chip design is the most R&D intensive segment accounting for 65% of total industry R&D, and fabrication (or front-end manufacturing) is the most CAPEX intensive segment accounting for 64% of total industry capex[16]. The value added also varies widely across the value chain (see chapter 3).

---

[13] A semiconductor foundry is a producer of chips designed by others.

[14] At least 50,000 wafers per month for most modern fabs. Wafers are generally 300mm in diameter. One such wafer would hold 150 (giant) chips of 20x20mm. This would equate to 7.5 million chips per month.

[15] OSATs are companies that offer third-party IC packaging and test services. Major OSAT companies include ASE (Taiwan), Amkor (US) and JCET (China).

[16] BCG x SIA, “Strengthening the global semiconductor supply chain in an uncertain era”, April 2021

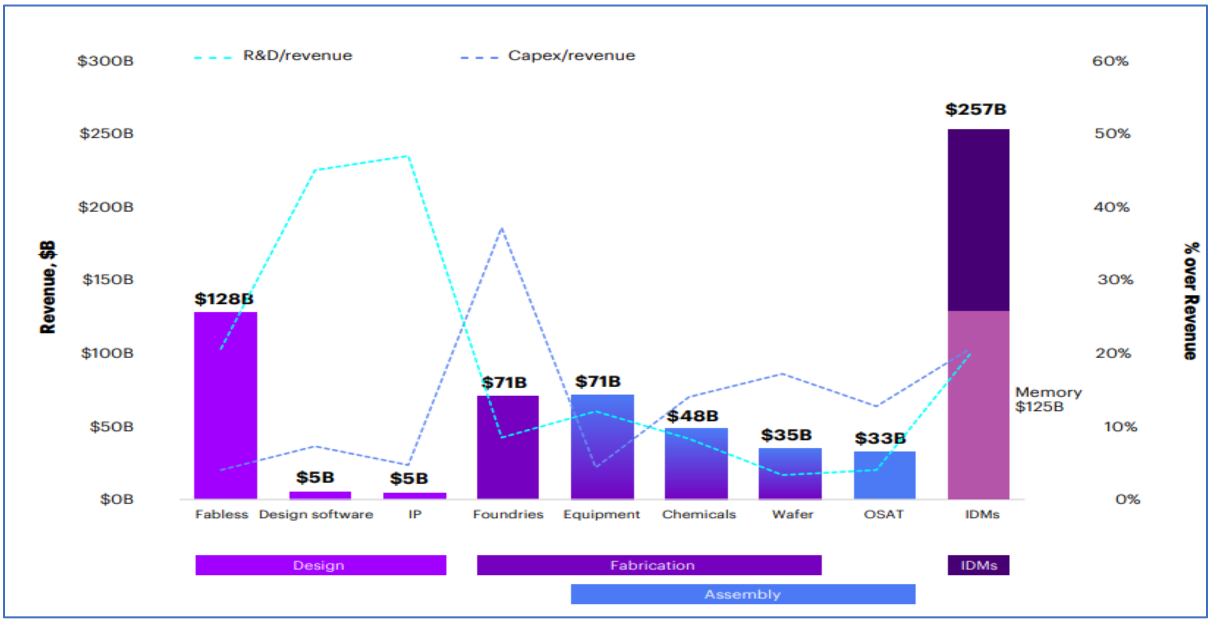


Figure 2. Revenue by Segment (Source: Accenture. 2022)

1.2.2 Interdependencies across the value chain

It can be observed that at the current stage of the industry no single geography or company dominates all steps of the value chain. There will always be some parts of a system that require innovative solutions from another geographical region and this is unlikely to change, given the high level of capital expenditure required to ensure a given region could satisfy internal demand with only domestic supply across all levels of the value chain[17]. Thus, chip production relies on collaboration and trade between the major semiconductor-producing regions. It is a highly innovative and efficient value chain but, as shown in the following Chapter, is not resilient. Figure 3 illustrates the main steps in the production of chips with a large geographical dispersion and a myriad of interactions that are typical within the industry.

Figure 3 shows the example where a smartphone is produced for a customer in Argentina. IP blocks from the UK are designed into the chip using EDA tools in the US. The chip design is verified in India before being passed back to an Original Equipment Manufacturer (OEM) in the US who uses it in the smartphone design. The front-end manufacturing is carried out by a Taiwanese foundry using silicon wafers supplied from Japan, and European chemicals, specialty gases and equipment to produce a bare die. The die is then sent to Malaysia for back-end processing where it is packaged and then tested using equipment supplied by the US. The chip is assembled into the smartphone in China from where it is distributed through commercial channels to reach the final user in Argentina.

