Policy Advice on International Cooperation on Semiconductors

Project Number: 101092562
Project Acronym: ICOS
Project Title: International Cooperation On Semiconductors
Responsible: VDI/VDE
Due date: 30 November 2025
Submission date: 30 January 2026

icos-semiconductors.eu

Table of Contents

This project has received funding (2023 – 2025) from the European Union’s Horizon Europe research and innovation programme under GA No 101092562.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

Executive summary

This deliverable of the ICOS project provides comprehensive policy advice to strengthen the European position in the global semiconductor value chain through coordinated international cooperation. The starting point is the current geopolitical situation, in which the EU faces both dependencies (e. g. on China, the USA) and strategic opportunities (partnerships with Japan, South Korea, India, Canada, etc.). Based on analyses, workshops, and stakeholder interviews, three areas of action are identified:

1. Coordinated action – Establish an open, transparent collaboration database, streamline decision-making and steering processes, and make greater use of already established organisations (research-technology organisations (RTOs) pilot lines, Europractice) as interfaces to international partners.

2. Strategic investment – Build targeted partnerships in key technologies and materials, prioritise European industry interests, expand the qualified workforce, and ensure IP protection and trust mechanisms.

3. Innovation support – Develop a long-term vision to specialise in future-oriented areas (photonics, quantum and neuromorphic computing, advanced packaging, sustainability) and launch focused R&D programmes, which are to be further expanded with opportunities for international cooperation.

For each of the seven non-EU countries examined (China, India, Japan, South Korea, Singapore, Taiwan, the USA) concrete cooperation instruments are proposed – from trade and investment agreements and talent-exchange schemes to joint research initiatives. In addition, the technologically complementary framework is always taken into account. Implementing these recommendations is intended to increase the resilience of Europe's semiconductor supply, expand technological leadership, and establish a balanced, win-win cooperation model with international actors.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

1 Overview

1.1 Purpose

This report aims at supporting the European Commission in implementing measures to strengthen the position of Europe's industry in the global semiconductor value chain. The analyses and filtering of ICOS results were built on D5.1, where a matrix with country specific frameworks was proposed as well as a set of formats for international cooperation was shown.

1.2 Responsibilities

While this deliverable is prepared in the context of WP 5, the outcome of this deliverable is based on the results of the work packages WP 2, 3 and 4, as well as on the conducted workshops within ICOS and the conducted interviews. Results from other work packages are referenced to accordingly.

1.3 Glossary

Term	Definition
3GPP	3rd Generation Partnership Project; global collaboration of seven telecommunications standards development organizations
5G / 6G	Standards in telecommunication - 5G = current standard; 6G = next generation standard
ADK	Assessment and Development Kit
AI	Artificial intelligence
ALD	Atomic Layer Deposition
BEOL	Back End of Line
CMOS	Complementary Metal-Oxide-Semiconductor
EDA	Electronic design automation
ESMC	European Semiconductor Manufacturing Company – Joint Venture between TSCM, Bosch, Infineon and NXP
Euro CDP	European Chips Design Platform
EUV	Extreme Ultra Violet (Lithography Systems)
IC	Integrated circuit
ICOS	International Cooperation on Semiconductors
IEEE	Institute of Electrical and Electronics Engineers
IP	Intellectual property
MSCA	Marie Sklodowska-Curie Actions
ML	Machine Learning
OSAT	Outsourced Semiconductor Assembly and Test
PCB	Printed Circuit Board
PDK	Process Development Kit
PFAS	Per- and Polyfluoroalkyl substances
R&D	Research and Development
RISC-V	Reduced Instruction Set Computer Version 5

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

ROK	Republic of Korea
RTO	Research and Technology Organisations
SME	Small and Medium-sized Enterprises
SMEE	Shanghai Micro Electronic Equipment
SOI / FDSOI	Silicon on Insulator / Fully Depleted Silicon on Insulator
TSMC	Taiwan Semiconductor Manufacturing Company
TTC	Trade & Technology Council
WP	Work Package

2 Goals

2.1 Current geopolitical situation of the EU with respect to semiconductors

ICOS deliverable D2.1 describes in detail the geo-economical position of the EU, giving insight into the European capabilities and dependencies with respect to semiconductor value chains. In addition, the geo-*political* situation of the European Union is changing rapidly. Increasingly, the EU is caught in the middle of the hegemonial rivalry between the US, China and further growing instabilities. These developments have shifted the attention to new geopolitical scenarios, for which the EU must now prepare. With respect to international relations, the previous EU semiconductor policy strongly emphasised de-risking from the dependencies on China. Risk scenarios included: What if the EU loses access to TSMC foundry services? What if China (further) limits EU access to the global supplies of materials such as Gallium, Germanium, Tungsten, Copper, Phosphorus, Arsenic, Boron and rare earth elements required in semiconductor production? What are the implications if China continues to appropriate European know-how via companies under its control? While these scenarios still have their validity and urgency, the world order is undergoing a transition and the European Union must find its place. In this process, all dependencies in the semiconductor value chain must be brought to the table and the associated risks must be mitigated. As an example, the US has a monopoly of industry-grade chip design software, a sensitive part of many supply chains. In addition, sanctions or customs duties have emerged as favoured geo-economical instruments of the current US administration, applied to many countries in the world. What would be the implications of possible US trade or restrictive measures affecting EU products, equipment, or services in microelectronics? The likelihood for this to actually happen is unknown to us. Yet, the impact of such a scenario on the modern high-tech economy of the EU could be very damaging, which, in turn, commands an appropriate mitigation of the risk.

2.2 Strategic goals

While the above scenarios call for rapid action, the situation of EU with regard to semiconductor production and research remains comparatively positive. Besides its economical weight, as a market and producer, the EU maintains a strong position with respect

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

to many fields, such as power electronics and EUV equipment, where high-level engineering in materials and production technologies are required. Emerging fields like advanced packaging, photonics or quantum computing are well suited to expand that profile for the future.

