INNOVATION FINANCE ADVISORY STUDIES

Financing the digital transformation

Unlocking the value of photonics and microelectronics

European Commission

European Investment Bank
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60 years

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Unlocking the value of photonics and microelectronics

Prepared for:
DG Research and Innovation
and DG Connect
European Commission

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European Investment Bank Advisory Services

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Consultancy support: Deloitte Luxembourg

Foreword

You might not know what photonics and microelectronics (or semiconductors) are or how they work, but you surely are employing elements of these branches of science already in your daily life. Further, it is sure to be among the deep tech fields that will drive new developments in a wide range of digital areas. It is no exaggeration to say that photonics, which uses the science of light to create key technologies, and the semiconductors that function as the "brains" of electronic devices are vital to the economic future of Europe.

These high-technology fields are key "enablers" for consumer goods, the automotive and defence sectors, and renewable energy, among other industries. These **building blocks of the next digital revolution** are based on **"deep technologies"** that are differentiated from ICT-based innovation because they are founded upon engineering innovation and/or scientific advances (which makes them inherently more risky).

The first digital revolution, built around platforms and apps, fuelled the innovation and growth of the last decade. However, the innovation potential of these technologies is nowadays incremental, rather than disruptive. Investors and companies looking for the next big thing now focus more on enabling technologies based on **deep tech**. This second digital revolution will drive economic growth for years to come by improving current products and services, creating new markets, and solving major societal and environmental issues.

Deep tech applications such as artificial intelligence, big data, additive manufacturing, robotics, the Internet of Things (IoT), and autonomous driving will require faster, more reliable, more energy efficient and more powerful photonics and semiconductor components. **The success of Europe in this next wave of innovation will ultimately depend on photonics and semiconductor components.** Europe is well-positioned to reap the benefits of this digital revolution in terms of technologies, expertise, skills and knowledge. Nevertheless, photonics and semiconductor sectors are characterised by high complexity. Photonics and semiconductor companies have difficulty financing through the "Valley of Death" from demonstration-scale to commercialisation. **There is a clear need for an EU intervention to improve funding available for European photonics and semiconductor companies.**

I am delighted that the European Investment Bank and the European Commission joined forces to commission this study, conducted by our Innovation Finance Advisory service. The study provides concrete actions for the EIB, together with the Commission. These actions are directed to increase supply of financing to the photonics and semiconductor sectors. They also improve sector visibility, coordination between public funding programmes and follow-on financial instruments and advisory services to improve the investment readiness of projects.

It is with great pleasure that I welcome this study and the actions resulting from its recommendations. They will be valuable additions to the EU's toolkit as it aims to support innovation and sustainable economic growth in Europe.

Alexander Stubb
Vice-President, European Investment Bank

Preface

The photonics and microelectronics sectors are high-technology fields with a diverse range of applications across multiple economic sectors and end-markets. From everyday objects such as mobile phones to strategic sectors such as aerospace and defence, both present 'enabling' features used in other industries and are seen as important sources of innovation and positive economic leverage.

These sectors offer a tremendous opportunity for Europe, as they will shape the way we work and live for years to come. They will contribute to addressing important societal issues. Their pervasive character will make photonics and microelectronics to play a strategic role as Key Enabling Technologies (KETs) for the digital revolution.

Europe has strong technology leadership, high quality scientific research and a growing number of innovative SMEs and start-ups. However, this study shows that companies and project promoters at the forefront of technological innovation often have limited access to finance. Aiming to maximise return on capital, investors tend to direct funds to those opportunities offering the highest return compared to risk ratio, ideally with the possibility of a fast exit. In this equation, photonics and semiconductor ventures often do not compare favourably, because of the substantial risk involved, long development lead-time and significant capital investments.

Given their high degree of complexity, investing in photonics and microelectronics ventures requires significant technological expertise. Actions are required at EU level for Europe to remain competitive and to support these strategic sectors in order to be at the forefront of the digital transformation.

This study provides an insightful view of the key issues and challenges for these sectors. It lays out a comprehensive and concrete set of recommendations on how to improve access to finance and mobilising capital to exploit the full potential of the important technological knowledge available in Europe. The study gives concrete ideas that would make funding more accessible for companies in early stages and improve availability of capital in the critical scale-up phase. The recommendations underline the importance of enhancing coordination between EU and local initiatives and promote the development of an enhanced and joined-up ecosystem for KETs innovation.

I would like to commend the work done by the Innovation Finance Advisory services of the European Investment Bank. The 'Access to Finance' study addresses a necessary element of industry's digital transformation. The European Commission will look into the set of recommendations and work closely with the EIB on their implementation.

Mariya Gabriel
Commissioner for Digital Economy and Society

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Executive summary

This report details findings on access-to-finance conditions in the photonics and micro-electronics /components (or semiconductor) sectors and recommendations on ways to improve them. The photonics and semiconductor sectors are essential Key Enabling Technologies (KETs) and represent important building blocks of the next digital revolution, which will be based on deep technologies. Deep Tech can be differentiated from ICT-based innovation, because it is based on engineering innovation and/or scientific advances (and is, therefore, inherently more risky, is capital-intensive and requires much longer time periods for R&D). Typically, KETs encompasses a group of six technologies, including micro-/nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies, which can also be termed Deep Tech.

