Towards an NL Chip Plan

Establishing a stronger NL Chip sector

NL Academy of Technology and Innovation

DECEMBER 1ST, 2022

PROF.DR. G.Q. ZHANG, TU DELFT
DR.IR. J.P.H. BENSCHOP, ASML
IR. R. BLICKMAN, BE SEMICONDUCTOR INDUSTRIES
PROF.DR.IR. A. VAN DEN BERG, UT
PROF.DR.IR. B. NAUTA, UT
PROF.DR.IR. P.G.M. BALTUS, TU/E
DRS.IR. W.G. JACOBS, ACTI

AcTI
technologie&innovatie
Netherlands Academy of Technology and Innovation

Preface

Since the recent shortages and the increasing importance of chips for our society, the semiconductor industry has been in the spotlight. In response to the EU Chips Act, EZK (Ministerie van Economische Zaken en Klimaat) has asked NL AcTI (Netherlands Academy of Technology and Innovation) for advice on the Dutch position to be pursued in the light of European and global developments.

EU Chips Act- The EU Chips Act is the European response to the geopolitical dynamics in the semiconductor industry and the current shortages of semiconductor products. The EU's market share has fallen below 10% in the past 10 years[1]. In addition, the EU has limited production resources for the most advanced semiconductors and the EU is highly dependent on a limited number of players outside the EU for semiconductors.

The EU therefore wants to give a new impulse to the semiconductor industry and has indicated that it wants to increase production capacity to 20% by 2030. With the global market projected to grow from €500 billion in 2022 to more than €1,000 billion in 2030, which means roughly a quadrupling of the European semiconductor industry. Goals have been set for maintaining and strengthening research leadership, strengthening Europe's innovation capacity, solving the shortage of talent and trained staff, and developing smart strategic partnerships.

Process- This advice has been drawn up by a partnership between education, science and industry. AcTI worked with a core team of the 6 authors who each consulted their own network and collectively represent the semiconductor ecosystem broadly. We would like to thank everyone who contributed (see 'Acknowlegdments' at the end of the report).

About AcTI

AcTI is an independent entity that assists the government with advice in the field of science, technology and innovation from an ecosystem approach. NL AcTI has a large membership base of authoritative engineers, including their network, who broadly represent science, education and business.

In addition to the advisory function, AcTI also has a forum function to discuss the opportunities and threats that technological developments entail. Finally, through a pivotal role, AcTI is committed to strengthening the ecosystem for startups and scale-ups and guiding them through knowledge, insight, and network. Internationally, AcTI represents the Netherlands in the European and global ecosystem of *Academies of Engineering*.

[1] Kearney, summer-fall 2021, Europe's urgent need to invest in a leading-edge semiconductor ecosystem

Summary

AcTI recommendations- As this 3-page summary is quite extensive, we would like to start by listing the five recommendations we make with this report to ensure and further strengthen the global leadership position of the Dutch semiconductor sector:

A. Set up an NL Chip Competence Center to leverage national knowledge and resources
B. Invest in Human Capital for semiconductor sector specifically
C. Implement an Industrialization Pilot Line infrastructure complementary to other countries in the EU, focusing on Dutch strengths
D. Align EU research Roadmaps & funding to enhance impact and efficiency
E. Install Business Creation Programs to fuel new business growth through start-ups and scale-ups

About semiconductors- In recent decades, semiconductors have been undergoing major development in three technological areas. 1) Moore's law focuses on IC[2] miniaturization down to the nanoscale ('More Moore'), resulting in an enormous development of 'brain' capacity. IC miniaturization & increasing number of transistors per chip will continue through innovation in lithography, materials, system integration and design-technology-co-optimization. 2) The development of mainstream semiconductor technologies by adding 'non-brain' functionalities ('More than Moore'). 3) Heterogeneous Systems – the combination of 'brain' and 'non-brain' functionalities with other domains (such as Sensors, MEMS[3], Actuators and Power Electronics) in a compact single system. These 'High Value' systems are essential for applications and end products.

NL Position- The Netherlands has a strong technology position in the fields of: 1 Semiconductor equipment; 2 Advanced device, and circuit designs; 3 Designing for X (reliability, quality, efficiency, testing, circularity); 3 'More than Moore' devices;5 Heterogeneous System integration, and Packaging; 4 Quantum Computing. The Netherlands is particularly strong in the application sectors of Mobility (e.g., Automotive), wireless Communication, Radar, Energy, Life Sciences & Health, and Agriculture & Food, wherein there are tremendous potential to further grow driven by NL semiconductor technology and business.

According to our interviews, it can be concluded that nearly all Dutch companies in the semiconductor value chain have strong growth ambitions for the coming years – companies in semiconductor equipment, designs, device and component manufacturing, and companies making end products – despite the expected shrinking economy due to the inherited industrial cycles, the pandemic and geopolitical tension. This gives the Netherlands a unique opportunity to gain more global technology and business leaderships, from both middle and long-term perspectives, wherein government can play an instrumental role to cultivate and facilitate the ambition of the sector.

Quantum Computing ('Beyond CMOS[4]') and Photonics ('More than Moore') are promising technologies that are functionally largely complementary to semiconductors in the future. In addition, semiconductor technology is and will remain the basis for future industrialization and commercialization of these technologies for many decades. For this reason, too, it is necessary to fully invest in the upcoming wave of semiconductor development.

[2] Integrated Circuit
[3] Micro Electro Mechanical Systems
[4] Complementary Metal-Oxide Semiconductor

A. NL Chip Competence Centre (ChipNL)- Semiconductor is a knowledge, talent and capital-intensive industry. Despite the great efforts of top sector Holland High Tech in the past years, in order to maintain and further expand our position, there is an urgent need to setup a "Quantum Delta/ PhotonDelta" alike national organization, so called ChipNL. We need ChipNL to define a joint vision, mission, targets and strategy, to leverage national knowledge and resources: to address issues in the field of Human Capital (shortage of trained people and talent development), industrialization pilot Infrastructure (strengthening innovation capacity), Research Roadmap and Funding (better targeting of research and required resources), and Business Creation Programs (creating more starting up and scaling up companies for economic return).

