

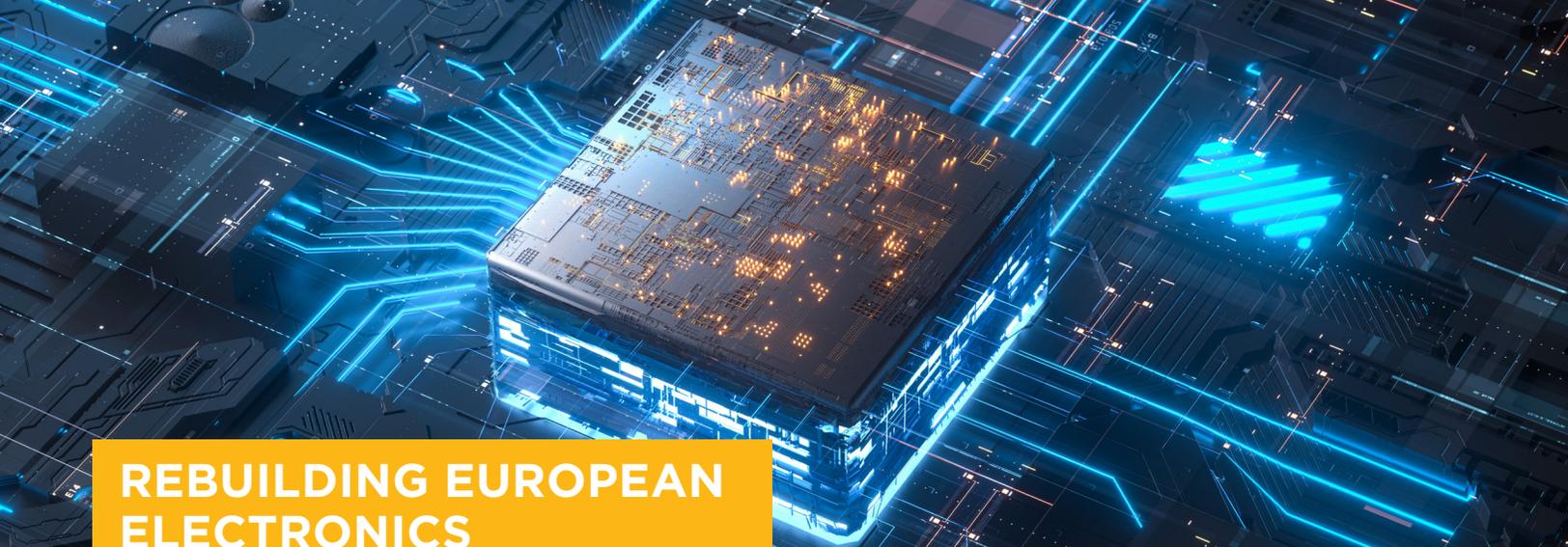


PROMOTING SILICON TO SYSTEMS MANUFACTURING

AN IPC REPORT ON EU INDUSTRIAL POLICY



JULY 2023



REBUILDING EUROPEAN ELECTRONICS MANUFACTURING

EUROPEAN INDUSTRIAL RESILIENCY:

Promoting a Silicon to Systems Policy Framework

Today, electronics are everywhere—from personal devices and electric cars to wind turbines and industrial systems. Electronics are foundational to almost all modern technology. As such, a vibrant electronics manufacturing industry is vital to Europe’s industrial resiliency, regional security and technological innovation. The importance of electronics will only grow as all industrial sectors increasingly look to electronics manufacturers as key enablers for product innovation and the region’s digital and green transitions.

In passing the Chips Act, the European Union (EU) made a strategic, but narrowly crafted commitment to the electronics industry. The Chips Act will strengthen the region’s position as a global leader in semiconductor innovation and

manufacturing. The EU is not alone in bolstering this segment of the electronics industry. Governments globally are investing billions of Euros to build up their own domestic semiconductor capabilities. These investments are premised on a now universally accepted fact: Chips are the most critical building blocks in the advanced technologies that are reshaping almost all aspects of human life.

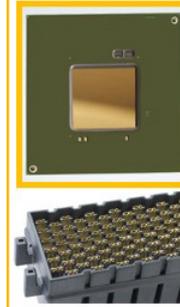
Chips are indeed important building blocks in electronics, but the near singular focus on the semiconductor industry has obscured the critically important segments of the broader electronics ecosystem, which includes printed circuit board (PCB) fabrication and electronic assembly (EMS), that is responsible for producing electronics systems. Despite their importance, the PCB industry segment has faced significant erosion in capacities, capabilities, and global market share over the last 20 years, while the growth potential of electronic assembly (EMS) in Europe is significant but unrealized. The EU only accounts for 2% of global PCB production and 11.5% of electronic assembly. Revitalizing and growing these segments is essential to building a robust European electronics manufacturing ecosystem to ensure industrial resiliency, advance the twin transitions, and promote European innovation.

SILICON TO SYSTEMS: AN OVERVIEW

Semiconductor chips have no functionality on their own. They gain functionality by being placed, along with many other components, on PCBs by electronics assemblers to create systems. These electronics systems feature prominently in the defence/aerospace, high performance computing, information technology, automotive, and medical sectors, but electronics are increasingly important to every industry and are, indeed, central to each industry's digital transition. So, electronics manufacturing, while largely hidden from view, is an enabling activity for innovation across every sector of the economy.