Key Concepts

The photonics and semiconductor sectors are **high-technology fields with a diverse range of applications across multiple economic sectors and end markets (from everyday objects such as mobile phones to strategic sectors such as aerospace and defence)**. Both present "enabling" features used in other industries and are seen as important sources of innovation and positive economic leverage.

- **Photonics** is a family of technologies based on the science of light, including fibre optics, light-emitting diodes, optical sensors, lasers, photonics chips and integrated circuits. Photonics products have a vast array of applications and are at the core of key technologies in our daily lives, from displays and camera sensors on mobile phones, to medical and diagnostic equipment.
- **Micro-electronics/components (or semiconductors)** are essential for all goods and services which need intelligent control in sectors as diverse as automotive and transportation, aeronautics and space. Semiconductors are the "brains" of all modern electronics. They pervade our daily lives as key components of consumer electronics such as mobile phones or the aerospace systems, defence and surveillance essential for national security.

The findings outlined in this study are based on feedback collected through more than 50 interviews with market participants, including entrepreneurs and companies active in the sectors, financing intermediaries (VCs, venture debt players, banks) and other sector promoters (clusters, associations, research technology organisations, government agencies).

This study was commissioned as a **follow-up to the European Investment Bank InnovFin Advisory study of Access-to-Finance Conditions for Key Enabling Technologies companies** (the "KETs I study" available at: *http://www.eib.org/attachments/pj/access_to_finance_study_for_kets_en.pdf*) in 2015. The present study carries out a mapping of the key access-to-finance conditions for companies working in the photonics and micro-electronics/components sectors in Europe. Furthermore, the report explores to what extent the conclusions drawn and recommendations made for KETs companies in general also apply to photonics and semiconductor companies and identifies the need for more targeted measures.

This study also has a clear link with the EIB InnovFin Advisory study on "Financing the Deep Tech Revolution: How investors assess risks in Key Enabling Technologies (the "KETs II study": *http://www.eib.org/attachments/pj/study_on_financing_the_deep_tech_revolution_en.pdf*) published in March 2018. The purpose of the KETs II study was to identify bottlenecks in the due diligence process and technological assessment that KETs companies with revenues below €50 million encounter when seeking finance, and to explore potential solutions.

There **are clear common issues between the photonics and semiconductor sectors and KETs**. Photonics and semiconductor companies share very similar characteristics with other KETs (such as high technology risk, capital intensity, etc.) resulting in the same issues and difficulties when looking at access-to-finance conditions. But this study also shows that these companies have **specific characteristics and features unique to these sectors**. In particular, **photonics and semiconductor** companies:

- **tend to be concentrated in technology clusters** (where they can benefit from knowledge exchange and networking, access to equipment and infrastructure, etc.);
- find **partnerships with large corporates** crucial for business development and bringing products to the market;
- are being supported by **national funding agencies as key enablers** especially in the early stages.

Strategic importance of photonics and semiconductors

The digital revolution based on platforms and apps developed in the ICT sector have fuelled the innovations of the last decade. However, the potential of these digital technologies is nowadays increasingly linked to their broader adoption across multiple sectors of the economy, rather than only focused on disruptive innovation. Investors and companies looking for the next big thing now focus more on enabling technologies for the next digital wave of innovation based on **Deep Tech**.

In this context, semiconductors and photonics (similar to other KETs) are strategic sectors for the Deep Tech revolution. They have a huge potential to fuel innovation and economic growth, because they provide the building blocks for disruptive technologies such as artificial intelligence, big data, additive manufacturing, robotics, Internet of Things, autonomous driving, etc.

The key factors that make these sectors so strategically important include:

- High economic leverage: for example, the photonics industry is estimated to bring a positive "leverage" impact to 10% of the European economy, with leverage ratios that may go up to 50, between the photonics market size and the total market size impacted.
- Multi-disciplinary nature of these sectors: they enable process, goods and service innovation throughout the economy, and they cut across many technology areas with a trend towards convergence and integration.
- Significant growth in demand potential in the near future supported by new market needs calling for technology responses from the emergence of Internet of Things, the computerisation of cars or the growing need for power electronics (such as motor drives and power converters), and faster and more energy-efficient data transfer in communications technologies.
- Data protection, security and defence: photonics and semiconductors applications are at the heart of aerospace systems, defence and surveillance systems. Europe cannot depend on other countries for technologies at the core of such key strategic sectors. This could make Europe vulnerable and put the continent's security at risk.

The race to establish new standards and new security models will be key for Europe to establish itself as a market leader in new technologies. Such standards and models depend upon and are linked to technologies developed by semiconductor and photonics companies.

Structure of photonics and semiconductors industries

In this context of growth and innovation, **the structure of the photonics and semiconductor industries is important,** because it impacts the financing dynamics at play in the two sectors.