We recommend the ChipNL being established in collaboration with the relevant departments of TUD, UT, TU/e and other potential partners from the semiconductor industry, TNO, QuTech, Quantum Delta, PhotonDelta, CITC[5] etc. The aim of this functional integrated national center is to achieve significant technology and business impact comparable to IMEC[6], Fraunhofer, and LETI[7], but in the complementary key technology domains wherein the Netherlands has and will have global leadership positions. ChipNL is an umbrella organization with four focus areas: 1 Human Capital; 2 industrialization Pilot Line; 3 Research Roadmap and Funding; and 4 Business Creation Programs. By planning, coordinating, monitoring and adjusting at national and strategic level, with all key stakeholders in the field, ChipNL can blaze a new path to greatly enhance the global competitive position of the Netherlands in the decades to come.

B. Human Capital- There is already a shortage of talent and if we don't adjust, this problem will only get worse. Therefore, educational institutions and leading semiconductor companies need to identify future needs and tailor a national (ecosystem-wide) semiconductor education and training programs accordingly.

Educational capacity (staff & infrastructure) must be increased proportionally. Due to the individual character of the education at the academic exit level, doubling the number of graduates in this field academic level requires doubling of professors and Ph.D. students who make this happen.

Attention must also be paid to the expensive cleanroom training facilities that are required for the intended training and R&D programs. For this, EZK[8] could help by supporting existing university cleanrooms to increase their training capacity, and to interact with other EU Public Administrations for better access to other EU facilities, such as IMEC, Fraunhofer, LETI, and Europractice.

It is also important to make the world of chips visible in secondary schools, and to ensure that the Netherlands is made attractive for foreign talents, starting from making related high education programs in English. The administrative threshold for bringing foreign talents to the Netherlands must be lowered. A fund is also needed to finance semiconductor research by top talents. All this is already being done in Asia, the UK and the US. What is more, the US and China all are establishing specialized semiconductor faculties, to quickly increase the number and level of future semiconductor working forces and talents.

C. Industrialization Pilot Line infrastructure- Various cleanroom infrastructures exist in the Dutch open innovation ecosystem. With support from NanoLabNL and GF2[9] programs, TUD, UT, TU/e are strengthening their fundamental and long-term research infrastructures, especially in the field of

[5] Chip Integration Technology Center
[6] Interuniversity Microelectronics Centre
[7] Laboratory of Electronics Information Technology
[8] Ministerie van Economische Zaken en Klimaat
[9] Nationaal Groeifonds 2nd round

Quantum Computing and Photonics. Please note that the infrastructures of both Quantum and Photonics are mainly based on monolithic and pure research needs. In addition, there are also some small-scale cleanroom Infrastructures such as Else Kooi Lab (4' Silicon, Sensors, and MEMS), Holst Center (Flexible Electronics), Nanolab Twente, CITC (Packaging), and TNO & QuTech (Quantum).

Together with the key ecosystem stakeholders of Semiconductors, Quantum, and Photonics (SQP), we identified a unique and golden opportunity for the Netherlands to setup an Industrialization Pilot Line for Heterogeneous System Integration (IPL-HSI), by combining our future needs and leading expertise of SQP. IPL-HSI will not only strengthen our semiconductor leadership position, but also provide an essential impulse to enable the further industrialization and commercialization of Quantum and Photonics and close the gap of their current pure research-oriented infrastructure with further business creation. Both Quantum (Quantum Delta and QuTech) and Photonics (PhotonDelta) strongly endorse the importance of establishing this pilot line.

Note that IPL-HSI is complementary to the current facilities of IMEC, Fraunhofer, and LETI, since currently only NL has the unique position with leading research expertise and (potential) industry bases in the combined domains of Semiconductors, Quantum, and Photonics. Moreover, multiple NL equipment vendors have expressed strong ambitions to take a larger role in the emerging market of equipment for heterogeneous system integration, reflected by the semiconductor equipment projects of NextGen HighTech supported by GF2. NL is unique in the proximity of the complementary heterogeneous system integration equipment ecosystems, so NL can achieve faster innovation than anywhere else in the world. Combining the technology know-how of IPL-HSI with the leading expertise of HSI equipment vendors, will generate a unique value proposition and business potential for the Netherlands.

IPL-HSI will be the NL high tech business card in the coming decades, and it will be established through a public-private partnership (PPS[10]), with the help of EZK, local governments, funds from the EU Chips Act, and industry participation. Such a facility will require an additional investment in the order of €100M on top of existing semiconductor infrastructure investments.

D. Research Roadmap & Funding- Thanks to the efforts of top sector Holland High Tech, the greater part of semiconductor related research agendas has been embedded in several application-focused roadmaps. In addition, in order to come up with a coherent and strategic guidance, incorporating all key development trends and opportunities of semiconductors, and to better align with EU policies and initiatives, we recommend developing an overarching NL Strategic Research and Innovation Agenda (SRIA) for semiconductors in light of the European ECS[11]-SRIA and other international roadmaps.

Besides committed funding from EU Chips Act JU[12], Eureka and IPCEI[13], with GF3[14], NWO[15], a funding program should be developed for semiconductors that is comparable to the existing programs for Quantum and Photonics, to realize the NL ambition and plans in response to the Chips Act. Funding for top talent, mentioned under Human Capital, should be included.

It is also important to establish several joint NL national research and innovation platforms under the umbrella of ChipNL, as the key technology pillars, by combining the best competencies in the NL research ecosystem, such as: Advanced chip and heterogeneous system designing platform;

[10] Publiek-private samenwerking
[11] Electronic Components and Systems
[12] Joint Undertaking
[13] Important Projects of Common European Interests
[14] Nationaal Groeifonds 3d round
[15] Nederlandse Organisatie voor Wetenschappelijk Onderzoek

Designing for X platform to support “made in NL” strategy; Packaging, module and heterogeneous system integration platform; Wide Bandgap Semiconductors platform for Power, Radio Frequency and Optoelectronics devices, etc. These platforms will play an important role in empowering the semiconductor related business creation in the Netherlands.