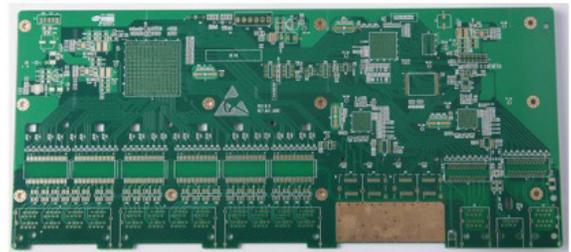
A robust electronics ecosystem is necessary for the design and manufacturing of finished products incorporating electronics. Any disruptions, bottlenecks, or capability gaps within this end-to-end ecosystem leads to delays in new products and innovations, limiting the ability to manufacture the most advanced electronic systems. It takes all elements within the supply chain—from *silicon to systems*—to successfully produce electronic hardware products and to meet customer and end-market demands.

It takes all elements within the supply chain—from *silicon to systems*—to successfully produce electronics.



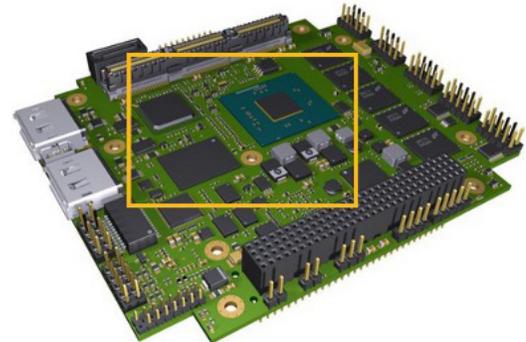
ELECTRONIC COMPONENTS

Active / logic components (Processor, memory)
Passive discrete components (capacitors, resistors)
Connectors (power, USB, ethernet)



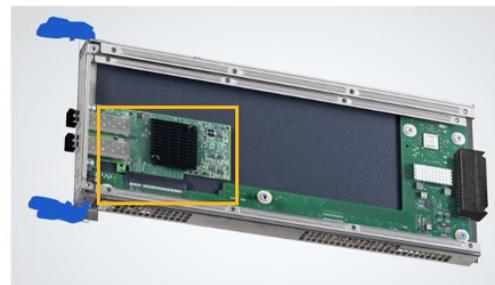
PRINTED CIRCUIT BOARD (PCB)

Multi-layer plastic laminate w/solder mask
Electrical connections - copper features and traces



PRINTED CIRCUIT BOARD ASSEMBLY (PCBA)

Printed Circuit Board (PCB)
Electrical Components
Interconnect joining materials (solder, adhesive)



PRINTED CIRCUIT BOARD ASSEMBLY W/MECHANICALS

Printed Circuit Board Assembly (PCBA)
Card-Level Mechanicals (heatsink, card bezel, screws)
Thermal Interface Materials

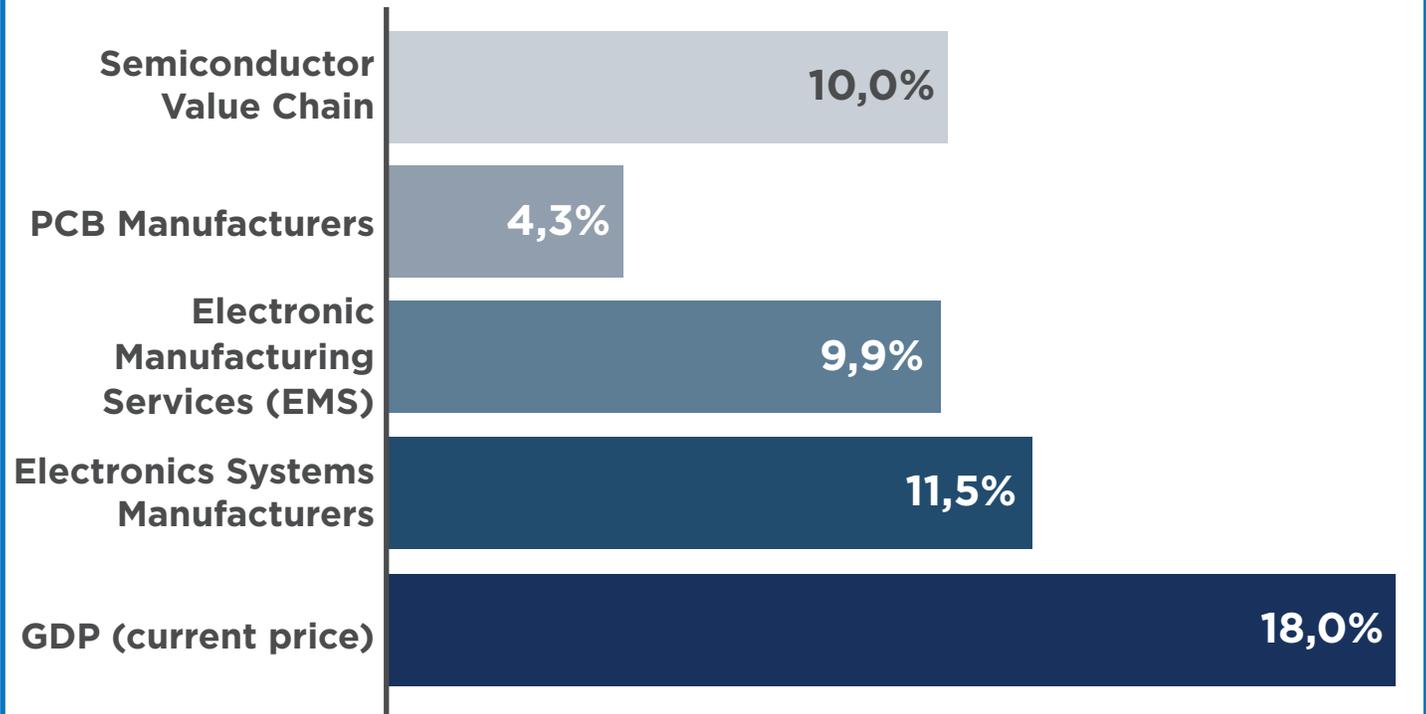
Illustration: IPC - Silicon to Systems Ecosystem



Importantly, customer demands are always changing to reflect technological advancements, especially in silicon chips. Everything follows silicon. The effect is to place ever more challenging requirements on PCB and EMS companies. The more sophisticated semiconductor packages become, the more complex the corresponding PCB designs must become. Final system-level assembly by

EMS providers is where the final product comes to life; it's where electronics are assembled, powered-on, burned-in, firmware/software loaded, and final system tests are performed. In much the same way that density and power are pushing the limits of conventional PCB fabrication, so, too, is it increasing the requirements on conventional electronics assembly.