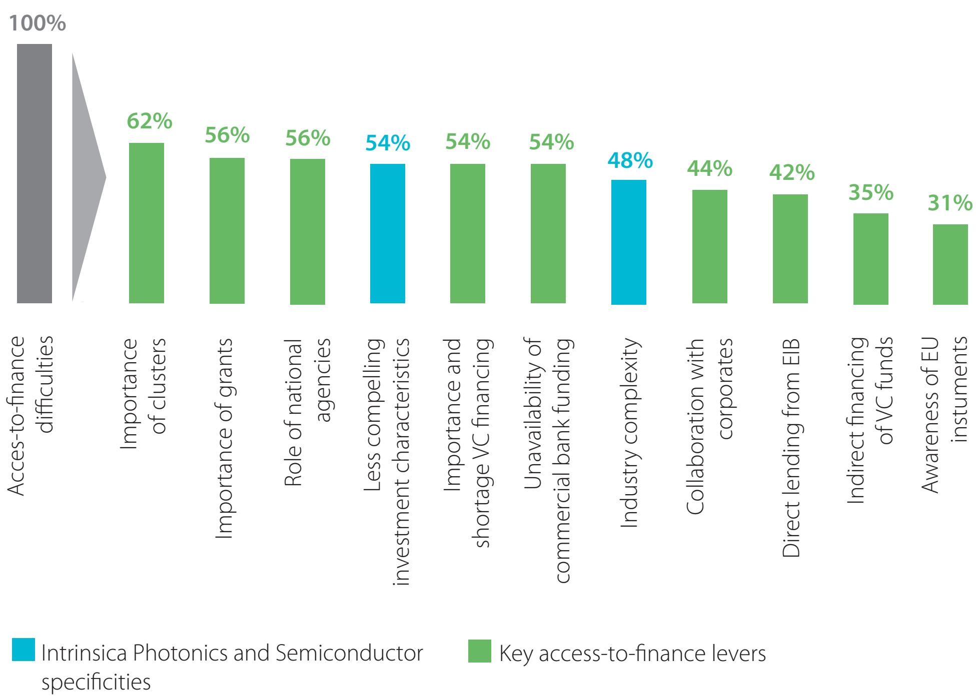
Commercial applications in photonics and semiconductors (such as microchips for supercomputers or lasers for medical equipment) tend to be controlled/managed by large established corporates in Europe and globally. These large corporates typically have a broad presence in their respective value chains. They manage and commercialise integrated customer propositions comprising multiple technologies assembled into a functional whole. For example, companies such as Philips manufacture integrated imaging and sensing devices for the medical industry, and companies like Ericsson provide end-to-end communications infrastructure solutions to telecom providers worldwide.

At the other end of the spectrum, small and medium-sized innovative companies in the photonics and semiconductor space typically focus on a niche where their technology can deliver value. In other industries young companies may be able to achieve fully fledged commercial success and to grow on their own. Companies in the photonics and semiconductor sectors tend to have to collaborate with or to become integrated into larger established players to effectively fit their niche technology into broader integrated propositions.

1.1 Key findings

To understand access-to-finance difficulties, we have explored through interviews and analysis a range of financing issues relevant to the photonics and semiconductor sectors. In this report, we distinguish (i) **intrinsic sector specificities** making financing more difficult in the sectors in scope compared to other sectors, from (ii) **issues and opportunities related to financing levers** of the access-to-finance landscape. These topics are shown in the table below in decreasing order of their mentions in the interviews conducted, and are discussed in the following pages and in the body of this report.

Percentage of interviews conducted making reference to key financing issues



Finding 1: Grants are an essential funding lever for photonics and semiconductor companies

We find **that public grants are a critical lever** in the photonics and semiconductor sectors, and often **one of the first (and for some time maybe the only) funding resources** for young companies. As such, grants promoted under Horizon 2020, ECSEL or national agencies are generally seen as extremely useful and important tools. We also note that virtually all companies interviewed have at one point in their life cycle made use of grants. From a private investor standpoint, grants also reinforce a venture's credibility and lower its risk profile.

Of particular importance, we note the role of the **ECSEL Joint Undertaking** programme. It stands out for its ability to **direct funding to large cross-border projects in the field of semiconductors**, which is seen as an important driver of research funding in the area of semiconductors, as well as a vehicle to encourage collaboration between research start-ups or labs and established corporates.

Beyond ECSEL and European grant programmes in general, we note that attention should be paid to **follow-on financing needs of companies** benefiting from these grant programmes. At the later technology readiness levels, when growth and commercialisation funding needs tend to gain in scale, grants must be complemented with much more significant sources of capital. We will come back to the pertinence of coordinating and handing over later-stage financing opportunities from grant providers to other public or private providers of capital.

Synergies with previous reports:

KETs I study findings:	▲▲	KETs II study findings:	▲

Note: ▲ = Low ▲▲ = Medium ▲▲▲ = High

Finding 2: National funding agencies are important financing and support providers for innovative companies, but they lack dedicated support programmes for photonics and semiconductors

Over half of the companies interviewed in this study received support from their respective national funding agencies. Support generally took the form of grants or some form of direct financing. Respondents shared generally very positive feedback concerning their interactions with national agencies, praising the ease of **access to and proximity** of these agencies, as well as the agility of their decision processes and **ability to respond to company needs in relatively short periods**.