Furthermore, the EU is not acting in isolation. Other countries face a similar situation and are looking out for partners to pool their resources. Some of them are natural partners in other areas beyond semiconductors. In that sense, the changing geopolitical scene has also opened the window for exploring new opportunities. The recent trade negotiations with South America or India can be seen in this light. In those partnerships, microelectronics is a field with particular relevance to all modern economies, affecting vital functions such as state organisation, education, trade and defence. The EU, with its wealth, solid standing in R&D infrastructure, and highly qualified workforce, is well equipped to achieve a leading position in key semiconductor technologies, supported by a network of international partners to address inevitable dependencies.

The value chains of microelectronics are distributed and global. Equipment, know-how and services either require years, sometimes decades to build up know-how, or they face price competition from countries where production costs are lower than in the EU. In addition, microelectronics technologies are developing fast. Constant strategic adjustment and effort are required to maintain one´s current position in the competition. Bearing this in mind, an EU semiconductor strategy must focus on three pillars:

- Secure a functional access to technologies and capabilities that are vital for economic growth and defence, i.e. materials, advanced logic, sustainable electronics and recycling, mature node manufacturing, PCBs, memory. In the light of the recent geopolitical developments, restoring resilience and reliability in these areas is a short-term task.

- Establish new strengths in emerging topics, e. g. photonics, quantum computing and processors beyond classical Moore-type designs. In this respect, advanced packaging and chiplet technologies fulfil a special role as an enabler for the above emerging areas.

- Reinforce the EU position in fields with strong expertise, e. g. advanced industrial equipment and processes for CMOS-based fabrication, power electronics and EUV equipment.

In this report, we consolidate the findings of the ICOS project and propose instruments to advance in each of these pillars, in section 4.2.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

3 ICOS database

This chapter gives a brief overview of the tools and data we based on our findings.

3.1 ICOS overview

The policy and instruments we propose are based on the work of the ICOS consortium of the last three years. The results from the deliverables were summarised, consolidated and used to evaluate the most promising technological main- and subtopics for each non-European country under investigation.

The relevant ICOS deliverables, which were used for the work in WP 5, are listed in Table 1.

Table 1: Overview of the used Deliverables for the work and analyses of WP5

Deliverable	Main Author	Summary
D2.1 Economic analysis of the EU and international semiconductor ecosystem	Léo Saint Martin (Decision)	The D2.1 report provides a concise overview of the global semiconductor ecosystem, analyses the strengths, weaknesses, and dependencies of the EU, USA, Japan, China, Taiwan, South Korea, India, Malaysia, Singapore, and other countries, and proposes cooperation and investment measures—including an assessment of the photonic integrated circuit market.
D2.2 Past and existing EU-international cooperation	Cian Ó Murchú (TYNDALL)	The D2.2 report provides a concise overview of existing and planned EU-international cooperation, business partnerships and funding projects in the semiconductor sector.
D3.3 Recommendations for international research cooperation	Paolo Motto Ros (IUNET)	The report D3.3 assesses country-specific strengths and weaknesses in the semiconductor value chain and derives recommendations for international research cooperations.
D4.2 Cooperation cases an advanced computation	Nadine Collaert (IMEC)	The D4.2 report analyses global strengths and gaps in advanced-computation technologies and provides brief recommendations for targeted international cooperation to enhance the EU's competitiveness.
D4.3 Cooperation cases on advanced functionality	Jyrki Kiihamäki (VTT)	The D4.3 report outlines EU-international cooperation opportunities for advanced semiconductor functionalities (sensors, power, energy-harvesting, and photonics technologies) and presents country-specific strengths, gaps, and recommendations for partners such as the United States, Japan, South Korea, Taiwan, Singapore, and others.
D4.4 Priorities for cooperation	Ryoichi Ishihara (TU Delft)	The D4.4 report defines filters to prioritize EU semiconductor cooperation projects and provides concrete recommendations on supply-chain resilience,

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

		talent attraction, environmental impact, SME support, and technology leadership.
D5.2 Report on potential R&D initiatives /collaboration/partnerships	Peter Ramm (Fraunhofer EMFT)	The D5.2 report provides a confidential analysis of expert feedback, surveys, and interviews to recommend concrete R&D initiatives, collaborations, and partnerships for the European semiconductor industry.

3.2 Warsaw workshop

On May 12, 2025, the ICOS project held an interactive workshop in Warsaw under the title *"Turn Risks into Chances: Closing Gaps in the Semiconductor Value Chain."* The event brought together more than 50 international participants from research, industry, academia, and public policy. Co-hosted by VDI/VDE-IT and Queen's University Belfast, the workshop aimed to identify key challenges in Europe's semiconductor value chain, prioritise strategic actions, and collaboratively develop viable solutions for strengthening European competitiveness in this critical sector. The methods used within the workshop and for the analysis are described in Table 2.

Table 2: Description of the used methods

Method	Goal	Explanation
Boat Experience	Collect information	The method is normally used for retrospectives. We used it to visualise the current situation in order to obtain all important information about the status of the semiconductor value chain. The sails/wind represent what is going well and what is driving us forward. The anchor symbolises the obstacles and problems, in line with the motto: what is holding us back?
"How might We…?	Brainstorming	The "How Might We" (HMW) method is a user-centred design thinking tool that transforms complex problems into positive, creative questions to inspire innovative solutions. It turns challenges into open-ended questions (e.g., "How might we...") that encourage brainstorming without anticipating solutions
Impact/Effort Matrix	Prioritisation of tasks	The impact-effort matrix (also known as the cost-benefit matrix) is a strategic tool for prioritising tasks, projects, or ideas based on their expected impact and the effort required to implement them.
SWOT Analysis	Finding strengths and weaknesses to address	SWOT analysis is a strategic planning tool used to evaluate the strengths, weaknesses, opportunities, and threats. In our case for the semiconductor value chain.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

3.3 Stakeholder interviews

The interviews with stakeholders were conducted together with Task 5.3. All in all, we conducted 15 interviews with different stakeholder from large industry companies, SMEs and research and technology organisations (RTOs). More details about how we conducted the interviews and which questions were asked are provided in ICOS deliverable D5.2.

While D5.2 analyses the results of these interviews with regard to possible cooperation in the field of research and development, the present deliverable D5.5 analyses the results of the interviews with regard to international cooperations along the entire value chain.