---

[17] See BCG x SIA, "Strengthening the global semiconductor supply chain in an uncertain era", April 2021, Exhibit 21, estimating the cost of hypothetical semiconductor self-sufficiency by geographic area.

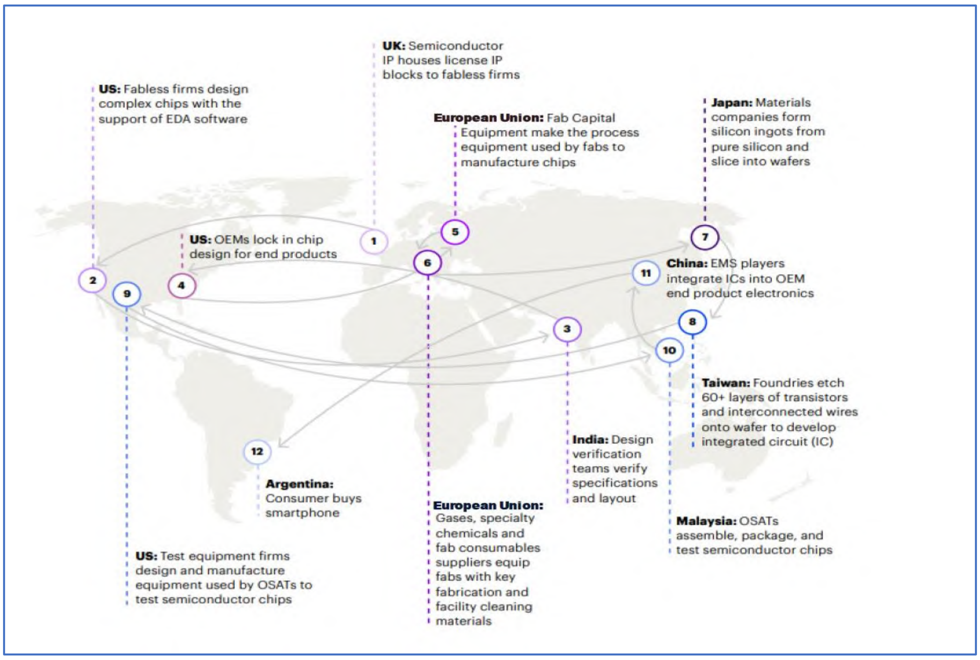


Figure 3. Illustrative example: Global Semiconductor Supply Chain for Smartphone (Source: Accenture. 2022)

Figure 4 is another example of the whole range of companies involved and the complex interdependencies for the production of chips for wireless and video processing applications.

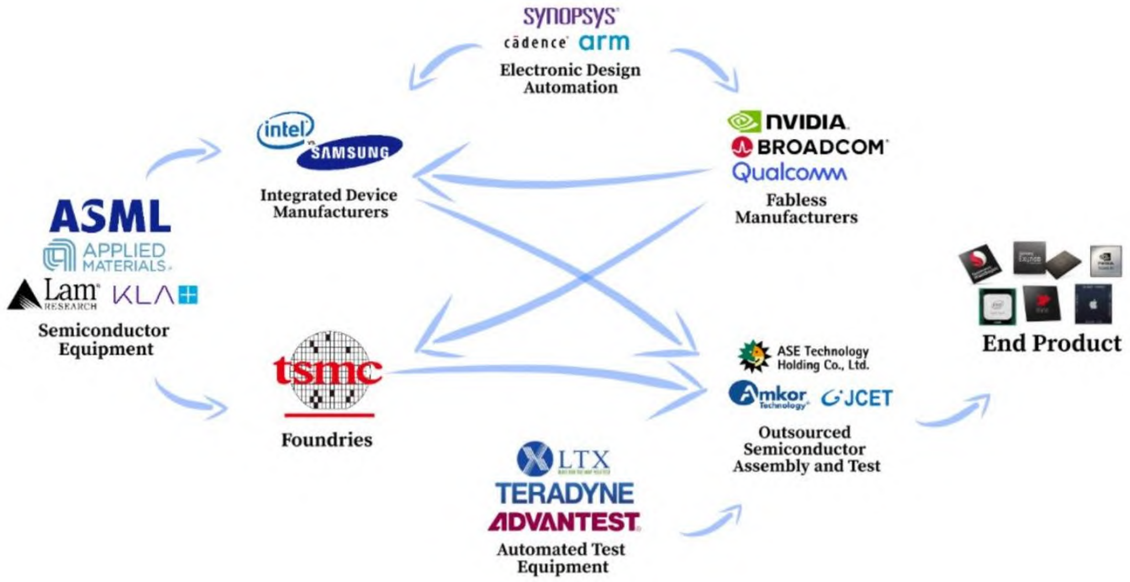


Figure 4. Complex interactions to develop wireless and video processing chips

1.2.3 Concentration and potential choke points within the supply chain

Producing a single chip requires up to 1500 process steps[18], each based on hundreds of variables. Some process steps during wafer fabrication, such as oxidation and coating, lithography, etching and

