German Association of the Automotive Industry

Position

Semiconductor crisis

Requirements for future relevance, competence and resilience for Europe

Berlin, May 2023

Abstract

The semiconductor industry gained significant attention over the last years, due to the semiconductor crisis, which had severe implications on many supplied industries, such as shutdowns of automotive production lines. Semiconductors were suddenly on top of everyone’s mind, as the “tiny chips” enable many of today’s vehicle functions, ranging from interior lighting over seat control to blind-spot detection; thus, their shortage directly impacts product and feature offerings. Players from high-tech and consumer electronics industries were confronted with chip shortages as well, putting overall supply security in Europe at risk.

Going forward, the semiconductor industry will remain a critical foundation for technologies the world depends on and will play an even more essential role in enabling a functioning economy. Looking at the increasing demand for technologies across all industries, the chip demand is set to rise over the coming decade. This is especially true for the automotive sector, where semiconductor demand is expected to triple by 2030 on a global scale, from an approximately 8 percent market share in 2021 to roughly 14 percent in 2030 – outgrowing other market segments, such as industrial electronics, as well as the total semiconductor market. The key drivers are autonomous driving, connectivity & shared services, and electrification [ACE(S)].

Given the importance of semiconductors for the European industry and especially for the automotive sector, it is strategically important for Europe to become more than just a "passive consumer" of semiconductors. Rather, Europe must become an "active player" in the semiconductor value chain.

European automotive companies will not only need the newest, leading-edge semiconductor technology nodes, but will have the highest share of demand in nodes ≥90 nm. The semiconductor market is also subject to high dynamics on the supply side. To strengthen their respective position within the industry, Chinese players increasingly invest in their own semiconductor industry (~143 bn USD compared to US with ~53 bn USD and EU with ~46 bn USD), especially in larger node sizes ≥90 nm while the US seeks a Chip 4 Alliance (US, Korea, Taiwan, and Japan). On the current trajectory, the EU’s dependence on China and Asia for mature nodes in general will increase from 35 percent to 45 percent.

In the automotive industry, the global semiconductor crisis, driven by supply disruptions and the resulting bullwhip effect (fluctuations in demand along multi-stage supply chains), caused a significant drop in global production volumes of around 9.5 million vehicles in 2021, of which around 2.4 million would have been produced in Europe. Even when accounting for all currently planned and announced fab buildup projects, the European self-sufficiency is expected to further decrease until 2030. In this situation, an unexpected reduction of semiconductor imports would strongly impact not only the European automotive industry but might also spill over to other industries.

With this document, the VDA (German Association of the Automotive Industry) highlights the current problems of today's European semiconductor ecosystem and possible mitigation measures to overcome them. In an initial scenario, a “local-for-local” view is taken, encompassing the semiconductor demand for products manufactured in Europe. The aim of this scenario is to build up capacities (measured in million wafers per year or mwpy) in order to reduce supply risks and enable the availability of relevant capabilities.

At first, the focus was placed on an effective risk mitigation for front-end manufacturing. In this initial scenario, around 37 additional front-end fabs would be required for capacity buildup. This translates to capex requirements for front-end capacities of roughly USD 205 billion resulting in a required public capex contribution of around USD 77 billion assuming a competitive contribution share of 30 to 45 percent depending on the technology segment. As part of this capacity buildup, different competencies per technology segment would be addressed to enable a comprehensive semiconductor front-end buildup. Additional investments in R&D, equipment and materials, as well as back-end capacities, are to be considered on top.

To increase the relevance of the European chip industry and ensure its growth, a massive expansion of the entire ecosystem (front-end, back-end, equipment, materials, workforce, and energy) would be necessary. Therefore, the VDA motivates a European risk mitigation plan to address the identified challenges in the EU and achieve resilience throughout the value chain, via an effective and efficient buildup of capacity and respective capabilities. Additional support can be provided by creating a network beyond the EU, together with institutions or regions that have similar interests.

The report is based on several sources, including a market analysis by McKinsey & Company. The conclusions and recommendations of this study are solely attributable to the VDA.