E. Business Creation Programs- Finally, it is important that there is not only coordination in the field of human capital, industrialization pilot line, and research roadmaps and funding, but that there is also clear need to create more semiconductor related business in the Netherlands, by more intensive cooperation between research institutions and companies, and by increasing investment for both startup and scale-up. Because ChipNL has an overview and sees the cohesion, it is able to set up and coordinate more and various cooperation programs between knowledge institutions and companies, e.g., via joint research and innovation, startup and scale-up programs. These programs aim to bridge the gap between research and innovation and its industrial exploitation. It cannot be emphasized enough that intensified collaboration between science and industry is of the utmost importance for creating and maintaining an NL strategy in the field of semiconductors. It will also work on attracting more commercial investment funds from the markets to support semiconductor companies.

Introduction

The EU Chips Act aims at strengthening European leadership in research and technology, building more European innovation capacity, increasing production capacity, attracting talent and solving the shortage of skilled personnel, and mitigating potential future disruptions in the supply chain.

Three pillars are introduced to achieve those goals:

1. **Chips for Europe**- aims to increase innovation capacity in advanced semiconductor technologies through five capacity building activities: capacity building activities: 1 Design capacity; 2 pilot lines; 3 Resources for quantum chips; 4 Competence centers; 5 Access to capital for startups/ scale-ups/ SMEs. This is done through the Chips Joint Undertaking (JU) which replaces the Key Digital Technologies Joint Undertaking (KDT JU).
2. **Security of supply**- focuses on the measures and activities that contribute to security of supply – in particular by increasing production capacity. For example, there are labels for 'first of a kind' production locations that make it possible to receive state aid. In addition, there are preconditions for various measures.
3. **Coordination Mechanism**- proposes a governance coordination mechanism to enable monitoring and crisis response through a European Semiconductor Board (ESB). It concerns powers to intervene with the participation of the Member States in the event of supply chain disruption.

This advisory report mainly focuses on the first pillar, but there is a (potential) link with the 2nd pillar with regard to the 'first of a kind' production facilities. There is also an indirect link with the 3rd pillar, because an NL Chip Competence Center can help with the rapid provision of information and a Dutch position in international cooperation in times of disruption.

Content of this report

This report is made up of four parts. First, the developments and Dutch competences in the field of semiconductors are discussed, as well as existing (high level) growth plans. We then explain how we think the Netherlands can set up an NL Chip Competence Center (ChipNL). Recommendations are then made for the four themes with the greatest challenges and which have also been designated as activities within ChipNL. Finally, we conclude with some recommendations about the next steps.

Preface
Summary
Introduction
1. Dutch Position
2. NL Chip Competence Centre
3. Human Capital Roadmap
4. Industrialization Pilot Line
5. National Roadmap & Funding
6. Business Creation Programs
7. Next Steps
Acknowledgments

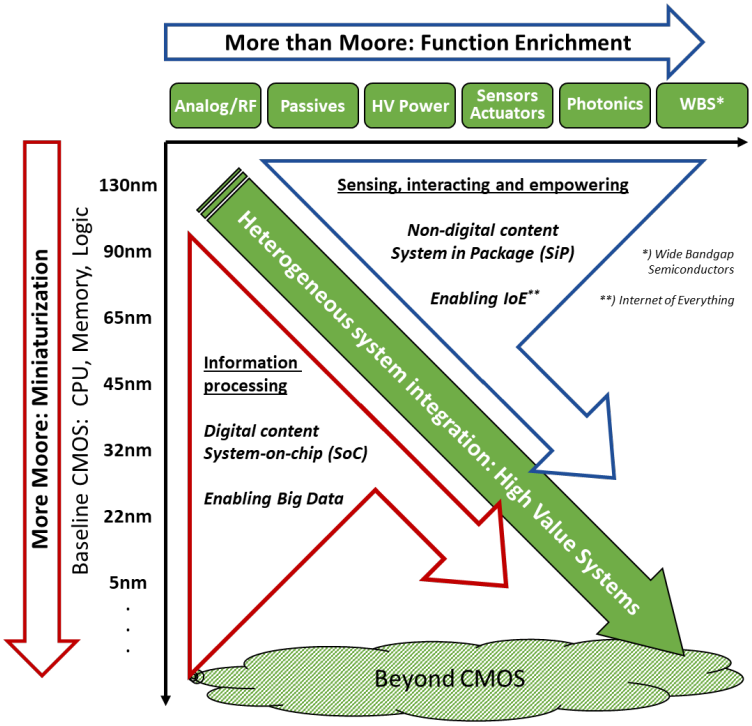
1. Dutch Position

Before discussing the key semiconductor technologies and knowledge required to enable Dutch innovation and economic leadership, we will first provide a brief overview of the key semiconductor developments.

About semiconductors

In recent decades, driven by advanced semiconductor devices, materials and design tools, the advancements of semiconductors are mainly driven by three technologies:

- Moore's law aimed at IC miniaturization down to the nanoscale (“More Moore”), resulting in an enormous development of ‘brain’ functionality (memory and computing). Although the semiconductor industry is close to the physical limit of CMOS[16], the number of transistors per chip will certainly continue to increase ('hyper-scaling') in the coming decades, driven by new materials, process, system integration and design innovations.
- "More than Moore" technologies create and add various ‘non-brain’ functionalities that are becoming mainstream semiconductor technologies, targeting the creation of high performance and multifunctional systems, leading to virtually limitless technological possibilities and application possibilities.
- Heterogeneous systems combine microelectronics with other domains such as sensors, actuators and power domains – as described in the two points above – in a single compact system. Heterogeneous systems are the essential step towards applications, end products and systems, and business creation.