---

[18] Jan-Peter Kleinhans and Julia Hess, “Understanding the Global Chip Shortage”, November 2021.

doping, are repeated hundreds of times, depending on the specific chip. There are thus many points in the production process that are prone to disruption. Disruptions in semiconductor materials can have far-reaching ramifications across the value chain. For instance, in February 2019, a faulty batch of photoresist chemicals forced TSMC to scrap a large quantity of silicon wafers with a value of USD 550 million[19]. More recently, the closure of the 3M plant in Belgium, which produces fluorinated coolant for semiconductor manufacturing, has led to major concerns in the industry as there is no alternative supplier[20]. The most recent Chinese lockdown has had the effect that some raw materials and products are not being loaded and freighted from Shanghai, causing delays in various production sites worldwide.

Additionally, several levels of the supply chain are extremely concentrated, featuring limited alternatives for customers, which leads to strong lock-in effects. This creates the risk of single points of failure in supply chains with companies unable to find second or third source suppliers. For instance, TSMC in Taiwan and Samsung in South Korea are the only foundries capable of manufacturing the most advanced chips (at nodes below 5 nm) and ASML (NL) is the only supplier of advanced Extreme ultra-violet (EUV) lithography equipment. Currently there are more than 50 points in the global semiconductor value chain representing potential single points of failure. These represent more than 65% of the global market value[21].

East Asia is the most important region for back-end manufacturing (assembly, test and packaging) and this **high geographic concentration of companies increases the risk of supply chain disruptions**. For instance, Ajinomoto Build-up Film (ABF) substrates produced in Japan and Taiwan are essential for every chip that uses laminated packaging. ABF substrates connect different components within a chip and are widely used in chips for graphics cards, servers, smartphones, laptops, etc. Shortages have persisted for some time[22] and are causing delays in chip production as well as price increases.

Typically, front-end manufacturing of dies takes between 8 and 28 weeks, with the back-end processes of assembly and packaging taking 4 to 10 weeks, and testing taking another 2 weeks. In total, producing a semiconductor can take more than 6 months. Consequently, **the industry is characterised by long-term planning, with customers placing their orders well in advance, with very little flexibility for deviations.**

The semiconductor value chain is complex and global with many interdependencies, and relies on collaboration and trade between regions. The supply chain is however far from being resilient; disruptions at any point can have ramifications across the full value chain. Choke points may emanate from concentrations of specific essential technology within a single company or within a single geographical region.

---

[19] In the electronics industry, materials take center stage (acs.org). Chemical and Engineering News.

[20] https://www.eetimes.com/3m-cuts-output-of-hazardous-material-used-in-chip-production/

[21] Semiconductor Industry Association. Input to the Department of Commerce on 'Semiconductor Manufacturing and Advanced Packaging Supply Chain'. 5th April 2021

[22] 41 Phil Garrou. 2021. "IFTLE 479: ABF Substrate Shortages; Consolidation Continues","IFTLE 479: ABF Substrate Shortages; Consolidation Continues", 3DInCites.

2. The Chips Crisis

2.1 Unprecedented Global Semiconductor Shortages

As highlighted in the previous chapter, semiconductor supply chains are highly interconnected with many actors across the globe and numerous choke points which can impact production. Over the past 2 years, Europe and other regions of the world have witnessed disruptions in the supply of chips, causing shortages across multiple economic sectors with potentially serious societal and economic consequences.

In a nutshell, the disruptions resulted from multiple factors, including the acceleration of digital transformation in industry leading to an increased demand in a large number of semiconductor components and devices; heightened demand for computers, electronics and technology products as lockdowns related to the COVID-19 pandemic led to a surge in remote working, home schooling and digital entertainment; COVID-19-related closures of key fabs; dislocations in global logistics and transportation networks coupled with shortages of raw materials, key components and intermediary products.

The shortage of chips has impacted downstream sectors such as automotive, energy, communications and health, as well as defence, security and space, forcing delays in production and factory closures across the world. The impact was severe and in the automotive sector, for instance, production in some European Member States decreased by one third in 2021[23].