Automotive demand for semiconductors increases 1.7 times stronger than the overall market until 2030

Worldwide chip demand in the automotive industry is likely to triple by 2030 – from just under USD 50 billion in the year 2021 to around USD 150 billion in the year 2030. This significant increase is especially rooted in the fact that technological trends in the automotive industry, including ACE(S), result in a higher number of chips per vehicle than today. Over the same period, the global semiconductor market will only grow by a factor of 1.8 (from just under USD 600 billion to USD 1,100 billion) – thus the growth in chip demand of the automotive industry is 1.7 times higher than the average growth across all sectors. Accordingly, the automotive industry's required supply share of chips will rise from around 8 percent in 2021 to around 14 percent in 2030 (see Figure 1).

Figure 1:
1.7x higher growth of automotive semiconductor demand compared to total market demand until 2030

Global semiconductor market, USD bn

	2021	2030	2021, %	2030, %	Growth factor, 2021-30
	Europe				
Automotive electronics	47	147	8	14	3.0
Industrial electronics	59	131	10	12	2.2
Consumer electronics	52	95	9	9	1.8
Wired communication	37	63	6	6	1.7
Wireless communication	172	280	29	26	1.6
Computing and data storage	224	351	38	33	1.6
Total	591	1,068			1.8

1.7x higher increase

Note: Status as of April 2023; cross-industry view, global demand of all companies; supply/capacity in 2030 will remain in the same proportion as in 2021; automotive growth driven by doubling of semiconductor content per vehicle

Source: Omdia, McKinsey Center for Future Mobility

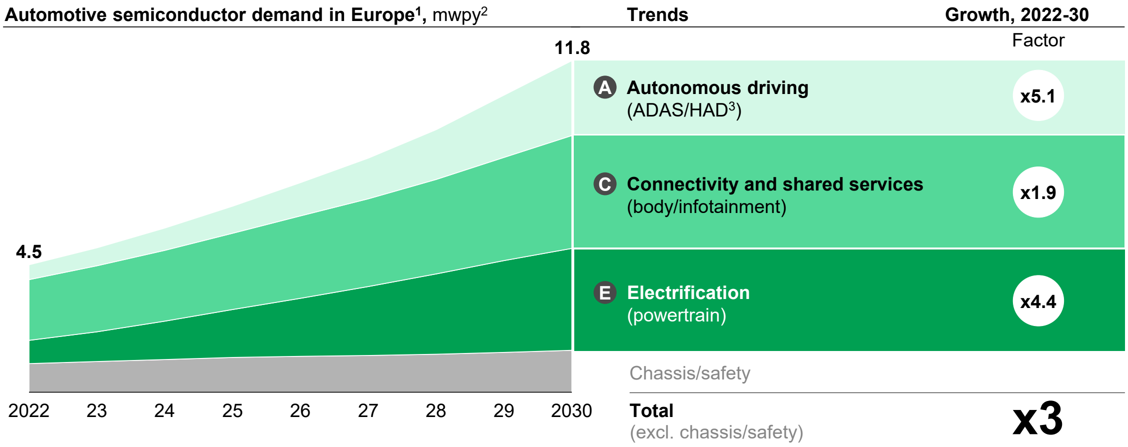
Automotive trends are driving the demand for semiconductors

As mentioned above, ACE(S) trends will fuel a sharp increase in the demand for semiconductors. These trends are expected to triple the total number of semiconductors required by the automotive industry by 2030 (see Figure 2) – and to double the semiconductor content per vehicle.

One key driver is the transition from internal combustion engine (ICE) vehicles towards battery electric vehicles (BEVs). The electric drive train highly depends on multiple insulated-gate bipolar transistors (IGBTs) or metal-oxide-semiconductor field-effect transistors (MOSFETs, incl. SiC[1] technology) in the inverter, while traditional ICEs require almost none. This leads to increased semiconductor content per powertrain by a factor of approximately 10 for BEVs (see Figure 3).

Further components driving this growth are ADAS/HAD[2]-related components, such as radar, camera, and LiDAR[3] sensors, and infotainment features, like center-stack displays, digital instrument clusters, and head-up-displays.