These three developments are visualized in figure 1.

The vertical axis shows IC miniaturization/ ‘brain’ functionality (“More Moore”).

The horizontal axis shows ‘non-brain’ functionalities for creating high-quality and multifunctional systems (“More than Moore”).

The green arrow through the center of the graph represents heterogeneous systems combining microelectronics and other domains into compact high value products and systems.

Figure 1: Global landscape of semiconductor technologies

[16] Complementary Metal-Oxide Semiconductor

New development wave

As indicated earlier, we have not yet reached the end of semiconductor technology development and unabated efforts are needed for research and innovation right now. We are only at the beginning of a new wave of semiconductor development. The challenges, possibilities and opportunities of future semiconductors and applications will be much more profound than we can imagine today.

Quantum Computing is one of the "Beyond CMOS" technologies (like indicated in figure 1, y-axis), and Photonics is one of the "More than Moore" technologies (like indicated in figure 1, x-axis). They have a promising prospect of becoming complementary technologies compared to semiconductors in the distant future. It is good to realize that the developments of Quantum Computing and Photonics are highly dependent on cleanroom infrastructure and equipment that is comparable to that used for semiconductor technologies. Intensive collaboration between the key ecosystem stakeholders of Semiconductors, Quantum, and Photonics (SQP) is an important prerequisite to become successful. For at least the coming decades, semiconductor technology will remain the basis for the industrialization and commercialization of these promising technologies.

Dutch leadership

Semiconductors are a vital economic sector for the Netherlands. On top of that, semiconductors are the key driven forces for other Dutch economic sectors with global leadership positions, such as mobility (automotive, 5G and beyond, etc.), energy, medical and healthcare, agriculture and foods.

The Netherlands has a strong position for the semiconductor technologies shown in figure 2 below, which are not only important today, but also vital in the future.

1. Semiconductor equipment
2. Design
   - Analog and RF circuit design
   - Component and device design
3. Packaging, module and heterogeneous system integration
4. Design for X (reliability, quality, yield, testability, circularity)
5. “More than Moore” devices:
   - Sensors,
   - RF components
   - Power Electronics
   - Photonics
6. Quantum Computing

Figure 2: Overview of technologies with Dutch leadership

Front-end and back-end semiconductor equipment is partially covered by GF2[17].

Within the academic world, the Netherlands occupies a leading position in the field of IC design. Our strength is in analog and RF circuit design. Dutch professors in this field are global academic leaders in this field and many IC design companies are already hosted in the Netherlands thanks to the available talent. However, there is still enormous growth potential for design companies in the Netherlands, both in size and number. The business potential is huge.

[17] Nationaal Groeifonds 2nd round

The Netherlands has a strong position in the field of Packaging, module and heterogeneous system integration. This is an area in which we must continue to invest and grow.

Design for X is a strong Dutch competence. It will be the key success factor to enable competitive manufacturing of many high value products and systems in both the Netherlands and Europe.

With regards to "More than Moore" devices, the Netherlands is at the forefront of sensors and WBS [18]related technologies in terms of research and design. Within this field, Photonics is covered by a national Photonics program

The Netherlands is fully committed to quantum computing, covered by national Quantum program.

In figure 2 below we have superimposed the sectors and technologies, resulting in a technology and application matrix. This provides an overview of areas in which the Netherlands has a leading position worldwide and needs to develop further in terms of technology and application.

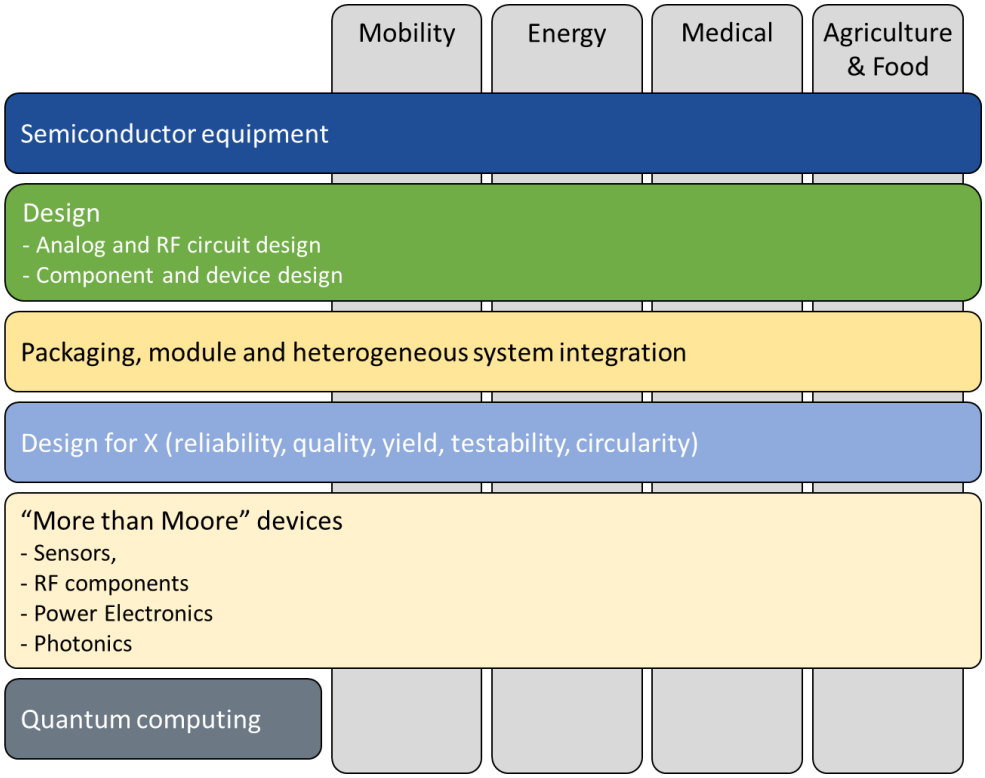


Figure 3: Key technology and application matrix for NL

Growth plans

Nearly all Dutch companies in the semiconductor value chain have strong growth ambitions for the coming years – companies in semiconductor equipment, companies in designs, companies in chip and component manufacturing, and companies making end products – despite the expected shrinking economy due to the inherited industrial cycles, the pandemic and geopolitical tension on top of this comes the European Chips act.