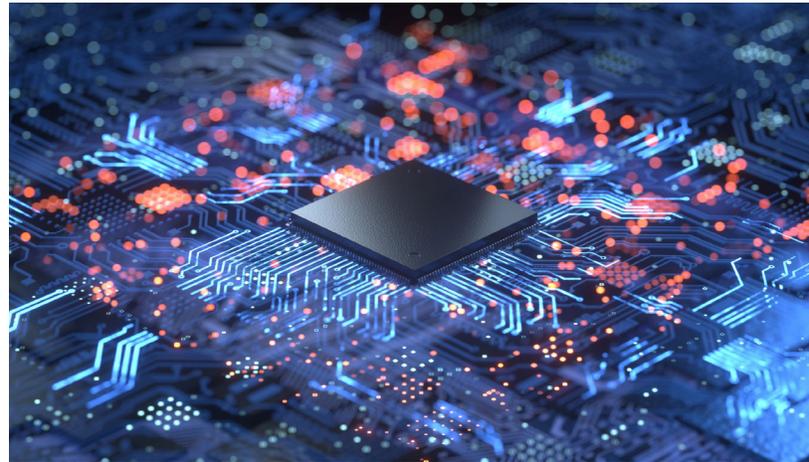
PRODUCTION IN THE EU27% WORLD (2020)



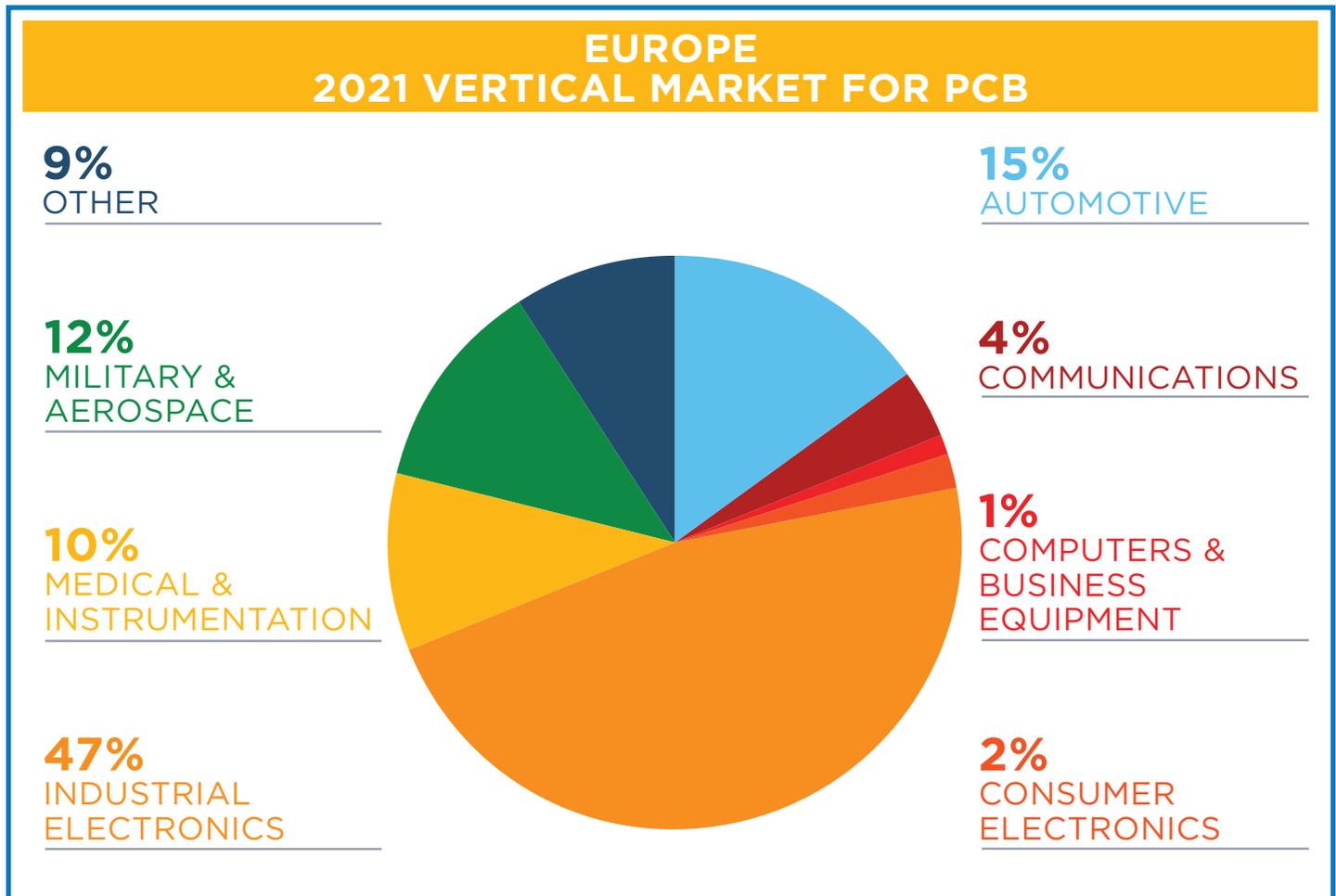
Source: Decision Etudes & Conseils

EU DOWNSTREAM USERS

European and North American companies were once clear market leaders in electronics manufacturing, but today fierce competition from Asia and elsewhere has forced them to increasingly specialize in higher-value, lower-volume goods to remain competitive in the global marketplace. This shift has led Europe to focus on embedded and professional systems: electronic systems embedded into automotives, diverse industrial equipment, aerospace/defense/ security equipment, telecommunication infrastructures, and health and care equipment. Embedded systems are opposed to “stand-alone systems,” traditionally corresponding to consumer electronics (phones, consumer PCs, consumer audio and video systems and home appliances).