Figure 2:
Future trends in the automotive industry to triple automotive semiconductor demand by 2030

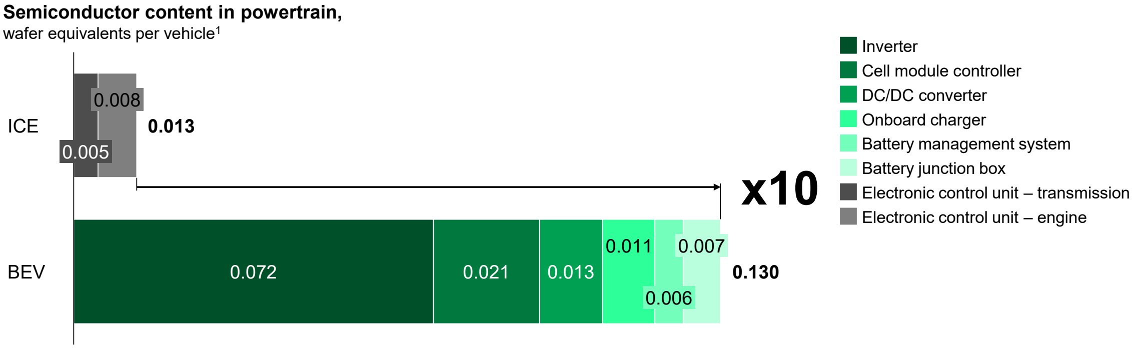


Note: Status as of April 2023; automotive view, global demand of European companies; non-memory devices only
1. Based on HQ end producer
2. 300 mm wafer equivalents
3. Advanced driver-assistance systems/highly automated driving

Source: McKinsey Center for Future Mobility

[1] Silicon carbide
[2] Advanced driver-assistance systems/highly automated driving
[3] Light detection and ranging

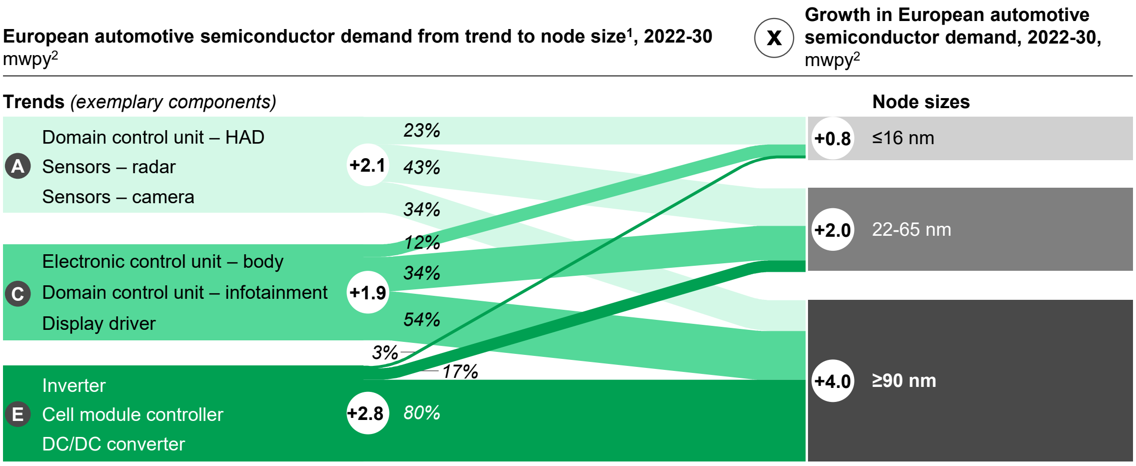
Figure 3:
Semiconductor content per powertrain for BEVs increases by the factor 10 compared to ICEs



Note: Status as of April 2023
1. 300 mm wafer equivalents
Source: McKinsey Center for Future Mobility

The strong growth (approximately 7 mwpy) of the demand of European automotive companies through the ACE(S) trends is mostly driven by large node sizes. For example, 80 percent of the additional semiconductors required due to increasing electrification are nodes with sizes ≥90 nm. This is especially true for devices that handle high voltages and high currents in components related to high-voltage batteries, such as the battery management system, or in components of the electric drive train, such as the inverter (see Figure 4).