[18] Wide Bandgap Semiconductors

Equipment

The Netherlands has very strong semiconductor equipment companies, with ASML being the world leader in lithography technology. ASML is also expanding its product portfolio to other semiconductor functions, such as metrology, in which Thermo Fisher is also a leading player. Equally important, the Netherlands has a very strong position in other front-end and back-end (packaging) equipment, such as ASM International, BESI, Boschman, etc. Moreover, the Netherlands has many SMEs working on unique semiconductor equipment, such as Nearfield Instruments, ITEC, VSL, etc. All these companies and their suppliers based in the Netherlands have great growth potential and plans.

Design

Chip design is a prerequisite for chip production. The Netherlands has a strong eco-system for chip design, and this should be extended. With a world-leading academic community, around 30 IC Design companies are active in the Netherlands, including global leaders like NXP, Qualcomm, Broadcom, Renesas, Marvell and Qorvo as well as a large number of (local) SMEs. Other companies are Chip design houses that design parts of chips for other companies. Most of these companies in the Netherlands are fab-less design companies, so they focus on product design and have their chips manufactured by a third party. Since we have the ambition to strengthen chip manufacturing in Europe, this has to start with designing them first. The Netherlands has an excellent position to become the European center for chip design. Talent attracts talent, and we can grow this.

OEMs[19]

Also, semiconductor chip and component manufacturing companies, such as NXP, Nexperia, Ampelon, ASM International, with global leadership positions in automotive electronics, industrial power electronics, sensors, etc. All have major growth plans in the Netherlands. The Netherlands does currently not have any large-scale (mainstream) chip foundries.

End-products

Many product and system companies enabled by semiconductors, such as Thales, Prodrive, and Philips, foresee good growth prospects, driven by a strong semiconductor industry and ecosystem. These growth plans will increase the Dutch leadership positions within the aforementioned economic sectors, such as mobility, energy, medical and healthcare, agriculture and foods.

[19] Original Equipment Manufacturer

2. NL Chip Competence Centre (ChipNL)

TUD, UT, and TU/e have many research groups with leading and strong semiconductor competencies, such as advanced design, sensors and MEMS, RF and communication, power electronics, heterogeneous system integration and packaging (see explanation in figure 4 below), design for X, etc. However, their value, global impact and economic potential for the Netherlands have not yet been fully exploited, due to limited scale and synergy, lack of resources, a missing industrialization pilot line, and organizational barriers.

We therefore recommend setting up an NL Chip Competence Centre (ChipNL) in collaboration with the relevant departments of TUD, UT, TU/e, industry, TNO, QuTech, CITC[20] etc. We succeeded to reach a joint vision with the key stakeholders from Semiconductors, Quantum, and Photonics (SQP), for the contents of ChipNL, wherein companies will play an important role. With the communicated key stakeholders, we will be able to work out more detailed plan, according to the detailed requirements of the Chip Act guideline.

The aim of creating this national umbrella for semiconductor development is to achieve significant technology and business impact comparable to IMEC[21], Fraunhofer, and LETI[22], but in the complementary key technology domains wherein the Netherlands has and will have global leadership positions. It will be a functional umbrella for currently available major semiconductor research teams and competencies in NL ecosystem, in which the following activities will be carried out:

1. Developing and coordinating Human Capital Roadmap;
2. Defining national Strategic Research and Innovation Agenda (SRIA), and establishing and coordinating key technology platforms;
3. Aligning existing research infrastructure, and establishing the IPL-HSI[23];
4. Business development via defining and coordinating academic-industrial collaboration programs, promoting incubation, attracting funds, PR and NL branding

Heterogeneous system integration and packaging

Given the technical development of complex systems into a small form factor, electronic chips are combined with their surrounding components in a small package. These components can be all kind of devices, e.g. sensors, actuators, RF, power management chips. Moreover, different IC technologies can be combined in one package. One example is a chip for a microprocessor, a dedicated memory chip, a chip for high voltage electronics, combined with a chemical sensor and an antenna. These systems cannot be integrated on a single chip but have a large added value. In Europe it will be very challenging to have competitive edge nanometer CMOS production lines, however producing heterogeneous systems Is an excellent candidate for the near future.

Heterogeneous systems can form a bridge between electronic chips and integrated photonics and in the future also with quantum computers. There is also a strong link to the packaging of integrated circuits; a heterogeneous system can be seen as the ultimate development of packaging technology

Figure 4: Explanation about heterogeneous system integration and packaging

[20] Chip Integration Technology Center
[21] Interuniversity Microelectronics Centre
[22] Laboratory of Electronics Information Technology
[23] Industrialization Pilot Line for Heterogeneous System Integration

3. Human Capital Roadmap

Human capital (HC) and talent development are essential for realizing the Dutch ambitions in the field of semiconductors. Shortage of trained person is already a big problem and bottleneck in the Netherlands. In the coming years, Dutch semiconductor-related companies are estimated to need more than thousands of graduates at various levels each year to realize their growth ambitions in the Netherlands. Sufficient resources and joint and decisive action are urgently needed to solve the shortage problem.

Talent development

Solving the shortage problem requires a joint national approach and closely aligned among the EU ecosystem. To achieve EU level synergy, we should first organize better in the Netherlands.

Attention must be paid to the educational capacity. Due to the individual character of the education at the academic exit level, doubling the number of graduates in this field academic level requires doubling of professors and PhD students who make this happen. PhD students have a large role in supervising MSc-level students in their projects. They are needed by industry as well for the more complex roles in the industry after graduation. Also, at other levels of education (HBO, MBO) capacity will have to be extended and need more educational staff.