2.2 Why has the supply chain become so fragile?

Since the turn of the century, the semiconductor industry has responded to market difficulties through consolidation and outsourcing to the Far East, particularly concerning production, and assembly and testing. **While this appears to have led to better utilisation of existing capacity, however it has reduced available spare capacity.** Thus, given the high capital expenditure and time required to set up new manufacturing facilities, there appears to be limited possibility to increase production if demand goes up considerably as it did from early 2020.

At the same time, the drive towards zero inventory approaches by some end user industries has led to a situation where in case of a sudden increase in demand for chips, there is very limited available inventory buffer to source from, until production can catch up. The result of this is a high susceptibility across the supply chain to surges in demand. A key problem is that once demand exceeds supply it takes at least 2-3 years to recover as there is a need for significant investment to increase capacity and inventory with a resulting long lead time for components.

In recent years, geopolitical tensions have been simmering. China depends on US-origin technology and imports of chips from Taiwan. With the "Made in China 2025" plan launched in 2015, China set itself the ambition of reaching 70% autonomy in chip-making by 2025 and to this end earmarked USD 150 billion to build up semiconductor design and manufacturing capacity. The creation of this fund has been linked to the growth in pace of cross-border acquisitions in the sector since 2015[24].

---

[23] William W. Pitkin, Jr. 2021. "Chip Shortages: Created by Demand, Geopolitics, Pandemic and Mother Nature". State Street Global Advisors.

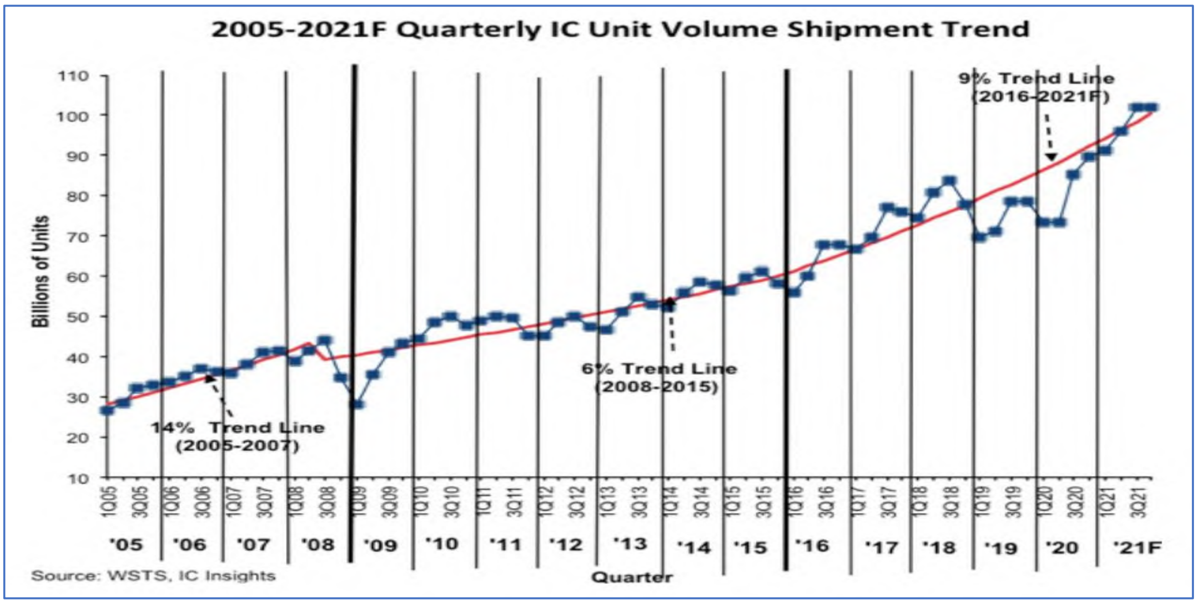
[24] Measuring distortions in international markets: The semiconductor value chain, OECD December 2019

The U.S. government has responded to this "concerted push by China to reshape the market in its favour"[25]. In 2019, the US Department of Commerce broadened the application of its Export Administration Rules (EAR) to curb the technological advance of certain Chinese companies by cutting them off from critical US-origin technology. Because of Europe's strong dependence on US-origin technology for chip design however, these measures have impacted European chipmakers trading with China.

The shortages over the past two years have exposed structural vulnerabilities in highly interdependent and global value chains already weakened by lean production strategies and geopolitical frictions pre-dating the pandemic. They have furthermore served to highlight Europe's dependency on supply from a limited number of companies and geographies.

2.3 Factors in the Current Chip Crisis

From the onset of the COVID-19 pandemic in early 2020, the entire semiconductor business has seen a strong growth in demand. **Shipments of chips increased by 40%** from around 73 billion in 1Q20 to approximately 102 billion in 3Q21 (see Figure 5).