Figure 4:
ACE(S) trends significantly impact the demand growth for node sizes ≥90 nm



Note: Status as of April 2023; automotive view, global demand of European companies; non-memory devices only
1. Based on HQ end producer
2. 300 mm wafer equivalents
Source: McKinsey Center for Future Mobility

Specifically, the additional demand in Europe caused by ACE(S) trends can be translated into roughly 27 additional front-end fab equivalents by 2030. About 19 fab equivalents of these will be needed in nodes ≥90 nm (see Table 1 for definition of fab equivalents).

In addition to automotive, other European core industries drive the semiconductor demand within Europe: While automotive electronics are assumed to contribute to roughly 50% of the total growth in semiconductor demand of European companies from 2022 to 2030, industrial electronics make up around 40% of this growth and other industries such as wired and wireless communication, consumer electronics and computing and data storage jointly account for about 10%. Considering that currently only 11 front-end fabs are in construction, being equipped, planned, or announced in Europe as of 2022[4], European companies might become more dependent on foreign supplies if no further actions are taken to enable and speed up investments into semiconductor fabs within Europe.

Table 1:

		Fab size		Capex[2]
Node size	**Device type**	**Total capacity[1]**	**Standard fab modules**	USD bn
≤16 nm	Logic	0.65 mwpy[3]	2	~22
22-65 nm	Analog; logic; optoelectronic, sensors, and discretes (OSD)	0.11-0.42 mwpy[3]	1	~4-7.5
≥90 nm	Analog; logic; optoelectronic, sensors, and discretes (OSD)	0.11-0.39 mwpy[3]	1	~3-6

Fab equivalents are defined according to the capacity ranges listed above

Note: Status as of April 2023; non-memory devices only
1. Incl. assumed average utilization rates of 92.5% for ≤16 nm, 92.5% for 22-65 nm, and 87.5% for ≥65 nm and above, with capacity ranges largely dependent on device type
2. Precise capex requirements largely dependent on device type and ranges for fab build-up in Europe
3. 300 mm wafer equivalents

Source: SEMI.org, VDA

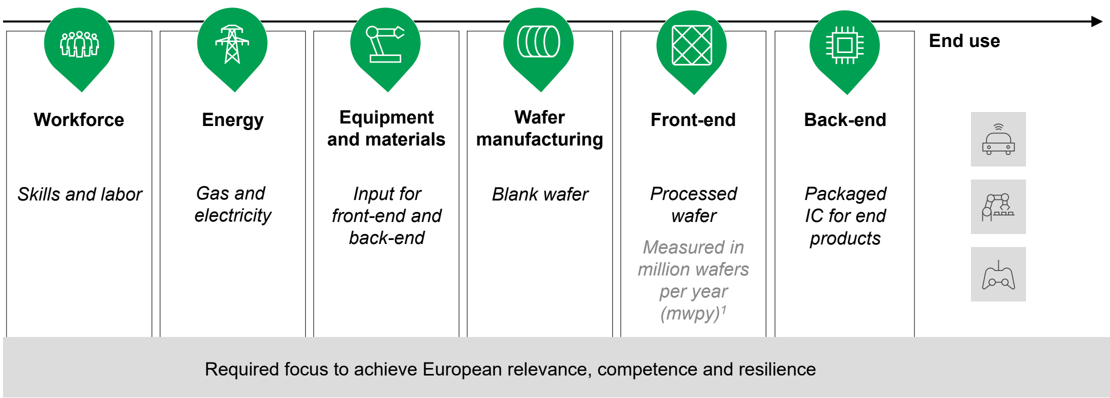
[4] SEMI World Fab Forecast (December 2022), inclusive Wolfspeed

Relevance, competence and resilience within the European semiconductor ecosystem require action along the entire value chain

Semiconductors are a key enabler for technological progress and innovation as they drive the performance of electronic and electro-mechanical devices – no matter for which use case or application area such as manufacturing, communication and transport. Key industries for Europe's economy such as manufacturing, communication and transport rely heavily on the use of semiconductors. Therefore, the semiconductor industry is vital to ensure Europe's position as an economic force. Being dependent on other regions can cause a risk as innovations and economic growth might be hindered through external influences.