We have to attract more local talent to this industry. It is necessary to develop a stimulation program to encourage BSc graduates from other technical disciplines and HBO students to flow into semiconductor MSc program. Minor programs in electronics for non-electronics students can kick start this. Also re-training mid-career engineers in other disciplines can increase the workforce. More attention must be paid to education and training in the field of semiconductors among all important stakeholders, changing from papers and talks to joint and urgent actions.

At the moment, the threshold for Dutch students to access to foreign infrastructure that is partly created with EU funds (e.g. IMEC in Belgium and Fraunhofer and Europractice in Germany) is too high. We therefore propose that EZK negotiates structured 'low/zero threshold access' to European pilot lines and competence centers for chip production, evaluation and testing infrastructure, through bilateral or multilateral government agreements. This should also apply for the other way around for ChipNL and IPL-HSI: EU parties should also have access to this infrastructure.

For IC design education and research, we rely almost 100% on outsourcing to other open research or industrial fabs (semiconductor foundries). Due to the high costs and lack of budget for educational purposes, bachelor and MSc hardly get the chance to test and verify their design. For the PhD students, due to the limited budget, they can only make a limited design iteration and have to wait a very long time to receive the physical prototypes. Also laboratory equipment to evaluate chips will be needed.

To train bachelor and MSc students for semiconductor process technology, they need to use cleanroom infrastructure, which is much more expensive than other specializations. Dutch universities have no special and sufficient budget to maintain and update even 4 inch cleanroom infrastructure, while in Asia and the US, there are special government funds to support 8 inch education infrastructure, with much larger training capacity.

Attracting and retaining talent

Currently, the whole world is fighting to attract talent in the semiconductor field. The administrative threshold for bringing foreign talents to the Netherlands must be lowered. Easier and faster working and living permissions, and attractive and competitive policies for talents and interns hired by relevant Dutch stakeholders (business, education and research institutions) are urgently needed. For example, getting a work permit for an international intern currently takes up to four months and an incredible amount of red tape.

The chip labor market is global. It's easy for people to move from one country to another and work there; the technology and the language used is the same everywhere. Therefore, it's important that the Netherlands remains an attractive place to work In addition to simplified and accelerated admission procedures, the Dutch financial 30% reimbursement ruling should be maintained. Finally, it is important to set up specialized research funding for top talents working in Dutch education institutions.

The importance of semiconductor technology for the Dutch economy (and the role and contribution of the Netherlands to European ambitions) must be better highlighted. This is an activity that ChipNL can perform. We also believe that ChipNL should develop a program to increase the visibility and the attractiveness of semiconductor careers, starting from early high-school level. We need to show international students and talent that the Netherlands has attractive study and career prospects in semiconductor related fields.

4. Industrialization Pilot Line

In order to realize the Dutch growth plans, the Netherlands will have to strengthen its semiconductor cleanroom infrastructures by investing, improving, synchronizing and sharing facilities within the Netherlands and with the EU, for both university research infrastructure and other open industrialization infrastructure.

Semiconductors related cleanroom infrastructures in the Dutch open innovation ecosystem can be summarized as follows:

- Currently, 3TUs are strengthening their long-term infrastructures for fundamental research, especially in the field of quantum computing and photonics, supported by NanoLabNL and GF2 programs. TUD is modernizing a cleanroom infrastructure for fundamental research in micro/nano technologies; TU/e for photonics; UT for sensors, photonics, quantum, actuators and materials.
- In addition, there are also various small-scale and specialized innovation cleanroom infrastructures such as Else Kooi Lab (TUD) for a 4' Silicon line and sensors/MEMS lab; Holst Center (TNO) for flexible electronics; CITC for packaging, etc. Each has different operating models, different levels of expertise and accessibility, different equipment life and relatively high cost.
- There is no wide bandgap semiconductor (WBS) related open innovation infrastructure for power electronics and RF technologies, which are essential for the Dutch automotive, communication, and energy sectors.
- Within the currently planned R&D infrastructures for quantum and photonics, the essential infrastructure of heterogeneous system integration with semiconductors is not yet included, and not yet covered by IMEC[24], Fraunhofer, and LETI[25].

Due to the major development trend of semiconductors, for example, the emergence of Chiplets, the System in Package (SiP) becoming the new System on Chip (SoC), heterogeneous system integration infrastructure will become the essential factor for future semiconductors. The infrastructure is especially crucial for future industrialization and commercialization of both quantum and photonics, and a unique opportunity for the Netherlands to gain a global leading position, considering the facts that:

- Currently the Netherlands has a strong position with leading research expertise and (potential) industrial bases in the combined domains of Semiconductors, Quantum and Photonics (SQP).
- The Netherlands has a strong global research leadership in the fields of advanced design, sensors and MEMS, RF and communications, power electronics., heterogeneous system integration (including quantum and photonics) and packaging, and design for X.
- Moreover, multiple Dutch equipment vendors have expressed strong ambitions to take a larger role in the emerging market of equipment for heterogeneous system integration, reflected by the semiconductor equipment projects of NextGen HighTech supported by

[24] Interuniversity Microelectronics Centre
[25] Laboratory of Electronics Information Technology

GF2[26]. The Netherlands is strong due to the proximity of the complementary heterogeneous system integration equipment ecosystems, so the Netherlands can achieve fast innovation.

Together with the key ecosystem stakeholders of SQP, we identified a unique and golden opportunity for the Netherlands to setup an Industrialization Pilot Line for Heterogeneous System Integration (IPL-HSI), by combining our future needs and leading expertise of SQP. IPL-HSI will not only strengthen our semiconductor leadership position, but also provide an essential impulse to enable the further future industrialization and commercialization of Quantum and Photonics and close the gap of their current pure research-oriented infrastructure with further business creation. Combining the technology know-how of an IPL-HSI with the leading expertise of HSI equipment vendors, will generate a unique value proposition and business potential for the Netherlands. Both Quantum (Quantum Delta and QuTech) and Photonics (PhotonDelta) strongly endorse the importance of establishing this pilot line.