Source: WSTS, IC Insights

Figure 5. IC Unit Volume Shipment Trend (source WSTS, IC Insights)

With little spare capacity, it was not possible for the industry to react quickly to this surge in demand. It could be met partly by depleting the limited inventory that was available. As a result, across the world, **lead times for components doubled** from roughly 10 weeks to 20 weeks for microprocessors, memory chips, power management and analogue chips (see Figure 6).

---

[25] PCAST Ensuring Long-Term U.S. Leadership in Semiconductors, Report to the President. January 2017

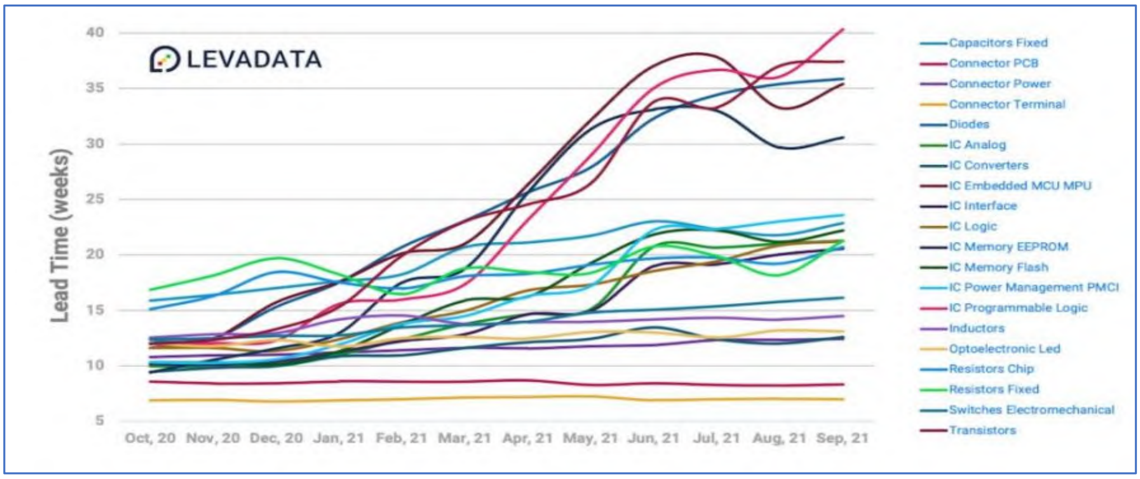


Figure 6. Increasing IC Lead Times During 2021

Demand has been further exacerbated by companies over-ordering and stockpiling components. To what extent stockpiling has moved future demand into the present is still unclear.

According to the Semiconductor Industry Association (SIA): "when market demand runs high, such as in a cyclical market upturn like the one the market is in now, front-end semiconductor fabrication facilities, or fabs, will typically run above 80 percent capacity utilization, with some individual fabs running as high as between 90-100 percent." As Figure 7 below shows, the industry has been steadily increasing overall fab utilization over the past two years and is estimated to have increased utilization even more during most of 2021 to meet demand.

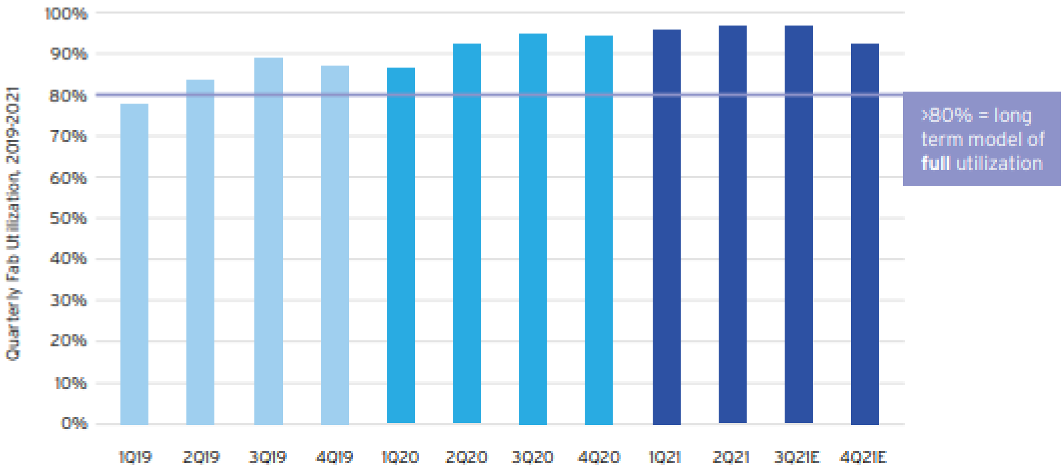


Figure 7. The industry has been steadily increasing overall fab utilization. (Source: SIA)

In addition to long term economic drivers that have reduced the flexibility of supply chains, there have also been a number of external shocks[26] and disruptions in the last two years including: earthquakes, the fire at the Renesas fab in Japan, ice storms in Texas, power outages at Infineon, NXP and Samsung fabs, as well as droughts in Taiwan and human errors.