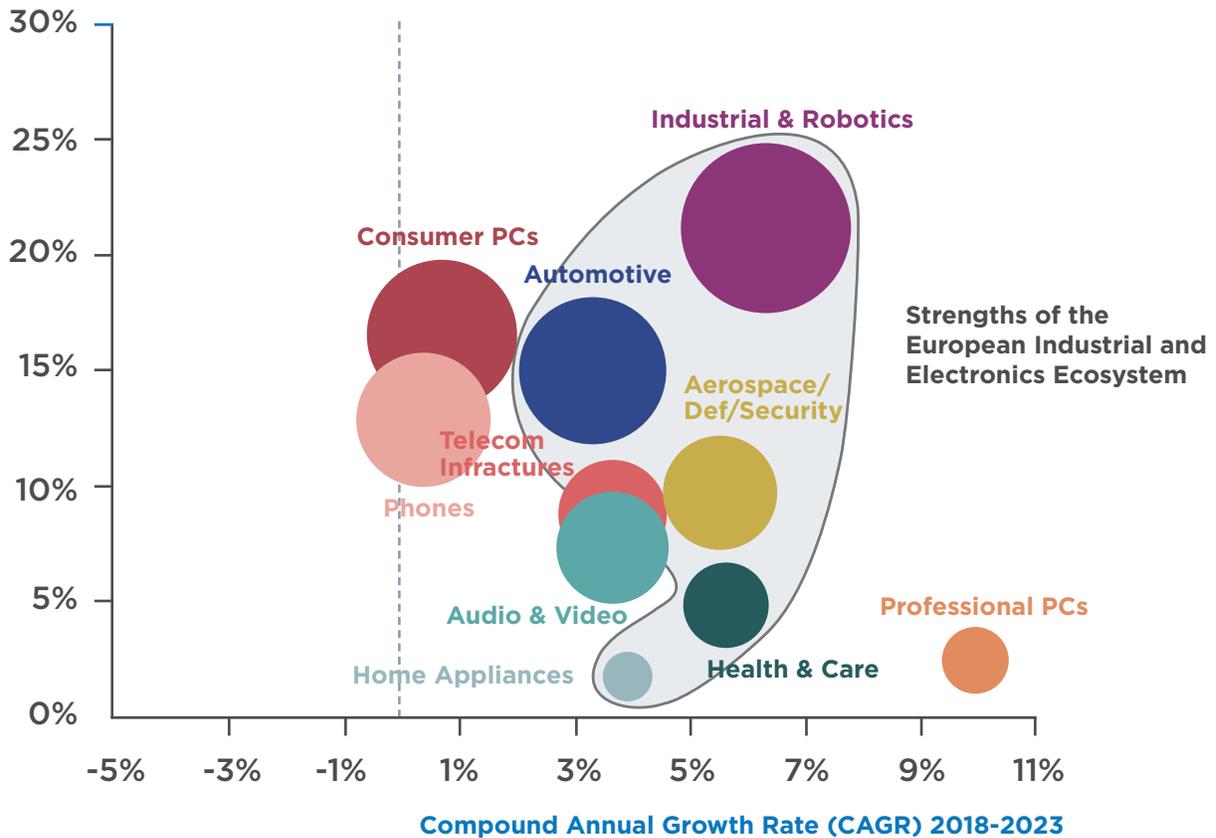
But in ceding to Asia the high-volume, low-mix manufacturing associated with consumer products, European electronics manufacturers have seen an overall decline in market share and profitability.



Source: World Electronic Circuits Council: 2021 Annual Report

GLOBAL ELECTRONIC SYSTEMS PRODUCTION BY SEGMENT 2018-2023

Production Share 2019



Source: DECISION Etudes & Conseil

The good news is that manufacturing for embedded systems is a growth market as electronics become integral to the workings of just about everything—from an Airbus A350 to 5G infrastructures to the factories that make both. Given Europe’s global leadership in key market segments, like clean, connected and autonomous mobility, industrial Internet of Things (IoT), Industry 4.0, and cybersecurity solutions, it increasingly makes sense to locate related manufacturing in close proximity. These markets have specific production needs that can make interaction between customer and supplier ideal, if not necessary. Global supply chain volatility related to trade wars, health crises and natural disasters underscore the importance of resilient, regional supply

chains. Key to maintaining European leadership in the digital technologies and sectors that underpin Europe’s industrial future which are enabled by electronics, is appreciating that the industry constitutes an ecosystem. Like any ecosystem, weakness in one area can undermine the health of the entire ecosystem and the entities that comprise it.

Global supply chain volatility related to trade wars, health crises and natural disasters underscore the importance of resilient, regional supply chains.

PCB INDUSTRY SNAPSHOT

PCB manufacturers produce the boards that mechanically support and electrically connect electronic components using conductive traces, pads, vias and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. PCBs have become increasingly sophisticated to accommodate ever smaller, more powerful electronics. Today, from a technological point of view, the PCB is no longer a passive base where components are placed, but rather an integral part of the final product.

IPC estimates that annual PCB production in the EU is approximately \$2B or roughly 2% of global production. This is a steep decline from the 1990s when the EU commanded 20-30% of global production. In the last 20 years, the number of EU PCB fabricators has also decreased

precipitously, falling two-thirds to fewer than 180 facilities employing approximately 15,000 workers. Over this time, the EU has become highly dependent on China, which now accounts for some 65% of total EU PCB requirements.