In spite of this very positive feedback, **few programmes are in place at national agency level to promote the specific development of the photonics and semiconductor sectors**. Our review shows that while transversal programmes exist that apply also to photonics and semiconductors, they rarely have a dedicated focus on the photonics and semiconductor sectors. Notable exceptions would nevertheless include the State of Saxony's KETs Pilot Line programme, which targets the photonics and semiconductor sectors (among others), as well as Sweden's VINNVÄXT. Dedicated support is important because there are a number of factors intrinsic to these sectors that exacerbate the scarcity of financing for photonics and semiconductor companies. These factors include: the inherent complexity of the technologies at hand, requiring significant technological knowledge and experience to be evaluated from an investor standpoint, and investment characteristics that include high uncertainty and risk, long development lead times and high capital intensity.

Coordination between agencies across different countries can be an important success factor because photonics and semiconductor ventures need to be connected with international technology and commercial partners. Ensuring sufficient focus on these sectors at national agency level and promoting cross-border coordination through initiatives such as ECSEL is, therefore, very relevant.

Synergies with previous reports:

KETs I study findings:	▲	KETs II study findings:	▲▲

Finding 3: Technology clusters are key supporting players for the photonics and semiconductor sectors

Several industry clusters are active in key regions to promote the photonics and semiconductor sectors. These include Silicon Saxony in Germany, which supports semiconductors and photonics, and Minalogic in France near Grenoble, which supports a range of technologies including semiconductors and photonics. Other notable examples include PhotonDelta (NL/BE), DSP Valley (BE) and Distretto HTMB (Italy).

These clusters contribute in a significant way to the development of photonics and semiconductor companies: by facilitating knowledge exchange and networking, by providing access to equipment and infrastructure, and by providing guidance and connections to potential financing partners. Photonic and semiconductor companies identified in this study are located in relative proximity to the key European clusters, which is a sign of their importance to broader technology development. Such a finding is also confirmed in the KETs II study, which highlights the importance of joined-up cluster networks for the promotion of the wider KETs ecosystem.

Key photonics clusters are located in Germany, the UK and France. There are also smaller clusters in Ireland and Lithuania. Geographic proximity between photonics companies offers clear advantages in terms of knowledge exchange, networking, etc.

Key semiconductor clusters are concentrated in Germany, France, Netherlands, Belgium and Italy. Most of these clusters are built around large companies such as ST Microelectronics in Grenoble (France) or Globalfoundries, and Infineon in Saxony (Germany). Moving towards Central and Eastern Europe, there is a less concentrated presence and a smaller number of companies operating in these sectors. At the same time, several clusters are also emerging in Central and Eastern Europe, e.g. the Photonics cluster in Lithuania.

Synergies with previous reports:

KETs I study findings:	▲	KETs II study findings:	▲▲▲

Finding 4: Corporates are important business development partners and often end up acquiring successful ventures

Photonics and semiconductor value chains are strongly integrated and large established corporates often play significant roles across these value chains, for example by integrating multiple technologies in an overall product proposition, and by organising the commercialisation of these solutions on a large scale. For young companies, **support often comes from these established corporates, rather than financial players. Corporates may provide both financial support and strategic business development assistance**, for example through access to certain equipment or intentional programming, collaboration throughout the technology development process or joint commercialisation.

These **collaborations are essential for companies, especially given the lack of financing available and the generally lower technology savviness among private funding players** (limiting the ability of financial players to bring value and advice to invested companies). However, as successful ventures grow, an **exit to a corporate partner (both EU- and overseas-owned) often imposes itself as a faster path to value.** For the founders, this offers the certainty of monetization and continuation of the project in a corporate context, at the expense of potentially more successful stand-alone development.

Synergies with previous reports:

KETs I study findings:	▲	KETs II study findings:	▲▲▲

Finding 5: Insufficient financing available for companies in the photonics and semiconductor sectors. Financing difficulties are most pronounced at early-stage and growth-stage