---

[26] Fusion Worldwide. 2021. "The Global Chip Shortage: A Timeline of Unfortunate Events".

2.4 Impact of shortages

The impact of these shortages of components has been dramatic with implications in a number of critical areas such as supply of medical devices, devices for broadband communications and components for the automotive sector, just to mention a few. This includes shortages of microcontrollers (40, 90, 150, 180, and 250 nm nodes), analogue chips (40, 130, 160, 180, and 800 nm nodes) and optoelectronic chips (65, 110, and 180 nm nodes).

Figure 8 shows some of the markets affected by these different semiconductor shortages. Goldman Sachs estimates that around 169 industry sectors globally have been impacted[27]. **Within Europe, the automotive sector is a significant market (accounting for 37% of the semiconductor demand) as well as industrial manufacturing (accounting for 25% of semiconductor demand)**.

Figure 8. Markets for different Semiconductors (Source ZVEI-PK)

Other important European semiconductor end-use sectors include communications (15%) and consumer electronics (7%)[28]. **The shortages have led to European companies struggling to source chips for cars[29] and medical devices such as ultrasound equipment, pacemakers, ventilators,**

---

[27] William W. Pitkin, Jr. 2021. "Chip Shortages: Created by Demand, Geopolitics, Pandemic and Mother Nature". State Street Global Advisors.

[28] Source: ZVEI-PK (see also section 3.2)

[29] Mark Fulthrope and Phil Amsrud. 2021. "Global light vehicle production impacts now expected well into 2022". IHS Markit.

etc[30]**.** The production of medical equipment has suffered chip supply disruptions resulting in a volume decrease for some medical systems of more than 70%[31].

A survey conducted by the European Commission[32] has shown that the vast majority of responding businesses reported being either directly or indirectly adversely affected by the current shortage in chips.

2.4.1 Example: the chips shortage and its impact on the automotive industry

Following COVID-19 lockdown measures and pessimistic demand forecasts for cars, automakers and their tier 1 (direct) suppliers cancelled orders during 1Q20 and 2Q20. When the rebound in demand for cars kicked in late 2020, the surge in demand for IT equipment generated by the COVID-19 crisis had already led to the world's largest foundry, TSMC, running at full capacity.

Other factors, notably geopolitics, had further exacerbated the situation. Under the Wassenaar agreement, the US had blocked Dutch-based ASML from shipping its EUV lithography equipment to China's major foundry, SMIC, preventing SMIC from advancing and growing to full capacity. At the same time, US chipmakers have had to shift their orders from SMIC to TSMC. Also faced with US sanctions, some Chinese chipmakers have been stockpiling in order to meet future demand.

As a volume business for TSMC, compared with automotive (which accounted for just 3% of its revenues in 2020), chips for IT equipment remained first in line.

The problems were then compounded by the limited resources in the value chain and the long manufacturing cycle times which are at odds with the "just in time" approach used in automotive. Additionally, automotive chips require stringent safety requirements (weather resistance, fault tolerance, redundancy, etc.) that must be certified, including the production process. This limited the number of fabs and packaging companies that automotive chip suppliers can utilise.

As a result, car companies are having to wait for periods of up to a year or more and car factories had to reduce production or shut down, laying off workers. In several EU Member States car production was severely affected: in the case of Germany, 2021 production fell by 34% when compared to 2019, back to 1975 levels [33]. In 2022, car production plans have been cut back and the lead times for chips are still twice as long as they were in 2019.

The above highlights the extreme dependency of Europe on the semiconductor value chain and the importance of a stable semiconductor supply chain for European industry.

The timeline of events and impacts for the automotive industry is shown for TSMC in Figure 9. This shows the major disruptions in chip manufacturing as supply chains were out of synchronisation with the demand from the automotive manufacturers. Vehicle demand came back strongly after the initial disruptions in 1Q20 and 2Q20. Due to chips not being supplied in time, estimated drops in global output amounted to 1.4 million light vehicles 1Q21 and 2.6 million in 2Q21.