As PCB production was outsourced, remaining European PCB manufacturers began to specialize. This specialization is focused on products with very high added value which includes products that are often very complex, have high speed of delivery requirements, or high reliability and quality requirements. This specialization has resulted in a high mix of products but that are often supplied in low volume - what is often referred to as "high-mix/low volume." These products are most often required for embedded systems in aerospace, defense, industrial robotics, transportation, energy, and healthcare.

Innovation in the EU PCB ecosystem will have a pronounced impact on the twin transition of most major EU industrial ecosystems and is crucial to European strategic priorities.

EU PCB MANUFACTURING: KEY FIGURES

INDICATOR	YEAR	FIGURE
Production	2020	2 B€
% World	2020	2%
SMEs% Production	2020	~ 30-40%
Average Annual Growth Rate	2016-2019	-6%
Employment	2020	~ 15,000
Number of Enterprises	2020	~ 175

Source: *in4ma and DECISION Etudes & Conseil*

PCB PRODUCTION BY COUNTRIES & REGIONS IN 2021 BY WECC MEMBER ASSOCIATION

0.1%
OTHERS EUROPE

0.1%
CENTRAL EUROPE

2.1%
WESTERN EUROPE

5.8%
OTHER ASIA

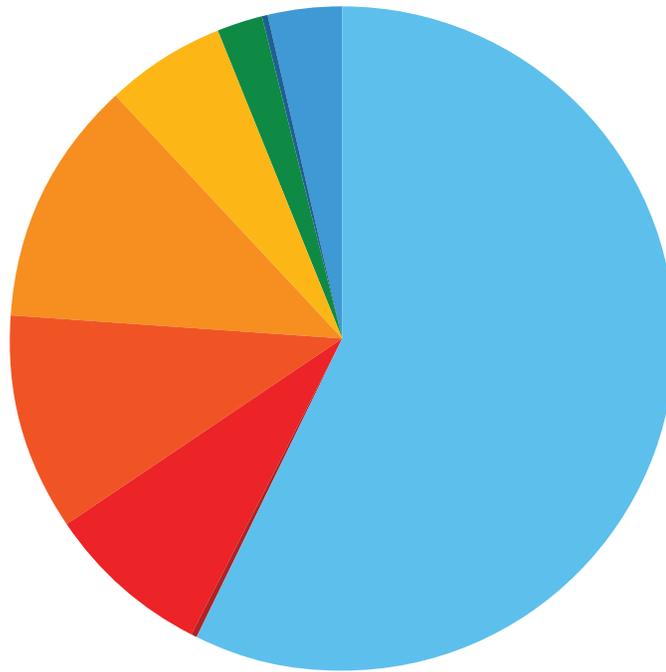
12.0%
TAIWAN

0.1%
MIDDLE EAST
& AFRICA

10.6%
SOUTH KOREA

7.8%
JAPAN

0.4%
INDIA



3.6%
NORTH AMERICA

57.3%
CHINA

Source: World Electronic Circuits Council: 2021 Annual Report

IMPORTS OF PCB IN THE EU27 IN 2020

7.0%
OTHERS

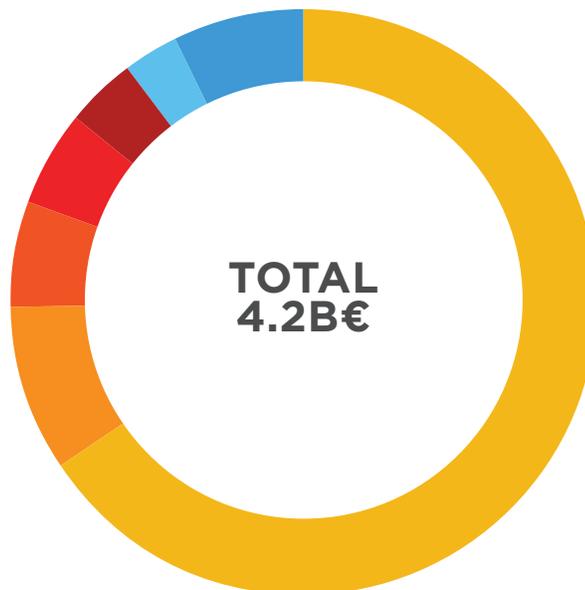
3.0%
USA

4.0%
HONG KONG

5.0%
THAILAND

6.0%
TAIWAN

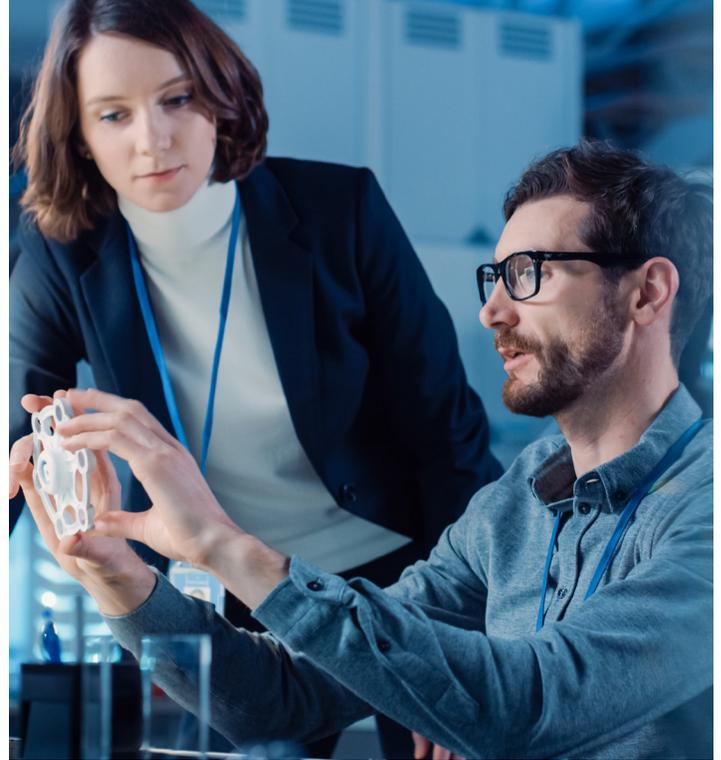
9.0%
OTHER ASIA



65.0%
CHINA

Source: Eurostat

EMS INDUSTRY SNAPSHOT



EMS companies mount, connect, and assemble electronic components on bare PCB boards to make printed circuit assemblies. Increasingly EMS companies further provide additional services and expertise, acting as pivotal partners in the digitalization process. Some European original equipment manufacturers (OEMs) assemble their own electronics, but many outsource their production to EMS companies. As outsourcing has risen and electronics have become a more crucial aspect of products and services, EMS companies have transformed into crucial players in the electronics value chain.