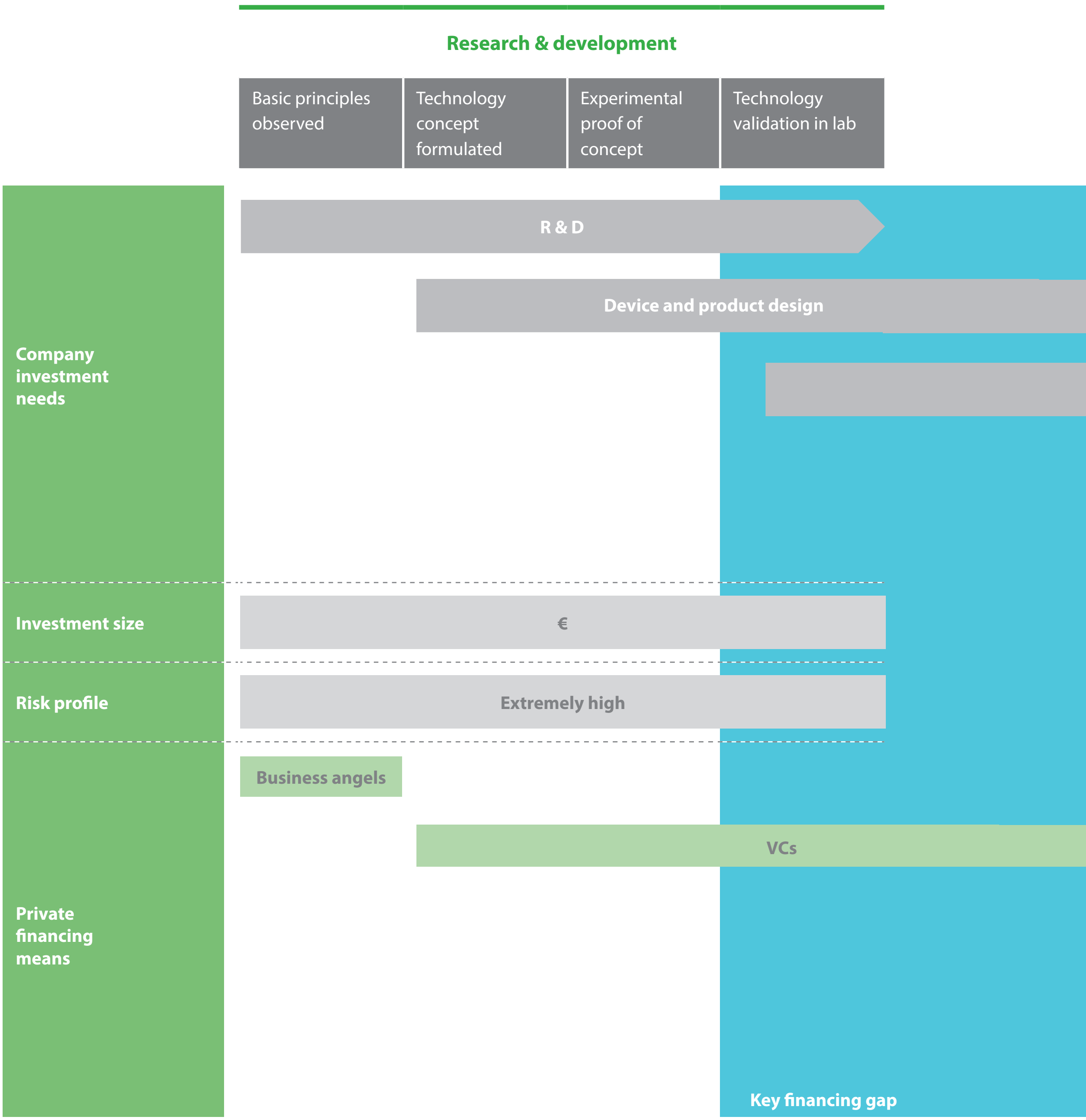
Virtually all of the more than 50 respondents agree that **access-to-finance conditions in photonics and semiconductors are challenging**. We find that companies in both sectors face these difficulties, which we see as the result of both supply-side risk aversion and lack of technology savviness, as well as less favourable investment characteristics of the two sectors. This situation holds true for the KETs sector in general confirmed by the findings of the KETs I and II studies.

These difficulties equate to a funding gap in photonics and semiconductors, and are **most concentrated around two stages of company development:**

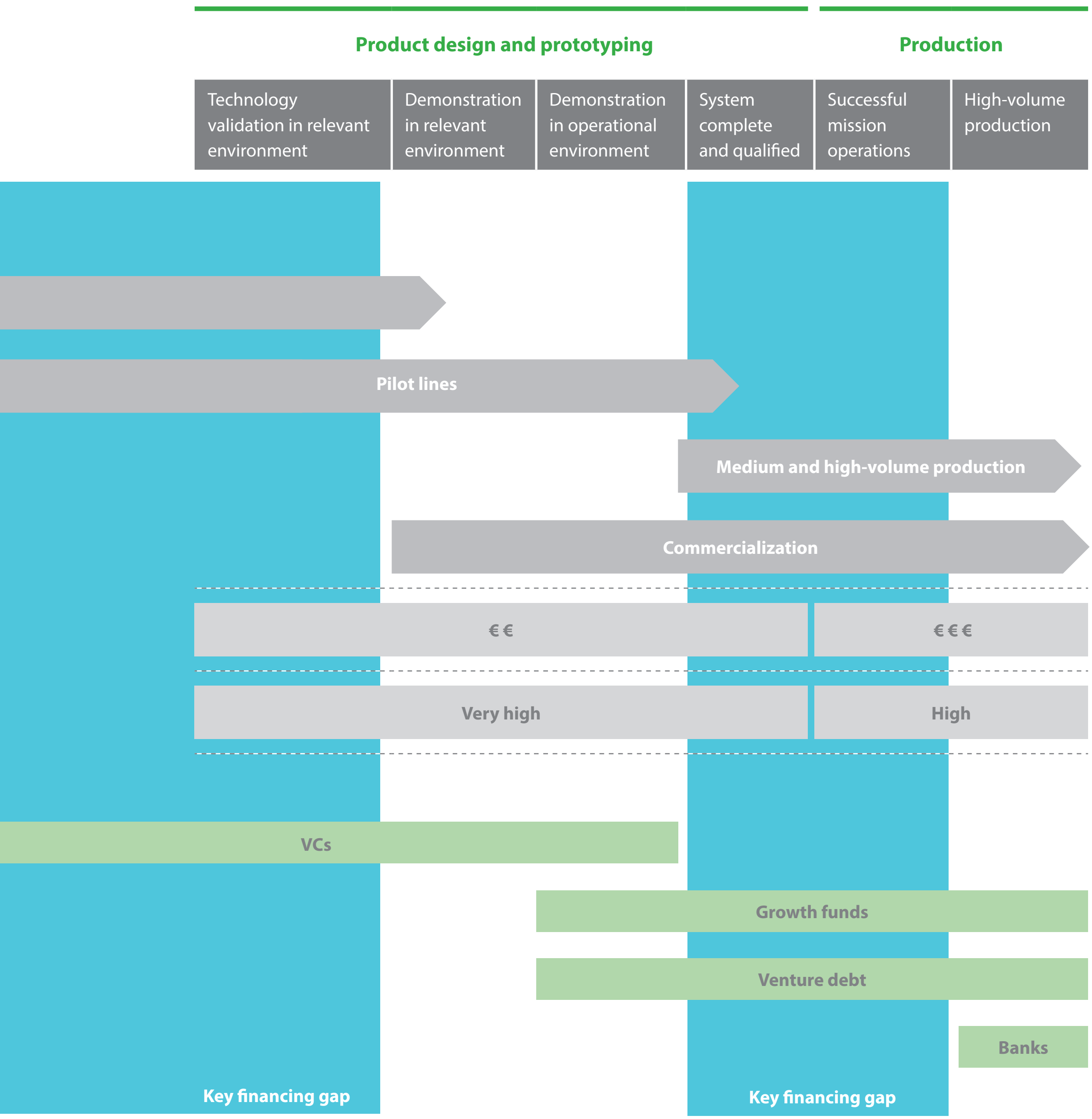
- **At early-stage** after the initial seed phase: this is when **risk is high and investment requirements begin to rise** (typically by around €1-5 million). At this stage, companies are essentially seeking to graduate from grant financing to private financing to support the product design phase.