Given the importance of semiconductors for the European industry and especially for the automotive sector, striving to become more than a "passive consumer" of semiconductors and aiming at developing towards an "active player" in the semiconductor value chain might be of strategic importance for Europe. When having European relevance, competence, and resilience as goal, and mirroring similar steps taken by the US and China, Europe would need to enable the growth of a comprehensive ecosystem along the semiconductor value chain, which comprises front-end, back-end, and wafer manufacturing. Furthermore, key inputs, such as equipment, materials, energy, and workforce, would be relevant (see Figure 5). In a first step, front-end and back-end manufacturing will be highlighted in the following, detailing the processes and related demand-supply dynamics.

Figure 5:
European relevance, competence and resilience require actions along the semicon value chain



Note: Status as of April 2023
1. 300 mm wafer equivalents

Front-end manufacturing focuses on wafer processing and is at the core of the semiconductor value chain, contributing the largest added value. Two types of players are involved in front-end manufacturing: integrated device manufacturers (IDMs), which process the wafers needed for their own chips, and foundries, which process wafers for chips designed by other semiconductor players. Front-end capacity, typically measured in million wafers per year (mwpy)[5], can be segmented along node size (in nanometers) and device type (such as analog or logic chips). Typically, node sizes are clustered into leading-edge nodes, advanced nodes, and mature nodes. Wafers with a smaller node size have more transistors per square inch, which corresponds to higher computing performance and efficiency. High-performance processors, for example, are migrating into smaller nodes to generate performance benefits, while other devices, such as those used for memory, tend to use nodes with a high performance to cost ratio. Power devices, on the other hand, keep using mature nodes, because the high current to which they are exposed cannot be handled by the more filigree advanced or leading-edge nodes.

After wafer processing in front-end manufacturing, wafers are separated into individual chips, packaged and tested in back-end manufacturing before they are delivered to the end user. There are two types of back-end players: IDMs and foundries with captive back-end capacities and outsourced semiconductor assembly and test companies (OSATs). The high degree of manual labor in back-end manufacturing makes operating costs one of the key drivers of plant profitability. Consequently, most back-end facilities are located in countries with low labor costs. In semiconductor back-end manufacturing, packaging is the central process step driving value creation. Today, European companies are largely dependent on non-European suppliers for packaging.

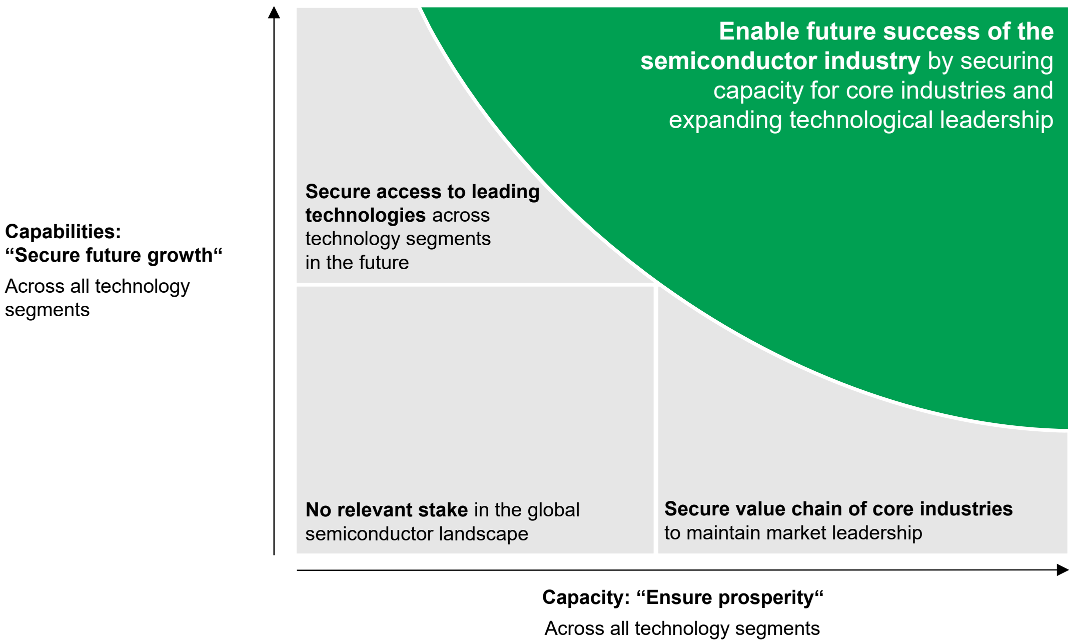
Besides front-end and back-end manufacturing, European relevance, competence, and resilience also depends on activities outside of chip manufacturing, including wafer manufacturing, and the core inputs, such as equipment, materials, energy, workforce, and skills. All these factors, which were introduced above (see Figure 5), are an essential part of effective risk mitigation for the European semiconductor ecosystem.