According to Dieter Weiss at in4ma, the EU EMS ecosystem accounts for roughly €52B in revenue each year. He counts 2,197 EMS facilities in the EU belonging to 1,881 companies. 80% of all EMS companies in Europe have less than 10 Mil. Euro in revenues and have a marketshare of 11,2%. Germany, Czech Republic, Hungary, France and Poland are the top five EMS producing countries in the EU. Western Europe manufactures 51% of all EMS products and Eastern Europe 49%.

The EMS industry experienced solid average annual growth of 5.6% over the 2013-2019 period fuelled by factory investment from large global EMS companies like Foxconn and Flex in Eastern Europe but also thanks to the growth of the downstream markets the EMS industry serves like automotive, industrial and aerospace.

Despite solid growth in recent years, the EU imports roughly 90% of required EMS products and services, and this proportion reaches 97% for consumer applications and telecommunications. Over 60% of EU

EMS production is performed by small and medium enterprises (SMEs) (<€1000 mil). The lack of large EMS companies in the EU is likely to pose a problem of resiliency in the near- to mid-term. Europe only has one company that generates more than €1 billion in annual revenue. Moreover, European EMS companies are often the key purchaser of parts and components on behalf of OEM partners. As a result of strategic dependencies on other nations, the European EMS industry is directly penalized.

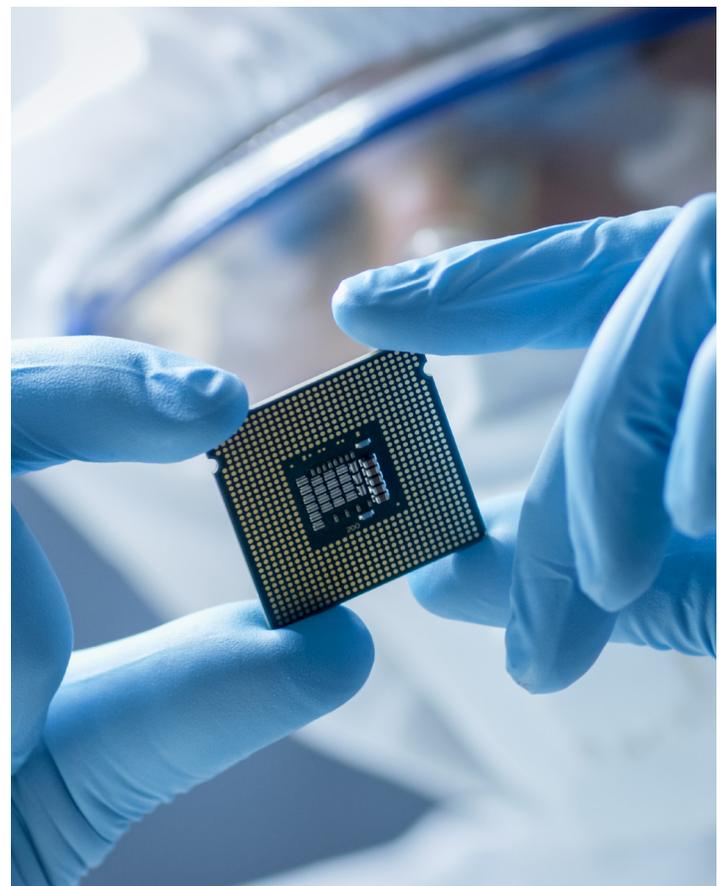
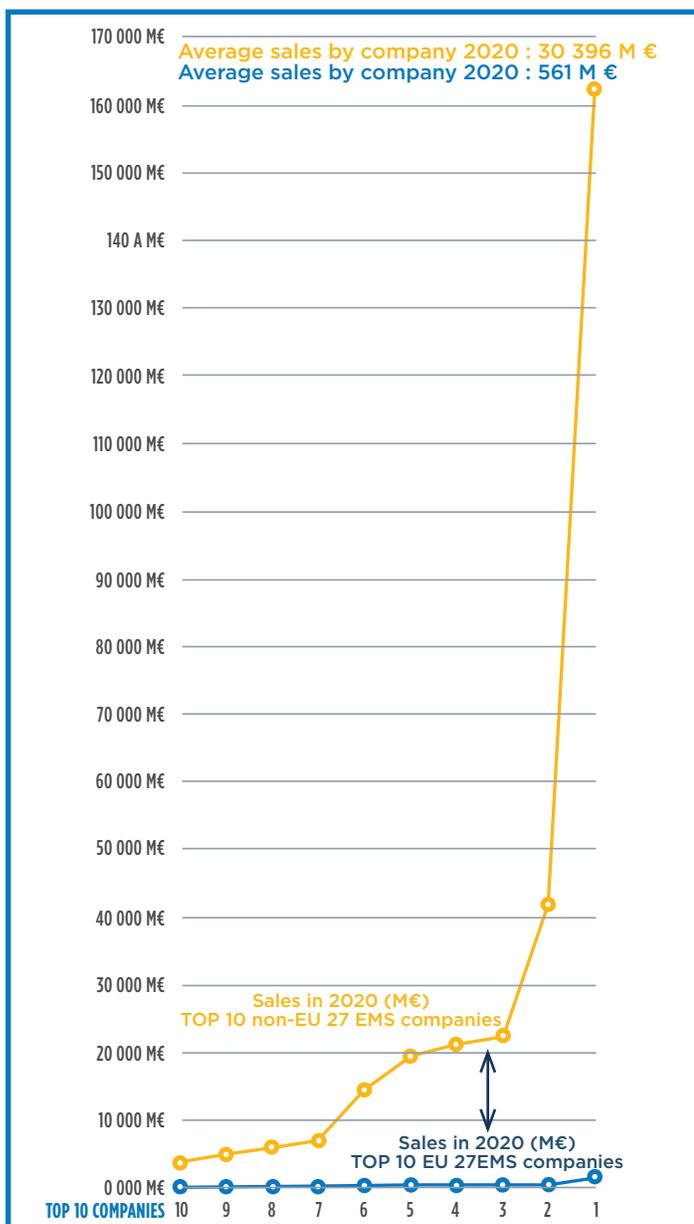
The main customers of the EMS EU ecosystem are the EU industries associated with “embedded systems” including automotive, industrial, aerospace, defense and healthcare. These end-user industries represent smaller volumes than consumer electronics and, as a consequence, the EU EMS ecosystem, which represents 10% of global production, is small compared to Asia. However, embedded systems are also associated with greater value add on average and electronics assemblies are at the heart of the competitiveness of most of the major EU industrial ecosystems: mobility, aeronautics/defense, renewable industries, energy-intensive industries, and healthcare.