- **At the growth stage of company development:** this is when industrialisation of technology and commercialisation require much larger investments (potentially above €10 million), while risks tend to remain elevated. At this stage, companies are essentially trying to launch medium- to large-

Photonics and semiconductors funding gap vs. technology readiness level



scale production of a product that has been proven viable based on earlier investments. Given short technology cycles and constant innovation in the sector, a viable product only remains so for a limited period of time, which tends to exacerbate the need to find commercial applications at this stage.



Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲▲

Finding 6: Technological complexity and less compelling investment characteristics are key issues limiting access to finance for photonics and semiconductor companies

We find that **two intrinsic factors contribute to expanding the funding gap** and to making access to finance difficult for photonics and semiconductor companies. These specific factors relate to:

- The **complexity of photonics and semiconductor technologies**, which requires a high degree of technological expertise for the evaluation of investment opportunities and results in those opportunities being considered by a less extensive range of financing players compared to more traditional ventures. For example, a semiconductor company may have to conduct years of tests before a new microchip can be installed in an electronic device.
- The **lower attractiveness of photonics and semiconductor investment characteristics**, as the sectors tend to combine **high technology and market risk** with **long development lead time** and **high capital requirements**. This often results in a less compelling proposition compared to more predictable and scalable VC alternatives. For example, a new photonic product is much more difficult to scale than products associated with internet and mobile technologies.

Key specific photonics and semiconductor financing issues

	Description	Key sub-issues
Higher complexity, lower visibility **48%**	• Photonics and Semiconductor business models tend to be **complex and not fully understood**; the Photonics sector is also broadly perceived to **lack visibility** given its often enabling nature for end-market applications	**Technological complexity** – requiring deep expertise to be properly understood and factored into a business plan or investment model. **Lower visibility** – enabling technologies integrated in variety of end-market applications but lacking own identity (mainly applicable to Photonics).

	Description	Key sub-issues
Lower attractiveness of investment characteristics **54%**	• Photonics and Semiconductor tend to present **less compelling investment characteristics** vs. other industries • While not necessarily disqualifying factors for high quality ventures, these elements tend to make the **Photonics and Semiconductor return vs. risk equation less attractive to investors** vs. other investment alternatives e.g., in software or e-commerce	**High technology risk** – high uncertainty on the applicability of the technology to address a given objective/market need. **High market risk** – uncertainty on the ability to monetize the given technology due to the risk of substitutes, the threat of faster competitors bringing a workable solution to market. **Long development lead times** – multi-year R&D lead-times to bring a technology from lab concept to working prototype, taking into account ongoing technological evolutions. **Capital intensiveness** – significant investments required to fund prototyping efforts at early-to-mid development stages, and later medium-to-high volume production capabilities.