3.4 ICOS internal consolidation workshop

Three main sections and the corresponding recommendations were filtered from the previous ICOS deliverables. For each recommendation, at least three possible measures were proposed, which were discussed and ranked by the ICOS team. For the final consolidation, an online workshop was held with those from the ICOS team responsible for the previous deliverables, with the aim of reaching a common understanding of the recommendations and possible measures. An online whiteboard was used for this purpose.

3.5 Decision support tool

The decision support tool is an excel table, which summarises the results of the ICOS deliverables, workshops and interviews. The ICOS consortium defined the main technological topics for international cooperation, as well as corresponding sub-topics.

Table 3: Overview of technological Topics and subtopics which could be used in international cooperation

Main Topics	Subtopics
Front End Technologies	FDSOI, EUV, CMOS Variations, Silicon Photonics, Non-Silicon Photonics
Advanced Packaging	3D integration, heterogeneous integration, multi requirement packaging, chiplet assembly, BEOL processes
New Materials	2D materials, BEOL materials, cryogenic electronics materials, (ultra) wide band gap, PFAS alternatives
High Performance Computing	NVM, computing-in-memory, neuromorphic computing, AI, Quantum Computing
Sustainability	„green electronics “, PFAS alternatives, sustainable manufacturing processes
Design	IC design, EDA design tools, RISC-V
Resilience	Rapid prototyping, lab-to-fab, Supply Chain Resilience, Skills
Application	power devices, sensing technology, communication technologies, computing

This project has received funding (2023 – 2025) from the European Union’s Horizon Europe research and innovation programme under GA No 101092562.

The purpose of the tool is to provide a high-level overview of technological topics based on the steps of the semiconductor value chain and potential non-EU cooperation partners, defined in the ICOS project as well as a high-level policy advice in form of a cooperation format.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

4 Policy advice on international cooperation in semiconductors

Based on the results, three areas of action are identified:

(I) Coordinated Action
(II) Strategic Investment
(III) Innovation Support

Derived from these three areas, the following three chapters present the corresponding recommendations.

4.1 Coordinated action – strengthen EU capabilities for strong international cooperation

A strong cooperation is characterised by mutual benefit between the partners. This type of partnership, also known as a win-win cooperation, is based on mutual benefits in terms of resource sharing, pooling of expertise, effective combination of complementary skills, or potential market expansion. However, in order to be an attractive cooperation partner, the EU must remain strong and, above all, become agile. The following recommendations therefore focus on how to maintain a strong EU.

4.1.1 *Establish an open and transparent collaboration database*

It is the nature of the EU that there is still a high degree of fragmentation, including both bureaucratic hurdles and a fragmented market. In addition to the common understanding of acting as a European Union, there are still useful and strategic, but nevertheless individual international cooperation initiatives at the level of each European country. Many Member States or organisations maintain contact points who offer advice to companies or entities willing to establish collaboration with an overseas country.

However, transparency is limited with regard to the providers, beneficiaries, and country coverage of these services. Even existing databases are sometimes confusing, have limited information, or lack good filtering options, which creates additional barriers for users. We recommend the establishment of a joint and freely accessible database in which all EU actors who need such information can easily access and search for information such as funding opportunities, contact persons, and/or information exchange for international cooperation.

i) Install **database / central website** on existing cooperation. This should include international contacts and legal advice (see point ii in this section), as well as for example advice on IP and on IP protection.
ii) Establishing of **transparency about all contact points existing EU-wide** (including both Member States initiatives as well as EU initiatives) will help to save time for stakeholders interested in international cooperation when initiating contact.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

iii) Transparency might aid the set-up of **coordinated EU contact points**. Such European contact points in international partner countries will help to improve understanding of the country and its people and facilitate any necessary administrative procedures. It should be ensured that new and existing structures, such as the ESB or the Industrial Alliance on Processors and Semiconductor Technologies, are linked together.

iv) The database/website can help **aligning** the strategies of EU Member States in the field of international cooperation by reducing the duplication of effort in initiatives and focusing attention on priority issues. Member States can learn from each other how to establish cooperation frameworks and who the useful contacts are. This will reduce the preparatory work on both sides.

v) Provide **new impulses** under the umbrella **of existing formats**. Europe, its Member States and their organisations already maintain trade or digital partnerships with stakeholders in various countries. These platforms and activities should be built on and expanded. Existing structures and personal contacts will speed up the set-up of new formats and foster trust.

vi) In addition, the database/website could serve to **collect feedback** from industry, academia and RTOs about the experience with collaboration in a certain country, providing valuable information for future instruments and advice.

Rather than creating an additional committee, focus group, or staffed information centre-since suitable structures already exist-we should concentrate on improving the flow of information, enhancing transparency, and establishing a regular feedback mechanism for service users. For example, a dedicated CSA could develop, maintain, and continually update a comprehensive database to meet these needs and provide the necessary coordination activities for the EU-wider network of contact points.

4.1.2 *Strengthen EU steering capacity by enhancing formats and processes*

The geopolitical environment is evolving rapidly. Therefore, the EU needs unified formats and processes, as well as a robust data basis, to enable quick and agile decision-making.

i) **Coordinate the semiconductor policies across the different bodies of the EU administration** to ensure a coherent and harmonised approach. While the European Chips Act provides the overarching framework, the specific interests and requirements trade, materials supply and research must be reflected in aligned operational policies. Accordingly, semiconductor-related measures adopted by individual EU entities shall be mutually consistent and mutually reinforcing. In addition, a dedicated increase in the EU budget for international cooperation should be introduced to support the harmonised initiatives and strengthen the EU's global position in the semiconductor sector.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

ii) **Improve the effectiveness** of regulatory and funding processes to enable smoother cross-border collaboration. The basis of informed improvement could be an **evaluation** of policy instruments, and collection of **feedback** from stakeholders who participate(d) in such instruments. Such feedback could be collected in an agile manner, e. g. using regular, very short, standardised questionnaires.

iii) **Accelerate decision-making** of political bodies, e. g. by establishing agile processes and a complete database for the field of international cooperation.

4.1.3 *Leverage RTOs and pilot lines*

One of Europe's strengths lies in the existing research and technology organisations (RTOs) in the Member States, including IMEC, Fraunhofer, CEA leti, VTT and Tyndall. Furthermore, with the establishment of pilot lines, Europe has created a second attractive instrument for closing the gap between research and industry. Here, we elaborate on the role of RTOs and pilot lines in international collaboration.