EU EMS MANUFACTURING: KEY FIGURES

INDICATOR	YEAR	FIGURE
Production	2022	51.5 B€
% World	2022	9%
SMEs% Production	2022	67%
Average Annual Growth Rate	2013-2019	5.6%
Employment	2022	244 000
Number of Enterprises	2022	2200

Source: in4ma and DECISION Etudes & Conseil

ELECTRONIC MANUFACTURING SERVICES (EMS)



EU imports roughly 90% of required EMS products and services.

Source: DECISION Etudes & Conseil

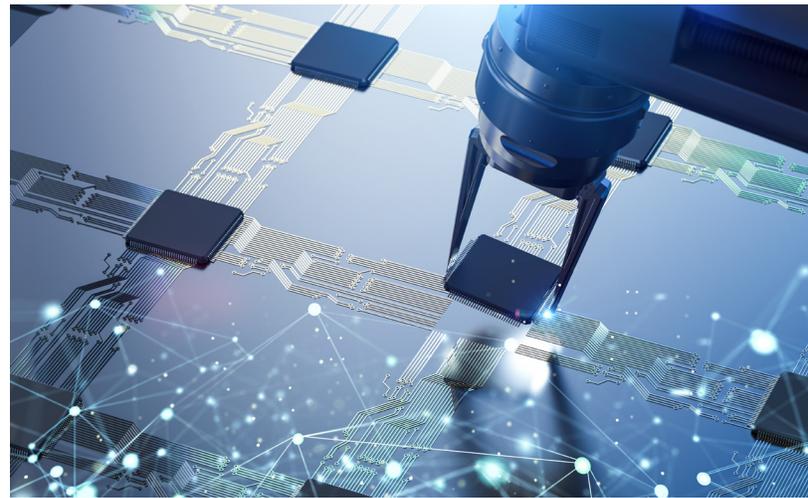
POLICY CONSIDERATIONS

Identified below are industry issues that require government consideration. In addition to these issues, the industry is seeking from the EU and member states affirmative declarations about the strategic importance of bolstering European electronics manufacturing. Ultimately, strengthening European electronics manufacturing requires both providing the industry funding support and implementing policies that drive demand for EU produced electronics.

RESEARCH & DEVELOPMENT & INNOVATION (R&D&I)

Innovation in silicon fabrication leads to direct impacts on the semiconductor supply chain and indirect impacts on the rest of the electronics industry. Put more succinctly, everything follows silicon. This reality has been long understood and practiced in the electronics industry, but cutting edge semiconductor advancements are placing more immediate and complex demands on the rest of the electronics manufacturing industry. In some cases, these demands are not being met. Defense and aerospace manufacturers, in particular, report growing difficulty sourcing boards domestically that can support the latest chips. The challenge of sourcing boards and assembly for the sophisticated chips has led some defense contractors to “dumb down” their designs.

Chip innovation, then, is dramatically changing how PCBs and PCB assemblies are designed and manufactured. There will be increasing need for the EU to invest in R&D&I to ensure that a pool of PCB



companies are able to develop, qualify, and fabricate ultra high-density interconnect (uHDI) PCBs and that EMS companies can upgrade their assembly operations to build high-quality, high-reliability final products leveraging these HDI PCBs.

R&D&I should extend as well to the materials used to fabricate PCBs and assemblies to meet higher technical requirements but also to achieve higher environmental standards by reducing materials usage and by increasing recyclability.

It is also worth noting that PCB and EMS companies are intrinsically R&D&I-focused industries although, more often than not, these companies do not have separate budgets for R&D&I. This point was made persuasively in a recent IPC report,

Leadership Lost. The report asserts of PCBs: “There is no analogous industry with such wide-ranging customization options coupled with the level of process complexity. Every order is akin to a research project, starting afresh on nearly every aspect of the PCB: scale, materials, feature sizes, interconnect methods, metallization options, final finishes, and quality standards.” R&D&I costs, then, are embedded into the operational task of fulfilling a customer order. The report adds, “All these factors add up to an industry with very tight profit margins and little or no funds left over for R&D or capital expenditures.”