[5] 300 mm wafer equivalents

The success of the semiconductor industry depends to a large extent on building up sufficient production capacities and ensuring technical competence

Effective risk mitigation would need to ensure investments in supply capacities to safeguard the value chain of core industries and secure market leadership. Further, investments in capabilities along all technological segments would be required to assure access to leading technologies in the future (see Figure 6). The buildup of capabilities is far-reaching and comprises not only leading-edge technologies, but also advancements in advanced and mature nodes. Areas for improvement are for example chip performance per watt, energy efficiency, and cost efficiency. These advancements rely on various technical enablers, such as innovative materials (e.g., SiC and GaN[6]), packaging innovations, and smaller node sizes. Fostering competences throughout all technological segments including the corresponding technical enablers would promote the future growth of the European semiconductor industry and thereby, the value chain for Europe's core industries (for example, automotive and industrials), which are a major driver of Europe's economic growth in the next decade.

Figure 6:
Ensuring sufficient production capacities as well as maintaining a technical pioneering role are central to the success of the European semiconductor industry



[6] Gallium nitride

Risk mitigation: A holistic scenario to increase European competence, relevance, and resilience encompasses the entire value chain, as well as global market dynamics

The initial scenario developed below is primarily intended to show how the resilience of the European ecosystem could be improved. Securing semiconductor demand for local production in Europe, including intra-European production by non-European manufacturers, is particularly crucial for this. This semiconductor demand will amount to about 22.4 mwpy in 2030, of which the automotive industry will account for about 8.3 mwpy.

Accounting for cumulative productivity gains, preexisting European front-end fabs will provide capacity for roughly 9.7 mwpy[7] in 2030, resulting in a gap of approximately 12.7 mwpy between current semiconductor supply produced in Europe and semiconductor demand for European production. This gap can be closed either by additional capacity buildup in Europe or by chip imports from other regions.

While a high degree of European independence might be desirable, fully local production of all required semiconductors might not be worthwhile for Europe. A risk mitigation scenario for front-end manufacturing would entail a purposeful buildup of capacities to reduce supply risks as well as ensuring the availability of relevant capabilities across technology segments. In addition, global partnerships are still needed for this development and for a functioning ecosystem.

Global front-end manufacturing capacities are distributed in various regions, most prominently, Taiwan, China, South Korea, Japan, the US, and Europe. The market share for these regions varies substantially, depending on the semiconductor technology segments. For example, logic chips with node sizes ≤7 nm are primarily produced in Taiwan; the expected market share in 2030 is over 60 percent. Analog chips with node sizes of 55 or 65 nm are primarily produced in China; here, the expected market share in 2030 is over 60 percent.

Consequently, imports play a significant role. This import dependency is again associated with risks that may be related to individual supply regions (for example, geopolitics, macroeconomics, infrastructure disruptions, or expropriation risks). With the help of regional considerations, these risks and thus the overall risk to European semiconductor supply could be reduced.

The front-end risk mitigation scenario considers three sequentially applied priority levels for the buildup of capacities to determine to which degree the European deficit per technology segment should be reduced.