First, RTOs as well as the pilot lines should be used to create new international links and act as **door opener** for international cooperation.

Second, as the players with presumably the least formal and the most international contacts, RTOs serve as **antennae for innovative knowledge** in the international communities. With ideas from the outside, they learn, improve and develop their own know-how.

Third, due to their frequent international contacts and need to publish, they are also **vulnerable to IP leakage** and require protection/guidance in this respect. More details are given in Section 4.3.4.

Fourth, obviously, RTOs serve as platforms for **workforce qualification**. Embedding qualification into an international context helps to keep the standards high and competitive.

Finally, a major task of RTOs and pilot lines is to **bridge the gap between laboratory and industrial manufacturing**. The slow time to market in the EU remains a competitive disadvantage. However, this situation is not immutable. As an example, the Dutch RTO IMEC is engaged to set up the Rapidus 2 nm fab in Japan within a few years. This example shows how powerful RTOs can be if they pursue a **customer-oriented mindset alongside their academic profile**. It also shows that it is important to know or create the **industry demand for future technologies**, and to develop matching RTOs for it.

Table 4: Evaluation of the recommendation "Expand pilot lines and bridge the "Lab-to-Industry transition" regarding benefits, risks, prerequisites and possible measures

Type	Expand pilot lines and bridge the "Lab-to-Industry" transition

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

Benefits	- implementation of innovation from third countries - reduction of idle times on pilot lines, which lead to more experience - improving TRL of pilot lines
Risks	- R&D transfer to international countries - Transfer of manufacturing and industry outside Europe - blocking research capabilities needed by EU industry
Prerequisites	- closely cooperate with European industry - set up accelerators for tape-outs, commercialisation and industrialization - service-oriented mindset
Possible measures	- dedicated funding for Europe's SMEs and 3rd party R&D - expand activities of Europractice and increase Europractice funding - Promote customer-oriented mindset, transparency, easy-access (open PDK, ADK, IP, tutorials) as well as short and reliable production times of the pilot lines.

Ultimately, the goal of European RTOs should be to learn from international partners, to maintain international standard research quality and to deliver high-quality R&D to the domestic industry.

4.1.4 *Use Europractice as an accelerator to bridge the "lab-to-fab" gap*

Europractice is a well-known platform in Europe for obtaining R&D results in tape-outs. However, the platform should be further expanded, on the one hand to increase the number of chip design finalisations and, on the other hand, to gain access to technologies outside Europe. To achieve this goal possible measures could be installed:

i) **launch tape-out competitions** for students initiated by industry and co-funded by EU and industry (50:50)
ii) establish Europractice as a **channel partner for international companies** (e.g. Rapidus, Intel, TSMC, Samsung)
iii) install **interfaces** between Europractice and other international research platforms (e.g. in Taiwan)

4.2 Innovation support based on a clear, long-term vision for the European semiconductor sector

The economic analysis of the European semiconductor value chain (D2.1) clearly identified its strengths and weaknesses, and thus also its gaps. These were further confirmed in the workshops and interviews done within Task 5.1 and Task 5.2. Based on the analysis of these results, it is necessary that Europe has a clear and long-term vision for the semiconductor sector. In the following subchapters we discuss the measures for the three critical points:

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

- address vulnerabilities
- pursue leadership in emerging technologies
- strengthen technologies that are already strong in the EU.

In the stakeholder interviews, stakeholders often reinforced the point of building on existing strengths. While this should not be neglected, the rapidly evolving technologies of the semiconductors industry sometimes command the paving of new ways. It is the role of policymakers to support industry in undertaking such transitions in order to address the needs of a national economy.

4.2.1 *Address critical vulnerabilities*

One of the most important recommendations is that the EU must address its critical vulnerabilities. The question is how this can be achieved successfully. Several alternatives are available in each case, and a decision must be made whether to close the gap via international cooperation, by setting up own infrastructure, by trade or by a combination of those options.

i. One of the most effective levers for remaining competitive is securing **access to advanced technologies**. For each technology which is not located in Europe, a decision should be made as to what it can be implemented in Europe (e.g. funding of international fabs in Europe like ESMC) or whether it is better to secure access through bilateral or multilateral cooperation.

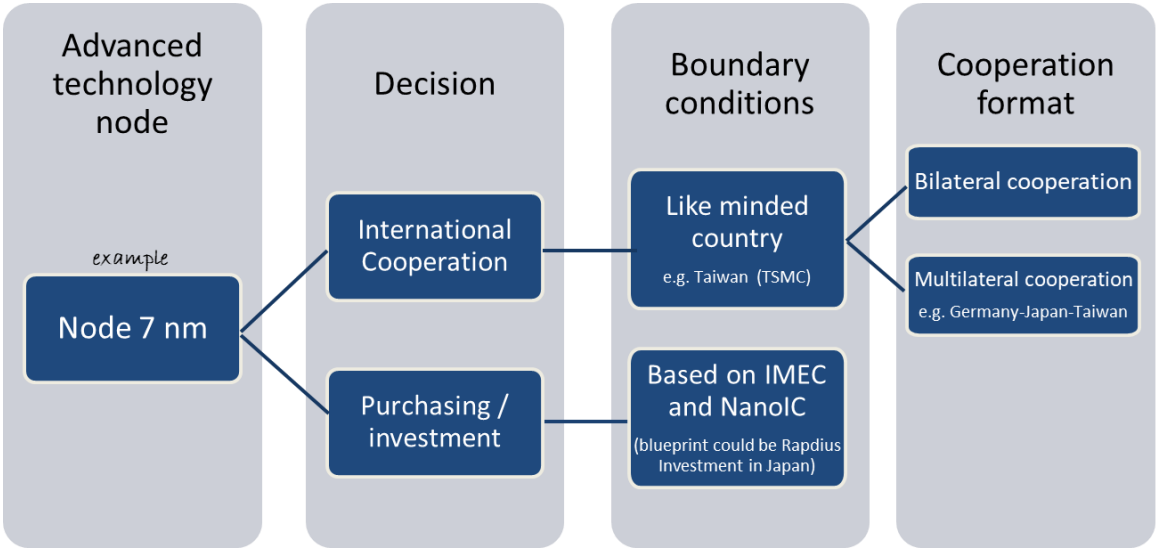

Figure 1: Example of how the process of decision can be done for advanced manufacturing

ii. Another necessity in this area is the **set-up of funding and securing access to foundries** for advanced chip design. Numerous activities have already been launched in this regard, such as the European Chip Design Platform (Euro CDP) and the related pilot