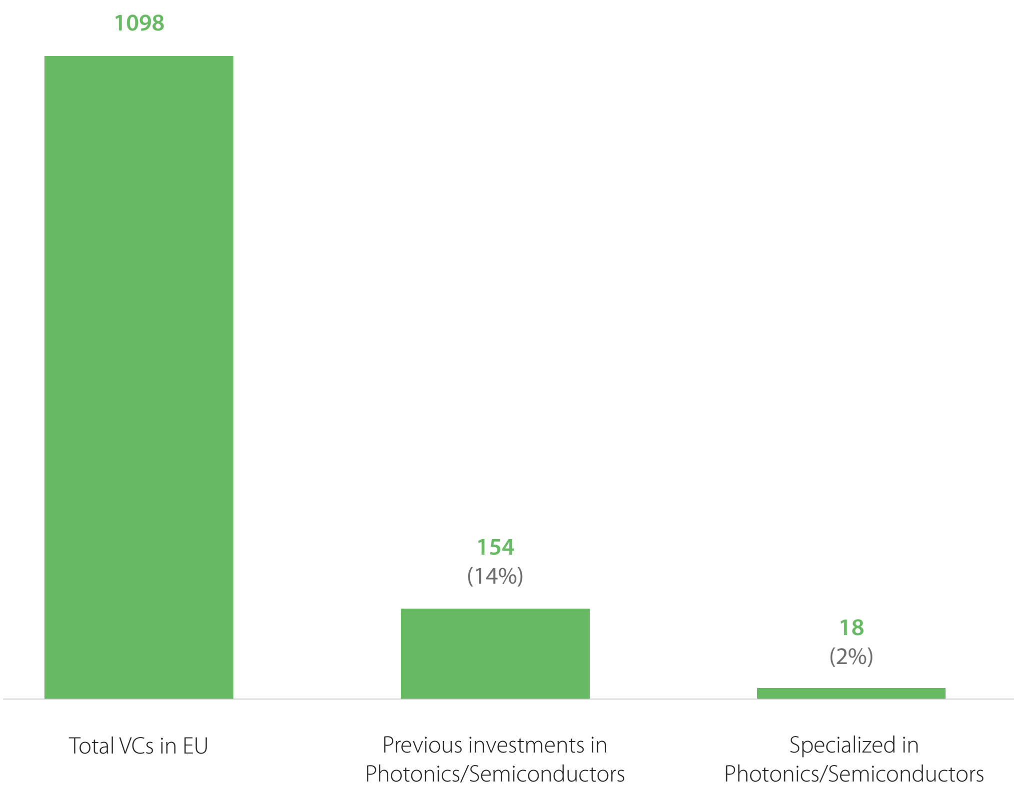
Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲▲

Finding 7: There is limited VC funding with sufficient focus and technology expertise to target the photonics and semiconductor sectors

The first reason for this shortage is that the **VC sector in Europe exhibits a limited appetite to invest in the photonics and semiconductor sectors**. In a context of maximising return on capital, European fund operators tend to direct funds to those opportunities offering the highest return compared to risk ratio, ideally with the possibility of a fast exit. In this equation, photonics and semiconductor ventures often do not compare favourably, because of their tendency to present high uncertainty and to require long development lead time and significant capital investments. In the words of certain fund managers, photonics and semiconductor businesses also tend to provide for less scalable returns. This perspective is reinforced by past investment experience of certain specialised funds, and the limited number of investment success stories in the two sectors.

Given the degree of complexity inherent to the sectors, **investing in photonics and semiconductor ventures requires significant technological expertise.** However, **few investment funds are specialised in high-technology opportunities**, let alone photonics and semiconductors. Funds in general tend to have limited appetite and ability to evaluate investment opportunities in these sectors. Through our review of VC providers in Europe, we found only 150 funds (~14% of the total number of funds in the EU) that have had past or present activities in the photonics and semiconductor space. Of these, only 18 (~2%) can be described as having primary investment focus on these sectors (which we defined as "specialised").



Number of photonics and semiconductor specialised VC funds in the EU

Source: Project team analysis

Financing **difficulties are high at early-stage**, when companies first seek professional financing to fit their initial technology to market and design a working product. But obtaining **follow-on "growth" financing is even more challenging** for those companies that do manage to secure initial financing and go on to validate the market potential of their technological solutions. Investment needs tend to increase significantly to finance advanced prototypes and actual production batches, even more so when considering the financing of medium to high-volume production capabilities. On the supply side, the few tech-specialised venture capitalists that may have invested in early-stage photonics and semiconductor companies **struggle to find financing partners for the ventures they support at later stages of development**, because risks remain high in relation to the size of investments required and the prospective returns.

Synergies with previous reports:

KETs I study findings:	▲▲	KETs II study findings:	▲▲▲

Finding 8: Commercial bank funding is generally not available to photonics and semiconductor companies

Similarly to other KETs companies, photonics and semiconductor companies exhibit characteristics which commercial banks tend to shy away from. In addition to **presenting high risk profiles and high probabilities of defaulting** in the early stages of development, these companies tend to have **little or no tangible assets** to pledge against any loan. This by itself makes such companies very difficult to pass a traditional bank's credit risk assessment process.

Even more than private venture capital investors, **banks tend to be risk averse and to avoid exposure to sectors showing high absolute risk**, even when business potential is high. In fact in our sample, we find that only the most mature and successful companies have developed bank lending relationships. This finding is confirmed by the KETs II study, which also looked at more innovative bank business models aimed at high-growth, Deep Tech companies. Those models include, for example, the use of trained experts to assess the risk of the underlying investment. However, the overall finding is that few commercial banks to date in Europe have invested in such expert teams, as the fundamental uncertainty underlying many early-stage KETs projects cannot be sufficiently reduced, even with better information about the technology, to make core features of the loan such as loss given default and probability of default fit into the standard bank business case.