7 Excluding exports in segments with domestic oversupply

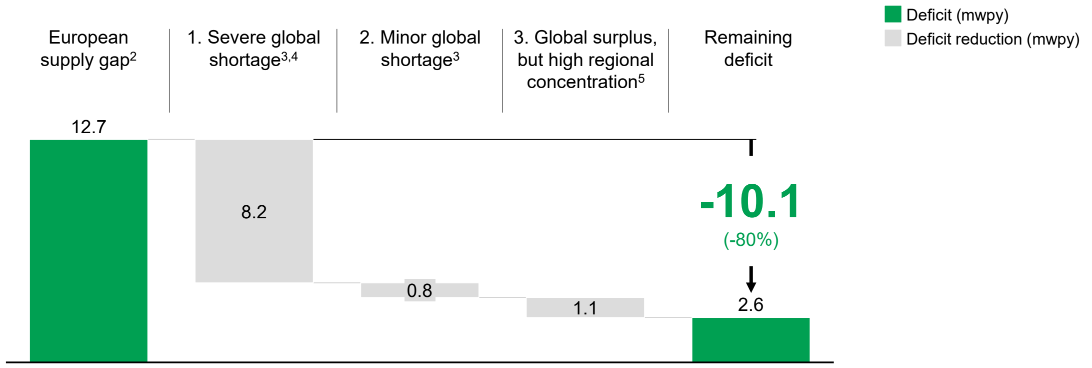
In the **first priority level,** technology segments with a severe global shortage are addressed. Severe shortages are given if the expected global shortage in 2030 is larger than the European deficit, implying that the global deficit situation is not pronouncedly driven by a European deficit but also by other deficit regions. For severe global shortage segments, a minimum deficit coverage of 70 percent is targeted for domestic capacities, building on the experience from the semiconductor crisis over the last years. In order to mitigate the European supply risks in segments with severe shortage, a total of 31 fab equivalents across all technology segments would be required by 2030.

The **second priority level** addresses technology segments that have minor shortages on the global market, which are areas where expected global demand exceeds expected global supply in 2030, but the global shortage is smaller than the European deficit. To determine what degree of the European deficit could be efficiently covered by domestic capacity, regional supply risks are taken into account, while also aiming at avoiding global overcapacities. This second priority level would require the construction of 2 front-end fab equivalents.

The **third priority level** covers technology segments where a global surplus is expected in 2030, however, Europe still faces a deficit in local supply and the supply out of Europe will be driven to more than 60% out of one or two regions resulting in strong regional dependencies. For this priority level, the risk mitigation scenario would involve building 4 front-end fab equivalents.

Figure 7:
Front-end risk mitigation scenario would lead to a reduction of the European deficit by ~10.1 mwpy

Reduction of the European deficit according to the risk mitigation scenario, mwpy[1]



Note: Status as of April 2023; cross-industry view, demand of all companies for production in Europe; non-memory-devices only
1. 300 mm wafer equivalents
2. Gap between 2030 European production demand and 2022 European supply incl. productivity gains
3. Global shortage defined as global demand > global supply (expected global supply in 2030 without additional fab buildup in Europe)
4. Severe shortage defined as shortage > European deficit within technology segment
5. Any capacity buildup in segments with global surplus needs to be carefully evaluated from a cost perspective; potential need for regulatory measures to ensure utilization of fab

Source: Omdia, SEMI.org, VDA

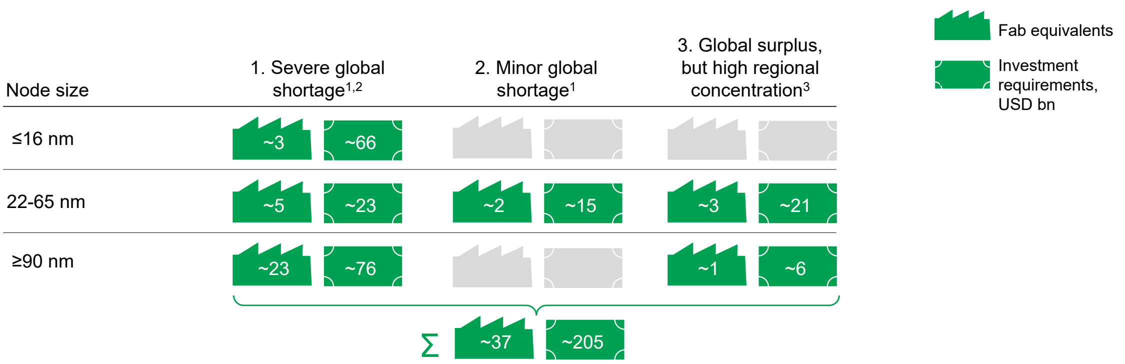
Overall, the risk mitigation scenario would lead to a reduction of the European deficit by roughly 10.1 mwpy (Figure 7) which translates to 37 fab equivalents and a total investment requirement of over USD 200 billion (Figure 8, see Table 1 for the investment assumptions per fab equivalent). Within this capacity buildup, it is essential to also address key capabilities across technology segments. Both public funds and private investments would be required to finance the risk mitigation scenario.