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

lines. These activities should be continued, and additional measures could be evaluated. One addition, for example, would be the integration of international chip design platforms into Europractice and Euro CDP.

iii. A third point is ensuring the **resilience of semiconductor supply chains** through **multilateral agreements and friend-shoring**. Alternative sources should therefore be identified and diversification achieved through international cooperation. Here, too, the focus of international cooperation should be on like-minded countries. In addition to potential partners described in Chapter 4.3.1 like-minded countries that are just beginning to invest in the semiconductor industry, such as Canada, Vietnam and Australia should also be taken into consideration.

The EU should use these three resources as efficiently as possible. For the sake of completeness, we would also like to point out further critical vulnerabilities:

i. Securing the **access to critical and/or raw materials** must also be a focus. This does not only apply to the semiconductor industry. Therefore, a joint effort with other critical industries should be initiated. Possible strategies here include diversification through international cooperation, strengthening the EU's sovereign capacities, or redesigning products.

4.2.2 *Strategically strengthen future technologies and enablers*

The strategic strengthening of future technologies and enablers is based primarily on research and development activities. However, careful consideration should be given to identifying which technologies are suitable for international cooperation. Increased research cooperation could be achieved through international calls for proposals. The current open international calls for example with Japan and South Korea are a good start. Furthermore, there exist national activities in Europe, e.g. Taiwan - Germany. In future, the technological topics for R&D calls should be based on the evaluated priorities in order to close the gaps in Europe. And the topics of those calls for proposals should be carefully selected within for example an existing European committee. In addition to these funding activities, or building on them, the transfer of promising R&D results to industry should be planned from the outset and could be achieved through new international proposals that include European pilot lines or international offers similar to the pilot lines.

The following table lists topics, where research or industry cooperation can help to establish the EU as a leader in the respective fields. The prioritisation was done in the consolidation workshop (see chapter 3.4).

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

Table 5: possible measures to strategically strengthen future technologies and enablers

Priority	Measure
1	Strengthen research collaboration in photonics, new materials, quantum computing, neuromorphic, in/near-memory, power systems, mixed-signal, and communication electronics
2	Build capacities for 2.5-3D packaging and chiplets as a strategic enabler
3	Use international collaborations to promote sustainable electronics
4	Support R&D in the field of alternatives to critical materials
5	Secure funding for development of open-source IP and tools. Strengthen EU Chip design

In the long term, these future technologies could be the ones that enable Europe to take on a leading role.

Most of the topics in the list exhibit a relatively low TRL and are, therefore, suited for academic cooperation with countries that possess a strong expertise in these fields. Dedicated research-funding programes should be established to support these areas. The topics include photonics, emerging materials, quantum computing, neuromorphic concepts, in/near-memory computing, power systems, mixed signal electronics, communications and low-power electronics. Chapter 5 provides detailed measures for each Member State.

Furthermore, one topic that stands out as almost mature for industry, is 2.5/3D packaging, including heterogeneous integration, and chiplet technology. Europe must accelerate its efforts markedly in order to keep pace with the rapid advancements of other global actors, notably Taiwan. Advanced packaging is of particular strategic importance because it serves as an enabler for many of the low-TRL technologies identified previously. For example, many emerging solutions such as photonics or neuromorphic computing rely on novel materials and building blocks. Their uptake will be greatly facilitated if they can be integrated as modular chiplets within conventional CMOS processors. The establishment of standardized interfaces and advanced packaging technologies for compatible interconnects will therefore be essential to the successful implementation and scaling of these new technologies.

Developing advanced packaging to leading standard will require a multi-step approach:

i) funding programme for RTO cooperation, e. g. with Taiwanese RTOs, to establish knowledge
ii) funding programme for the EU packaging industry for international pilot projects. Opening up of the APECS pilot line to RTO and industry customers from abroad, to develop their processes. For the latter, is it crucial that the international demand does

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

not block capacities for EU customers but focuses on developing new packaging processes, which must then be employed for domestic demand.

iii) funding programme for the EU packaging industry to enable transfer of process know-how from EU RTOs and APECS to the domestic industry

The aim of these activities should be to establish top-notch industrial advanced packaging capabilities in the EU.

4.2.3 *Reinforce EU strengths*

Last but not least, it is necessary to identify and strengthen the EU's strengths. Building on strengths is one of the buzzwords frequently mentioned by stakeholders. Europe's economic and technological strengths were analysed in WP 2 and WP 3. Among other things, there are a number of technologies that are frequently and repeatedly mentioned. These include EUV equipment, power semiconductors, sensor technology, advanced packaging technologies and SOI/FDSOI. Europe´s strengths can be reinforced by:

i. Set framework to preserve leading role in EUV equipment, in terms of funding as well as political support. In this context, it is necessary to support the existing relations with the leading-edge manufactures all over the world (Intel, Samsung, TSMC and, prospectively Rapidus). Where possible, they should be augmented with RTO collaborations, e. g. in the topic of chip design. Furthermore, constant political support is needed to enable optimal conditions for the export and further development of EUV technology made in Europe. In this context, sanctions against China from non-EU countries (like the US) pose a risk for European EUV developments, reducing ASML sales while pushing China to compete. Already now, Shanghai Micro Electronics Equipment (SMEE) is set to become a main competitor in the coming two decades [22].

ii. Aspire a leading role for setting standardisation frameworks in the field of chiplet, sensing and quantum technologies. At the moment, the standardisation framework in these areas has not yet been established (see D 5.3), which means that the European Community should leverage its R&D advantage and drive standardisation forward. Possible activities could be:

   a. strengthen pilot lines´ focus on the development of interface standards (e.g. for photonics)

iii. ensure active participation of EU experts in international standardisation bodies (e.g. IEEE) to promote interface and interconnect standards and to benefit from international best practices.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

4.3 Strategic investment - key elements of international collaboration beyond EU

Besides the technological prioritisation lined out above, ICOS identified a number of basic elements that should be part of the EU-international collaborations in semiconductor industry and research/academia.