Growing vibrant PCB and EMS industries in Europe will require more sustained investment in R&D&I, standards, automation, and an industry-government partnership, with a very long-term time horizon. It will also require greater clarity and prioritization of funding geared towards these key segments of the electronics industry.

FACTORY OF THE FUTURE

The factory of the future is now, and companies and governments not responding to this reality are being left behind. IPC estimates that Europe is 2-3 years and the U.S. 10 years behind Asia in a migration to the factory of the future. Increasingly, the migration to the factory of the future will be less an option and more a requirement as customers demand the quality, visibility, efficiency, productivity and yield it offers. In other words, successfully making this migration will mean the difference between relevancy and obsolescence in the global marketplace.

The factory of the future, however, is not just a requirement; it is an opportunity for European electronics manufacturers to strengthen their edge in a fiercely competitive global marketplace. Manufacturing smarter allows European companies to increasingly equalize costs and address important customer concerns, including quality, intellectual property protection, and supply chain transparency. It will also give companies a means to better support the EU’s commitment to the digital and green transitions.



The roadmap for the factory of the future, however, is neither simple, nor entirely clear. The industry’s leading manufacturers are making significant investments in a suite of technologies, processes, and talent, but most European EMS and PCB companies are SMEs with constrained resources for capital expenses. Given the industry’s thin margins and low volumes, government support is necessary more than ever to bolster manufacturing modernization. This also requires on-going mapping of existing resources and adjustment to changing needs to keep pace with technology requirements and industry needs.



WORKFORCE

The EU boasts an excellent education ecosystem that can train high-skilled workers, and yet, electronics manufacturers consistently identify a shortage of skilled workers among their greatest challenges. Companies report that they cannot hire and retain workers in sufficient numbers to support business growth and offset the aging, retiring workers. Training and upskilling, moreover, is inconsistent and financially challenging given high costs and high turnover. Some manufacturers report as high as 30% annual turnover in their workforce.

These workforce challenges have gone largely unrecognized by government even as the nature of the workforce has becoming increasingly complex. Although PCB and EMS facilities do not require the same capital investments as a semiconductor fab, engineering talent and a skilled workforce to run manufacturing operations are critical. Today, competition for engineers and staff skilled in high technology manufacturing in Asia is fierce. In the EU, the risk of knowledge-gap is growing. These issues must be addressed for the electronics manufacturing industry to remain globally competitive.

Importantly, there is a need to support workforce programmes across the electronics manufacturing industry from silicon to systems. Trying to establish independent workforce training programs to serve one industry segment will be challenging and expensive, not to mention a disservice to workers who today strive for portability in addition to upskilling. Creating a workforce pipeline for the electronics industry will also organically create an ongoing, sustainable pool of potential workers who will pursue the most meaningful opportunities as the electronics industry evolves.

For this reason, aligning semiconductor advanced packaging workforce training with broader electronics manufacturing workforce development, in particular, makes sense. The lines are blurring between integrated circuit (IC) substrate and PCB fabrication as well as between first and second level assembly. In fact, it is likely the case that the sophistication of IC substrate manufacturing today characterizes PCB and EMS manufacturing tomorrow. For this reason, the European Commission and Member States should view electronics interconnection as a key strategic priority, requiring a skilled workforce. This skilled workforce will naturally pivot to the opportunities that exist as the industry evolves.

TRUSTED SUPPLY CHAIN FOR CRITICAL SYSTEMS

A confluence of events, including the global pandemic and rising geopolitical tensions, have underscored the importance of secure, resilient supply chains, especially for technologies that are of strategic importance. The EU should define those critical systems for which domestic sourcing and/or sourcing from strategic partners is important. Identifying trusted supply chains can be a first step in defining the strategic industrial

base and measuring its health, so that appropriate programmes can be put in place to support its rebuilding. Trusted supply chains also promise greater security of sensitive electronics systems, given that PCBs and assemblies are increasingly being targeted by adversaries. Other countries are exploring opportunities to promote trusted supply chains for PCBs and assemblies across international borders, and the EU should encourage international collaboration also in this regard.



TRADE

European PCB companies report that they are disadvantaged by EU customs tariffs. Companies pay tariffs on the import of raw materials used to produce PCBs, but no tariffs on bare PCBs that are imported for assembly. This disparity makes it more difficult for European PCB companies to compete with competitors elsewhere on price. Resolving this issue is difficult as an increase in PCB prices may in turn make it more difficult for some EMS companies to compete on price.

Many industries point to large subsidies provided by foreign governments regarding many products of the electronics value chain (especially PCB). Further dialogue among industry and government leaders is needed to find solutions that will provide a more level playing field in a competitive global market place and enable sustainable re-industrialisation of the EU.



SUMMARY

Electronics are increasingly central to all industries and to the digital and green transition. The EU continues to have international dependencies in key aspects of the value chain. That chain is only as strong as its weakest link. Addressing vulnerabilities and building on strengths requires a “silicon to systems” approach. A silicon to systems approach strengthens the entire European electronics manufacturing ecosystem (including PCB manufacturing and hardware assembly) as a necessary means to a secure, resilient supply chain and ongoing EU leadership in technological innovation.

IPC is the global trade association for the electronics manufacturing industry. Our 3,100 member companies represent all facets of the electronics industry, including design, printed circuit board manufacturing, electronic assembly, and advanced packaging. IPC is the leading source for industry standards, training, industry intelligence, and public policy advocacy. Our work with industry is focused on one goal: building electronics better. Visit www.ipc.org