More concretely, the development of IPL-HSI serves the following four purposes:

1. Enabling fundamental research results to overcome the 'Dead Valley' of innovation, by enhancing a more robust national and allied semiconductor ecosystem to rapidly and securely mature advanced emerging SQP technology.
2. Facilitating the industrialization and future commercialization of heterogeneous systems, thus generating more novel high value end products and systems created and "made in NL".
3. Closing the gap of missing infrastructures, such as wide bandgap semiconductors for automotive, power electronics and RF applications.
4. Providing essential support to create more impactful design companies.

Public-private partnership

IPL-HSI will be the NL high tech business card in the coming decades, and it will be established through a public-private partnership (PPS[27]), with the help of EZK, local governments, funds from the EU Chips Act, and industry participation. It should be closely aligned with quantum and photonics programs, by all relevant universities and TNO, interested companies (equipment, design, chip, packaging, modules and systems), and selected local public authorities who will provide substantial financial commitment.

The role of IPL-HSI is represented in figure 5 on the next page. It will be much cheaper than advanced CMOS infrastructure, and with a much broader application and high business impact. It will enable business success and greater return on R&D investments of Dutch semiconductor R&D communities (e.g. universities, TNO, companies).

Production facilities that contribute to the security of supply and resilience of the European semiconductor ecosystem can qualify for an Integrated Production Facilities – IPF[28] label. One of the conditions is that it must be a 'first of a kind' facility. With such a label, state aid may be received. We expect that IPL-HSI is eligible for this.

[26] Nationaal Groeifonds 2nd round
[27] Publiek-private samenwerking
[28] Semiconductor design and manufacturing facilities in the EU, including front-end or back-end, or both, contributing to security of supply for the internal market

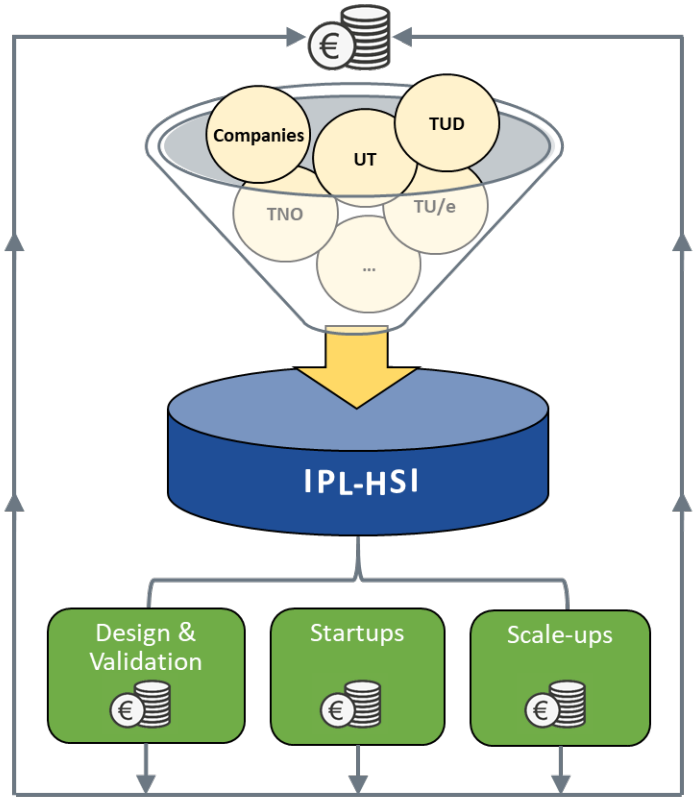


Figure 5: The role of IPL-HSI

Complementary focuses

IPL-HSI should be part of the new EU semiconductor pilot lines and may be subsumed and governed by ChipNL. The focus of IPL-HSI is complementary with IMEC, Fraunhofer, and LETI:

- IMEC is focusing on most advanced CMOS
- Fraunhofer is focusing on packaging and wafer technology
- LETI is focusing on optoelectronics

Contrary to that, ChipNL/ IPL-HLS will facilitate heterogeneous systems and 'More than Moore' development and create EU leadership for integration of heterogeneous systems and eventually SQP technology and business.

IPL-HSI requirements

We expect such a pilot line to cost in the order of 100 million Euros. If our suggestion for a pilot line is adopted, we advise ChipNL (to be established) to go deeper into the specifications required in close collaboration with all SQP stakeholders, based on a set of objectives.

5. Research Roadmap & Funding

The Netherlands has played a leading role in defining the EU strategic research agenda of micro/nano electronics, starting from 2004 with ENIAC, and later with the Dutch national innovation platform for micro/nano electronics and embedded systems (Point-One).

At NWO it appears very hard to obtain funding for semiconductors. The research agenda of NWO is built on societal challenges and key technologies. While societal challenges cannot be solved *without* semiconductors, research funding for semiconductors is rather small. In the Open Technology Program, semiconductors as such is not recognized as a societal goal, while semiconductor is the key enabler of nearly all societal needs**.**

To maintain and strengthen the Netherlands' future semiconductor leadership we strongly recommend defining a dedicated national semiconductor program (via GF3[29], Chips Act, NWO or other governmental resources) as part of the NL Chip Plan, in addition to the committed EU Chip Act JU funding, Eureka and IPCEI[30]. A program that is similar to the Quantum and Photonics programs is much needed because of the vital social and economic impact of semiconductors on the Netherlands today, tomorrow and the future, the intensified investment and strong competition from other leading semiconductor countries, and the cyclical nature of the semiconductor industry.

While the currently available plans of Holland High Tech cover some important elements of semiconductor R&D, they are fragmented and developed before the EU Chips Act. HTSM[31] has worked on relevant subject with a good start, especially focusing on funding programs. However, we need a holistic semiconductor research and innovation plan matching with NL long term ambition under EU Chip Act.