4.3.1 *Build strategic partnerships in technology and materials*

In light of the current upheaval in geopolitics, it is central to readjust the current network of international partnerships in order to make semiconductor supply chains more robust and enable growth and development in vital research areas. We identify the following principles on which the selection and implementation of such partnerships should be based:

i) **Prioritise:** The direction of any reach-out to external partners must be guided by clear strategic priorities such as those given by the EU Chips Act. Realistic goals as well as regular evaluation and readjustment are the best ways to ensure that such legislation fulfils its purpose and is indeed accepted by the EU semiconductor ecosystems as their strategy guideline.

ii) **Embed:** A policy instrument such as a funding program rarely exists as a standalone. To the contrary, such measures are much more likely to fruit when embedded into a framework of foreign and trade policies, in addition to the technological strategy. As an example, international industry collaborations will benefit from a mutual legal and tax frameworks while the organisation of a research exchange program is easier when building on the mutual trust established by existing trade agreements.

iii) **Diversify:** Pursuing collaborations with multiple international partners is a strategy to avoid dependency and ensure negotiating leverage. As an example, it would be advantageous to simultaneously maintain research collaborations with Taiwanese universities in advanced logic tape-outs, try to establish access to the Samsung facilities in South Korea in a similar fashion and try to establish a Europractice channel to the Rapidus fab in Japan. This strategy is particularly important if the EU is unlikely to establish its own fab in the foreseeable future.

iv) **Focus:** Some countries have a monopoly in a specific field that is vital to the European semiconductor value chains, such as South Korea in memory components. Those countries should be prioritised as key partners for international cooperation in their respective fields with the goal of setting up a reliable supply.

v) **Expand** the focus beyond traditional partners. Focus on complementary skills and mutual benefits. An excellent example for this is ESMC, the joint venture between TSMC on the Taiwanese side and Bosch, Infineon plus NXP on the European side, which sets up a 16/12 nm FinFET fab in Dresden, Germany. [13] While the fab

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

helps diversify and home-shore European supply chains, as well as enabling RTO access to trailing-edge tape-outs, it also provides TSMC with a foothold in Europe.

vi) **Replace:** If a monopolist supplier is not reliable, the alternative is to establish EU-owned resources. Such a decision is risky in itself, as replacing external suppliers at current state-of-the-art level may take a long time and significant resources to achieve. A benchmark can be helpful to assess these risks. As an example, the Rapidus fab in Japan was established in 2022 as an industry consortium, consuming up to 10 billion Euro state subsidies in the first 3 years. As of 2027, the fab is expected to be competitive with Intel.

vii) **Pool interests:** Other countries might be in a similar position, share the EU interests and be willing to pool resources. A possible example is the common interest of EU and China in open-source chip design, in particular its standardisation, as a move away from the dependency on the US EDA companies.

viii) **Prepare** for geopolitical risks, including the increasing dominance of China and a forceful reunification of Taiwan with China. Emerging risks cover possible sanctions or tariffs imposed by the US. In this context, countries such as the Philippines are likely to follow suit and match any actions taken by the US. Finally, Russian animosity and the risk of Russian aggression is growing. While there is no dependency on Russia with respect to semiconductors, this risk has an impact on the availability of financial resources in the EU as well as focusing resources towards defense technologies such as robotics and sensing.

These principles should guide the set-up of international collaborations. Next, we consider, which aspects are worthwhile to address in such collaborations.

4.3.2 *Prioritise domestic industry*

The joint European economy aims to be a prominent or in some fields leading supplier of microelectronics goods on the global market. This is the overarching goal of any semiconductor policy of the EU. Therefore, the central goal of the EU strategy should be to **strengthen the EU semiconductor industry by providing optimal conditions to grow** from their own strength:

i) A **stable, cost-efficient and high-quality supply** of components, access to equipment, tools and materials. International collaboration can help secure those.
ii) **Prioritise European suppliers**. The central goal of the EU strategy should be to strengthen the EU semiconductor industry.
iii) **Workforce** adequate in quality and quantity. Section 4.3.3 gives more inside here.
iv) **Top-notch research with easy channels to transfer** results to the market. While research is an international business, the main role of European RTOs and pilot lines should be to provide know-how for European companies.
v) A **market** to supply their goods to, domestically or internationally.
vi) A safe operating field and protection of **IP** and know-how.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

As shown by some of the interviews carried out among the industry stakeholders within WP 5, industry often favours growth in areas that are presently already strong, and avoids disruptive change. **The enabling of change and ambitious research as well as the support of market newcomers is the task of the policy-makers.** This process is vital for the continuous renewal of the industry and its strength in future technologies. Constant effort is needed to maintain a high standard in terms of funding, instruments and selection criteria.

4.3.3 *Strengthen EU workforce*

The demographic structure of most EU countries requires an influx of workers from outside the EU in many sectors. While the semiconductors manufacturing is an industry offering high quality jobs, these jobs cannot all be filled with workers from the EU. Certainly, EU-internal measures must be taken to improve the qualification and mobility of its own workforce. However, in cases where positions must be rapidly filled or specialist know-how is to be acquired, workers should be invited to the EU and talent exchange in academia and industry should be promoted. The exchange of talent and skilled workers must be an integral part of future international agreements and, where appropriate, be expanded in existing agreements.