In addition to front-end manufacturing, back-end manufacturing would require additional investments as well as other factors (such as labor costs mitigating for the high share of manual labor in back-end manufacturing) to make back-end manufacturing financially viable in Europe. Furthermore, to increase Europe's attractiveness as a semiconductor ecosystem, resilience activities outside of chip manufacturing, including wafer manufacturing, and core inputs, such as equipment, materials, energy, workforce, and skills, would need to be considered. In addition, global partnerships are still needed.

Supporting the local semiconductor industry is on many governments' agendas. In terms of the future competitiveness of Europe's key industries, it is increasingly important that the right incentives as well as a favorable environment for the semiconductor industry are created. Semiconductor players consider a variety of criteria when evaluating where their new plants would be located. First and foremost, European location-specific capital expenditure requirements and operating costs would need to reach a globally competitive level. Other requirements would be fast and efficient approval processes, political stability, workforce availability and qualifications, infrastructure, a robust power supply, and proximity to suppliers.

Figure 8:
Risk mitigation scenario for front-end would require a ~USD 205 bn investment for 37 fab equivalents

Capacity buildup according to risk mitigation scenario, # fabs



Note: Status as of April 2023; cross-industry view, demand of all companies for production in Europe; non-memory-devices only; European shortage defined as gap between 2030 European production demand and 2022 European supply incl. productivity gains
1. Global shortage defined as global demand > global supply (expected global supply in 2030 without additional fab buildup in Europe)
2. Severe shortage defined as shortage > European deficit within technology segment
3. Any capacity buildup in segments with global surplus needs to be carefully evaluated from a cost perspective; potential need for regulatory measures to ensure utilization of fab

Source: Omdia, SEMI.org, VDA

Current incentive schemes address some of the relevant location criteria. However, based on the risk mitigation assessment above, additional capex subsidies would be required to execute the risk mitigation scenario for Europe. Assuming that about EUR 30 billion (circa USD 32 billion)[8] of the EU Chips Act would be available for front-end fab buildup, this would allow for the construction of only about 15 greenfield front-end fab equivalents.[9] The applied allocation logic specifies that one fab per technology segment is built first, and the subsequent allocation is to the segment with the highest deficit. These 15 fab equivalents would cover about 60 percent of the demand for production in Europe – in contrast to the risk-mitigation scenario described above, which would lead to a demand coverage of about 90 percent (Table 2).

8 Assumed total volume of the EU Chips Act: EUR 43 billion
9 Number of fab equivalents achievable with the EU Chips Act strongly depends on the assumed allocation logic

To achieve relevance, competence, and resilience, a translation of the European risk mitigation scenario into an actionable strategy with concrete measures for a rapid fab buildup would be required. For this an effort by political institutions, industry chip customers, semiconductor players (front-end, back-end as well as equipment and materials) and enabling players (such as energy industry, workforce, research institutes) would be required. By building up the relevant capacities and promoting capabilities, Europe could become globally competitive and attractive as a hub for semiconductor players.

Table 2:

	Assumed contribution from EU Chips Act		Required contribution for risk mitigation scenario
Public capex contribution, USD bn	~32[1]	⟷	~77
Number of fab equivalents	~15	⟷	~37
Degree of demand coverage[2], %	~60	⟷	~88
European share of global supply[3], %	~9	⟷	~14

Note: Status as of April 2023; demand of all companies for production in Europe; cross-industry view; non-memory devices only
1. Assuming USD 32.5 bn of funds in EU Chips Act are available as public capex contribution for front-end fab buildup, assumed allocation: funding for one fab in each technology segment, allocate remaining budget to segment with largest deficit, number of fab equivalents achievable with EU Chips Act strongly depends on assumed allocation logic
2. Demand for production in Europe
3. EU target: 20%

Source: Omdia, SEMI.org, VDA, EU Commission

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About us

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