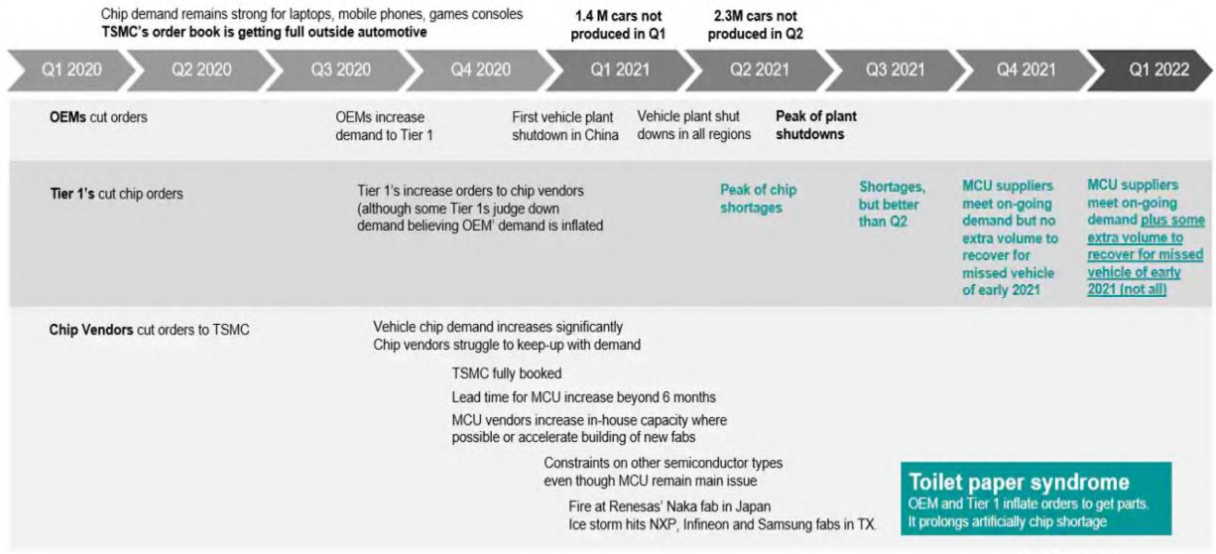
---

[30] Denise Roland. 2021. "Pacemaker, Ultrasound Companies Seek Priority Amid Chip Shortage". The Wallstreet Journal.

[31] Philips Healthcare

[32] In early 2022, the European Commission has carried out a targeted stakeholder survey ('EU Chips Survey') (https://ec.europa.eu/growth/news/stakeholder-survey-european-chip-demand-2022-02-16_en). The European Commission will publish an overview of the aggregated results of the EU Chips Survey as part of a Factual Summary Report during Q3 of 2022. These will help to provide crucial information on sources and impacts of the supply survey.

[33] Source: Verband der Automobilindustrie



Source: IHS Markit

Figure 9. Impact on TSMC of variety of disturbances during 2020 and 2021(source IHS Markit)

In 2021 disruption continued and was aggravated by the effects of the ice storms that hit NXP in Texas, along with the fire at the Renesas Naka 3 facility in Japan (the fire in the 300 mm cleanroom impacted a small area of the fabrication, but it damaged water supply, air conditioning, and manufacturing equipment). Water is used heavily in chip manufacturing for cooling; the drought in Taiwan which led to water restrictions also affected production.

2.4.2 Example: the chips shortage and its impact on the healthcare industry

The COVID-19 pandemic has put Europe's healthcare system under severe strain. For providers of medical systems, shortages of chips have been of particular concern as they are used in medical devices and systems for patient monitoring, x-rays, ultrasound, computed tomography, image guided therapy, respiratory devices, emergency defibrillators and contrast media injectors.

Shortages of processors, converters, programmable and logic devices for the healthcare sector have been reported by COCIR[34]. Salient examples of chip shortages on healthcare are the lack of programmable components used to process and transfer images for patient diagnosis and treatment in Magnetic Resonance Imaging (MRI)[35], and the gap between the demand and supply for a specific microcontroller in Patient Monitoring Line (PML) systems[36] that prevents the installation of tens of thousands of beds in intensive care. Such components are all the more difficult to substitute when they are designed to be compliant with EU regulations such as the RoHS directive. In addition to short-term measures to alleviate the situation in Europe, it is essential to ensure the mid to long-term resilience of the healthcare value chain, in which semiconductors is a critical input. This includes, for instance, priority access to key components in periods of crisis.

---

[34] COCIR is the European Trade Association representing the medical imaging, radiotherapy, health ICT and electromedical industries. http://www.cocir.org/

[35] Siemens Healthcare. https://www.siemens-healthineers.com/

[36] Philips Healthcare. https://www.usa.philips.com/healthcare

2.4.3 Example: The chip shortage and its impact on the EU space and defence

The space and defence domains are facing severe difficulties to procure components. As mentioned previously, semiconductor foundries give priority to markets with high volume demand, such as mobile handsets and IT equipment; space and defence account for approximately 1% of total market volume. The increased lead times during 2021 have had major effects on space missions and the deployment of services supported by EU space programmes (e.g. Galileo second generation, new sentinels part of Copernicus with advanced services for Earth environmental monitoring).