Here, three main routes are identified, for strengthening the EU workforce via collaborations with international partners, namely academic research collaborations, talent exchange programmes and the invitation of skilled workers to come and work in the EU. Each has their own requirements, chances and drawbacks:

Table 6: Evaluation of the recommendation "Academic research collaboration and talent exchange" regarding benefits, risks, prerequisites and possible measures

Type	Academic research collaboration and talent exchange
Benefits	- qualification of EU academics - access to tools, fabs and know-how of other countries, for research - access of students to advanced technologies to explore new ideas - increase the number of tape-outs for students using fabs abroad - fresh ideas in EU research - gathered know-how stays in the EU in the form of educated graduates and research groups - can be organized on state-level or even for individual institutions - for talent exchange: inflow of international students who might stay due to better job prospects in the EU - trusted personal contacts on a global scale
Risks	- outflow of IP at an early stage - universities are particularly vulnerable for IP loss as they rarely protect their IP professionally - for talent exchange: infiltration of EU universities with internationals who leak IP to their home country (such as China) while taking up EU-internal funding resources

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

Prerequisites	- Funding for EU universities - access of EU universities to effective IP protection measures and advice - if possible: trade or exchange agreements with the country of collaboration, e. g. to set the conditions for access to interesting infrastructure
Possible measures	- Research collaborations in pre-competitive R&D with Japan, Canada, Australia, Taiwan, South Korea. - Maintain and develop existing collaboration frameworks (Japan, Taiwan) - expand e. g. via MSCA actions or Erasmus+

Workforce development is frequently treated as a secondary objective, incorporated only superficially into research collaborations or trade agreements, and consequently receives limited financial resources and insufficient attention.

Here, one should bear in mind that at a **comparably low cost**, e. g. for international student exchange programmes, summer schools and small academic collaboration projects, much impact can be made in terms of a workforce that is qualified to international standard. This is crucial for a sector so dependent on applied research such as the semiconductor industry. Besides the third countries investigated in ICOS, there are further suitable partners for talent exchange such as Canada or Australia. Also, like-minded countries with dynamic population trends and ambition in the chip industry could be interesting, e. g. Indonesia, Vietnam or Morocco.

Furthermore, researchers establish international networks as a part of their work. Through collaboration programmes, these efforts can be channelled towards new, strategically important partners. Here, it is important to include both, lighthouse research centres and grassroots applications. That way, the measures can promote strategically important projects as well as reaching a broad distribution of researchers in the EU communities.

Table 7: Evaluation of the recommendation "Invitation of skilled workers" regarding benefits, risks, prerequisites and possible measures

Type	Invitation of skilled workers
Benefits	- close the workforce deficit of industry, e. g. in hotspots such as the newly erected First-of-a-kind facilities in Germany, Italy, France and Austria - benefit from qualification provided in other countries - retain qualified international graduates in the EU - transfer of know-how by people, international workers educate those who work with them
Risks	- societal acceptance in the EU
Prerequisites	- in case of invitation from a particular country: trade or exchange agreements with the country of collaboration, to set the conditions for the worker mobility

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

	- language qualification
Possible measures	- workforce development agreement with India, Indonesia, Vietnam, and Morocco for skilled workforce, for example but not limited to software (AI) and communication electronics. These countries have very dynamic population trends, can be considered as independent from both the US and Chinese ecosystems, have a willingness to play a role in the chips industry, and will welcome a cooperation with the EU to strengthen their ecosystems. - EU invitation programme for international graduates of EU universities

It is important to note that quantitative research on the workforce requirements of the semiconductor industry was not part of the ICOS project and should be carried out prior to setting up any workforce instruments such as invitation schemes.

4.3.4 *Establish trust and secure IP protection*

IP protection is an aspect of international collaborations that ICOS would like to highlight. International cooperation should always serve the purpose of advancing the capabilities of the EU. Naturally, a collaborating country will try to do the same from their perspective. Mutual interests and mutual gains are the optimal prerequisite of any collaboration. It is, therefore, important to have a realistic assessment of one's own strengths and weaknesses before entering into an exchange. A major weakness of European high-tech ecosystems is their painstakingly slow and sometimes inhibited transfer from research to market [16].

While the reasons for this are discussed elsewhere and measures need to be taken within the EU to address this problem, the slow time-to-market requires EU stakeholders to be particularly cautious in collaboration with countries that have a fast time-to-market. ICOS suggest following measures that help to prevent IP leakage:

i) Support RTOs in preventing leakage of sensitive research results. While RTOs are often aware of the dangers to their IP, an unbureaucratic standard tool for assessing risks in collaborations is missing. More importantly, the existing EU and national guidelines on IP protection in international collaborations must be made more transparent and accessible. Raising awareness and hands-on education campaigns for researchers would be helpful.

ii) Support start-ups and SMEs, for three reasons: First, they often carry highly innovative IP. Second, they are likely to contact international stakeholders in their search for funding, in particular in more expensive scale-up phases [17]. Third, very often they suffer from limited resources, insufficient networks, and a lack of international experience. Measures to strengthen SME ability to engage in international collaboration include:

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

- A central information point (e.g. a website) for SMEs, where legal expertise, links to national help centres and other public information about the relevant countries are collected and can be accessed by SMEs to better develop their international cooperation strategy.
- Offer instruments for financial risk-sharing for SMEs tackling international cooperation.

iii) **Support industry stakeholders** with robust frameworks for intellectual property protection while avoiding excessive regulatory burdens. Support is best done in the form of EU-trade or collaboration agreements. Existing agreements could be evaluated, gathering community feedback on IP protection in international collaborations.

iv) **Maintain a cautious approach** to engagement with China, with regard to both R&D cooperation and supply chain diversification. ICOS deliverable D5.2 gives a good summary of the stakeholder views on dealing with China. In addition, the slow time-to market in the EU [16] is a risk faced by RTOs and industry alike when collaborating with Chinese partners. However, this risk applies to other collaborations well, namely with countries who benefit from a regularly faster time-to-market such as the US [18] or India, who are in a better position to secure the benefits of the cooperation.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

5 Conclusion

The current geopolitical situation reminds us once again that we can only have a secure and sovereign semiconductor value chain if we do not remain alone. No one in the world will be able to control the value chain completely on their own, even if China and the US are working on it. This makes it more important for us in Europe to build on our strengths and close the existing gaps (reduce our weaknesses). International cooperation is one method of choice for this. But it will only be successful if both partners end up in a win-win situation. Therefore, we need a strong European basis in R&D and in industry.

The ICOS project team conducted an assessment of the semiconductor industry for seven non-EU countries. Emerging technologies in advanced computing and functionalities were also evaluated from R&D (RTO) perspective. Workshops and interviews were used to gauge the community's opinion on the challenges and possible solutions and to strengthen international cooperation. The final analysis of all these results will now lead to the final political advice. Which can be summarised in three main areas of recommendations: (a) coordinated action; (b) strategic investment; (c) innovation support.