As part of the EU initiatives, it is necessary to combine the semiconductor-related topics from multi-top sector plans into one aligned and coherent research and innovation agenda and roadmap for semiconductors. We propose to develop a focused and unified NL Strategic Research and Innovation Agenda (SRIA) for semiconductors, reflecting medium and long-term national needs, led by ChipNL, in close coordination with the ECS[32]-SRIA which was developed by the European Electronics Components & Systems sector, and other international technology roadmaps. The idea of developing a national roadmap is supported by the HTSM Roadmap Semiconductor Equipment team. They agree that chip level and equipment should work more closely together.

It should be noted that a SRIA for semiconductors is already present in KDT[33] SRIA, which is further elaborated in SRIA Chips JU[34]. It will be very important that a Dutch national roadmap serves as input to SRIA Chip JU. We absolutely recommend to create maximum alignment with this SRIA Chip JU. However, with a fine-grained bottom-up created Dutch roadmap, an all-encompassing picture is created with which Dutch interests are better represented and better insight can be obtained into how the Netherlands contributes to the European strategy. This makes it easier to participate in the EU SRIA, and also to avoid the risk that we will miss opportunities with unique NL strengths. The national version can also be useful for other instruments, such as NWO.

[29] Nationaal Groeifonds 3d round
[30] Important Projects of Common European Interests
[31] High Tech Systemen en Materialen
[32] Electronic Components and Systems - Strategic Research and Innovation Agenda
[33] Key Digital Technologies
[34] Joint Undertaking

6. Business Creation Programs

The attention for human capital, an industrialization pilot line, research roadmaps and funding, and intensified collaboration between science and industry are of great importance for creating and maintaining Dutch competitive edges in the field of semiconductors. However, our ultimate aim is to create more semiconductor related business in the Netherlands. This can be done through more intensive collaboration between research institutions and companies, and by investing more in both startups and scale-ups. We suggest establishing a national incubation network for semiconductor related startups, to make all available infrastructure easily accessible to startups, and to attract more and specialized semiconductor investment funds from the markets to create a better ecosystem for promising semiconductor related startup and scale-ups.

We can also take steps to pursue a more competitive and attractive industrial policy and to improve the business climate in the Netherlands. For example, the rental costs for start-ups and other companies on semiconductor-related High Tech Campuses are high. This does not invite these companies to move or for foreign companies to settle on these campuses and become part of clusters that can give an impulse to the necessary collaboration for innovation. As stated earlier under Human Capital, the semiconductor industry can certainly benefit from faster, simpler and more flexible procedures to attract foreign talent for education, research and business.

7. Next Steps

With this short-cycle report, we have tried, on the one hand, to provide insight into where the pain points are and where the opportunities lie in the Dutch semiconductor industry. The standpoints are indicative, but on many points certainly not worked out in detail.

For example, a quantitative analysis will have to be carried out in order to work out the human capital roadmap and detailed implementation plan. Such an analysis makes it possible to make a forecast of the needs (number, level and profile) of research institutions and the business community. This should then lead to a recruitment and education plan that should ensure the growth.

Important steps also need to be taken to arrive at a substantive elaboration when compiling a national SRIA, setting up research and innovation platforms, and developing business creation programs.

We consider it sensible that an NL Chip Competence Center is created that can take on these tasks. After all, in the first half of 2023, the European Commission will provide further indications for the further elaboration and implementation of the EU Chips Act, using the requested input from all member states. It is therefore important to act now, so that the Netherlands can feed the European Commission and will soon be well prepared and able to act quickly when it comes down to it, further international agreements have to be made and the resources are distributed.

Acknowledgments

Jeroen Langevoort, Founder, Axign
Hugo Westerveld, Site Manager, Cyient Semiconductors/ Ansem
Frank Hoekerswever, Manager of operations, Teledyne DALSA
Erwin Veldman, Managing partner, ItoM
Clemens Mensink, Founder, Chain IC
Tim Tiek, CEO, Board member Bruco IC
Mark Gortemaker, Sales & development manager, Bruco IC
Stephan Blaakmeer, Principal, Analog IC Design Engineer, Mems IC
Maarten Kuper, Directeur QBay Logic
Anne Wil Lukas, Directeur, Kennispark
Guus Rijnders, Wetenschappelijk directeur MESA+, Universiteit Twente
Timo Meinders, Zakelijk directeur, MESA+, Universiteit Twente
Bart van ’t Ende, Advisor foreign direct investment and international business, Oost NL
Pieter de Witte, Director Research Programmes & IP, Quantum Delta NL
Kevin Williams, Chair of the Photonic Integration research group of TU/e
Rogier Verberk, Member of supervisory board of Quantum Delta, TNO Director of Semiconductor Equipment Industry
Lieven Vandersypen, Director of research of QuTech
Ewit Roos, CEO, PhotonDelta NL
Lucas van Vliet, Dean of EWI (Elektrotechniek, Wiskunde & Informatica), TUD
John Schmitz, former COO of Sematech, Senior VP of NXP, former Dean of EWI, TUD
David Michalak, Senior Research Scientist, TNO
Jeroen van den Brand, General manager, CITC
Willem Endhoven, Managing director of High Tech NL
Tom van der Dussen, Cluster Manager Holland Semiconductors, High Tech NL
Ben van der Zon, Chair, Silicon Europe Alliance
Ivan Stojanovic, Project manager, Oost NL
Maarten Dirkzwager, Executive vice president, NXP
Arianne Bijma, Global manager talent programs and university relations, ASML
Arco Krijgsman, Project Manager Public Private Partnerships, ASML
Frans List, Senior Project Manager Strategic Technology, ASML
Charles Smit, Senior Vice President, Nexperia
Frank Boschman, CEO, Boschman BV
Willem van Driel, Fellow, Signify