The strategic importance of these two sectors is significant for Europe, thus creating the urgency of reducing the dependence of the EU industry from non-EU semiconductor suppliers. The inability of EU space and defence industry to autonomous and unrestricted access to semiconductors could have a considerable impact on the competitiveness of the sector, the security of EU citizens and EU's strategic autonomy.

2.4.4 Example: The chip shortage and its impact on industrial automation

The European industry uses many different types of semiconductors for the machines and equipment it produces, and to support industrial automation and electrification the need for chips is steadily increasing. The machinery and equipment industry is one of the EU economy's most valuable assets and advanced technologies, such as machine vision and robotics, are essential to keeping it globally competitive. Electrification of the industry is also a key component of the green transition and of becoming less dependent on (imported) fossil fuels, as recently stated in the RePowerEU Communication[37] that is calling for decarbonising industry.

The European machinery and equipment industry has suffered considerably under supply shortages. Of the 5.1 percentage points shortfall in EU-wide industrial production in the first three quarters of 2021, the machinery and equipment sector bore 0.8 percentage points, just behind the automotive industry with 0.9 percentage points.[38]

There are hundreds of different types of machinery and equipment being produced in Europe. This large diversity of European manufacturers makes collective procurement, R&D and investment efforts more difficult. The needs and timelines of the manufacturers differ. Additionally, the industry is characterised by specialised companies, often SMEs, which have limited bargaining power.

Even key EU companies producing semiconductors manufacturing equipment, including ASML, have been affected, which in turn is hampering the needed expansion of global production capacity due to severe delays (up to 3 years) in the delivery of tools.

2.4.5 Example: The chip shortage and its impact on the EU energy system

The digitalisation of the energy network and its transformation towards green power is affected by the lack of some semiconductor components, such as programmable devices (FPGAs). The shortage impacts particularly small to mid-size technology suppliers that play an important role in the value chain,, as the limited demand of some of these critical users translates into low delivery priority for chip vendors. That also severely slows down the installation and operation of wind turbines and photovoltaic systems and their connection to renewable generators. Examples like this would affect

---

[37] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN

[38] https://voxeu.org/article/impact-shortages-manufacturing-eu

the transformation of the European energy system, which is now even more urgently needed as a result of the Ukraine crisis.

2.5 Impact of the Ukraine Crisis

Russia's military aggression against Ukraine has had significant economic implications. Ukraine supplies various raw materials that are critical to chip manufacturing and that can be impacted by the current crisis: neon, palladium and C4F6[39].

Ukraine is a major source of inert gases, such as neon required for the semiconductor lithography process, and any disruption in the supply of neon and other noble gases could trigger shortages and associated cost inflation. Some 45%-54% of the world's semiconductor-grade neon, critical for the lasers used to make chips, comes from two Ukrainian companies, Ingas and Cryoin. They have halted their operations during to current crisis, which may lead to an increase of prices and aggravate the semiconductor shortage.

The stoppage impacts the worldwide output of chips, already in short supply after the coronavirus pandemic. While chipmakers keep some stocks of neon on hand, production could take a hit if the war continues.

Another effect has been the rise in price and likely disruption in the supply of natural gas, used as a source of power in fabs as well as for burning exhaust gases from the manufacturing process to make them safe. This will have a significant impact on operating costs.

The semiconductor industry uses air freight extensively. The flight bans over Russia have led to longer air freight routes, with corresponding cost increases and delays.

Russia is an important producer of metals like aluminium, nickel and copper. Aluminium is a conductor that is commonly used in packaging (wire bonding) and to manufacture passive components, such as resistors and capacitors, commonly used in all types of electronic equipment. Any disruption in the supply of any of these metals could cause prices to rise and subsequently impact the prices of semiconductor devices and electronic systems. However, it is important to note that most chip manufacturers have contingency plans, such as diversifying suppliers and maintaining high levels of inventory.

The global semiconductor value chain had already been weakened by lean production strategies and geopolitical frictions pre-dating the pandemic. The shortages have exposed structural vulnerabilities across highly interdependent supply chains and have furthermore served to highlight Europe's dependency on supply from a limited number of companies and geographies with severe consequences for many of its key industrial sectors.

---

[39] C4F6 Hexafluorobutadiene. A gas used in etch processing.