All proposed recommendations and associated measures contribute to these 3 areas of action. In Figure 2 an overview of some key elements which should be addressed in each area is shown.

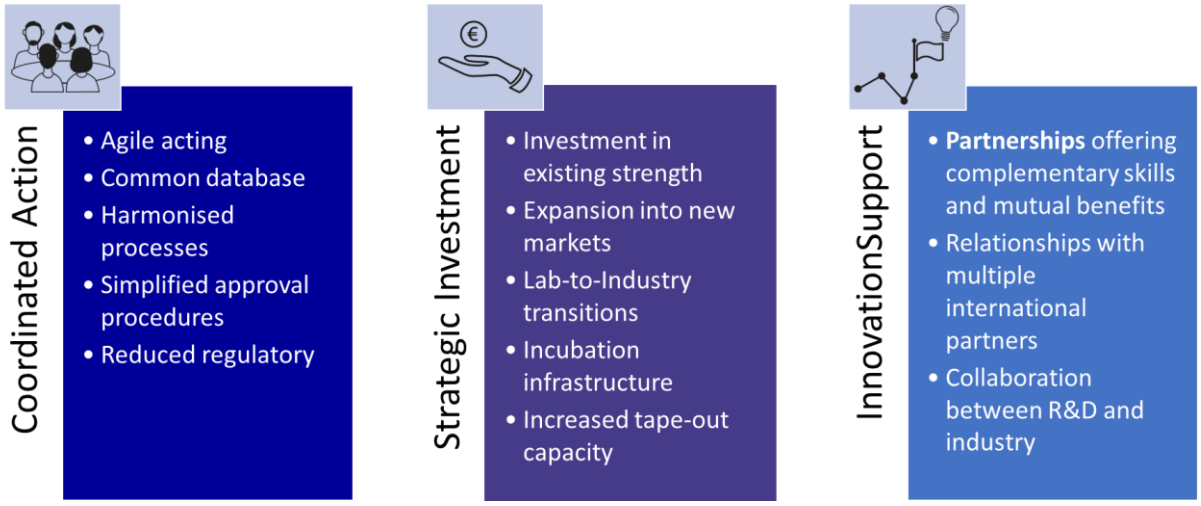

Figure 2: Overview of key measures within the three areas of action: Coordinated Action, Strategic Investment and Innovation Support

The recommendations made for the coordinated action will create the institutional, legal and diplomatic backbone, that will make any cooperation possible. This includes common rules, important contact points, coordinated national actions on Member States level and the possibility to make fast decision.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

The recommendations made for the strategic investment, like dedicated funding programmes, long-term budget commitments or workforce activities will help to achieve strong international cooperations.

The recommendations made for innovation support will lead to innovative products made in Europe to reach the market.

In the semiconductor world of the 21st century, no one will be the sole leader – but together we can remain so.

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

6 References

[1] ICOS Deliverables D2.1, D2.2, D3.3, D4.2, D4.3, D5.2

[2] The future of European competitiveness, Part A and B, September 2024

[3] Semiconductors: European Views on Four 2029 Tech Transfer Regime Scenarios; Policy Paper [Chips Diplomacy support Initiative]; September 2025

[4] Localizing the global semiconductor value chain – strategizing for growth while building resilience in the rapidly evolving industry; Shinichi Akayama, Daniel Chow, Subrat Gupta; 2024; Arthur D. Little

[5] Semiconductor and beyond – global semiconductor industry outlook 2026; PWC; 2025

[6] Semiconductors: a globalised market and a European dependency; Madlie Ericher, Johan Seux, Siessima Toe et Lucie Tournier; Les Thémas de la DGE (Théma n°27), Januar 2025

[7] Mikroelektronik-Strategie der Bundesregierung, BMFTR & BMWE, Oktober 2025

[8] Silicon Island – Ireland´s national Semiconductor Strategy; Government of Ireland (Department of Enterprise, Trade and Employment); 2025

[9] EU´s strengths and weaknesses in the global semiconductor sector; P. Bonnet, A. Ciani, J. Molnar, M. Nardo; European Commission, ISSN 1831-9424, 2025

[10] Chip Diplomacy – Analysis of technology partnerships; J. Hess, J.-P- Kleinhans; Stiftung Neue Verantwortung; October 2023 or https://www.interface-eu.org/publications/chip-diplomacy

[11] Semi Europe – Chips Act Report – 30 Semi Recommendations for a Chips Act 2.0 (In-Depth Report); S. R. Orlando, A. Padovani; Semi Europe; November 2025

[12] https://www.esmc.eu/de/index.html

[13] https://www.eca.europa.eu/de/publications/sr-2025-12

[14] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14842-Chips-Act-2_en

[15] https://en.wikipedia.org/wiki/Rapidus

[16] https://ec.europa.eu/commission/presscorner/detail/en/ip_24_3505

[17] https://research-and-innovation.ec.europa.eu/strategy/strategy-research-and-innovation/jobs-and-economy/eu-startup-and-scaleup-strategy_en#:~:text=On%2028%20October%202025%2C%20the,first%20investments%20in%20Spring%202026.

[18] https://europeanrelations.com/technology-and-innovation-in-the-eu-challenges-gaps-and-strategic-opportunities/#:~:text=On%20a%20national%20level%2C%20European,close%20the%20steadily%20increasing%20gap.

[19] https://www.edb.gov.sg/en/business-insights/insights/what-makes-singapore-a-prime-location-for-semiconductor-companies-driving-

This project has received funding (2023 – 2025) from the European Union's Horizon Europe research and innovation programme under GA No 101092562.

innovation.html#:~:text=Singapore%20is%20already%20an%20integral,generation%20of%20smartphones%20and%20EVs.

[20] https://esg.tsmc.com/file/public/e-APractitionerofGreenPower_2.pdf

[21] EU-US Trade and Technology Council - European Commission

[22] Chinas geheimes „Manhattan Project“ zum Bau einer eigenen Lithografiemaschine

This project has received funding (2023 – 2025) from the European Union’s Horizon Europe research and innovation programme under GA No 101092562.