We also find that existing bank lending promotion mechanisms such as the **SME guarantee are perceived by market participants as useful but not sufficient to overcome risk aversion and the high probability of default** presented by photonics and semiconductor investment opportunities.

Nevertheless, we note a few rare **exceptions of lending or venture debt players active in the technology market.** Players such as Barclays, Silicon Valley Bank or Kreos (venture debt fund) have developed dedicated lending practices aimed at high-risk, high-tech sectors. Some of their key success factors include familiarity with technology, strong relationships with leading equity providers and a track record in assessing the risks of technology-related ventures.

Synergies with previous reports:

KETs I study findings:	▲▲▲	**KETs II study findings:**	▲▲▲

Finding 9: There are opportunities to improve awareness of EU financing tools and their roll-out to the photonics and semiconductors sectors

We note a **lack of awareness and perceived complexity of public (funding) programmes** and instruments. The majority of start-ups referred to the need for more clarity and easier application processes. Some companies went as far as spending significant amounts of time and energy preparing complex applications, only to realise they were not eligible for the programme considered. This feedback also underlines the **potential for more consolidated financing guidance from public entitie**s, at national or European level, on the instruments on offer, the eligibility criteria and the practical aspects required for application to these programmes.

In terms of **direct lending**, we find that **activity aimed toward the photonics and semiconductor sectors is relatively limited**. We found no respondents that had received direct loans from the EIB, but we note that some companies received loans via their national agency backed by the EIB. The case of Heliatek also stands out (a German photovoltaic and solar film manufacturer that secured €20 million in loans from the EIB under the InnovFin programme alongside other private investors and subsidies). In spite of this, we observe a real need among companies for such direct lending instruments. Multiple financing players and entrepreneurs indicate a **need for non-dilutive instruments to complement private equity financing. Having to go through multiple rounds of equity financin**g, founders typically find themselves diluted to a significant extent. It is common for photonics and semiconductors founders to be diluted down to 1% or less of the company they founded. Instruments aimed at supporting business development that protect the interests of the founders are critical.

In terms of **indirect financing (i.e. intermediated via financial market players such as VCs and banks)**, we find that **existing programmes are perceived positively. They are seen as much needed** to encourage risk financing in general, but unfortunately they **do not appear sufficient to fully meet the specific photonics and semiconductor market needs**. Respondents highlighted that indirect financing is a good way to enhance VC investment capacity, while allowing private risk capital specialists to handle the investment process, with the intention of allocating capital efficiently to companies presenting sufficiently attractive propositions. However, the lack of Deep Tech knowledge among private funds, and the riskier/longer time horizon/capital intensive profile of photonics and semiconductor companies tend to limit their access to private funding.

Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲▲

1.2 Recommendations

The case for more dedicated measures

The key findings of this study confirm the conclusions of the previous KETs I and II studies and show that semiconductors and photonics share common characteristics and features with other KETs companies despite inevitable specific peculiarities for these sectors. Given the clear similarities, we believe it is important to **take a systemic approach in addressing access-to-finance issues** so as to embrace **the entire spectrum of KETs companies, rather than just photonics and semiconductor companies**. Such an approach should benefit from a more efficient deployment of resources, avoiding excessive fragmentation.

Therefore, our overarching recommendation is to consider **more dedicated measures focused on KETs companies, which would also include the photonics and semiconductor sectors. More sector-specific measures should be considered because KETs are facing financing difficulties**, due to their **technological complexity and specific investment characteristics (high risk, long development lead time and capital intensity)**.

More specific measures could also help **overcome the lack of focus and lack of technological expertise in the investment community**. By providing clearer public funding focus on these specific sectors, private players may be encouraged to dedicate more attention and to enhance their technical assessment capabilities to evaluate potential photonics and semiconductor investments.

The rationale for such measures finds its root in the strategic and crucial role that KETs companies have in the next wave of digital innovation based on **Deep Tech**. Europe is well-positioned to reap the benefits of this digital revolution in terms of technologies, expertise, skills and knowledge. However, improving access to finance conditions for European KETs companies is an important step for Europe to be at the forefront of the next wave of innovation based on Deep Tech, which will drive economic growth by improving current products and services, creating new markets, and solving major societal and environmental issues.

Proposals for improved access-to-finance conditions in photonics and semiconductors

We propose **five recommendations to improve access-to-finance conditions in the photonics and semiconductor sectors:**

01. **Strengthen existing indirect funding mechanism**s for private financing, to encourage private investment firms to allocate more attention and funds to Deep Tech companies, including in the photonics and semiconductor sectors.
02. **Adapt existing financial instruments and programmes** to better fit the risk-return profile of KETs companies via **dedicated resources** to support these companies.
03. Develop blended financial instruments (combining public and private funding) including **conditional grant, contingent grant and co-investment programmes** to better support Deep Tech/KETs companies, encouraging businesses to build on the momentum around grant issues and secure additional third party financing.
04. Promote further **coordination with national programmes**, to encourage more specific roll-out of funds to Deep Tech/KETs companies involving collaboration between national funding agencies and European entities.
05. Launch an **initiative to improve the visibility of photonics and semiconductors**, to raise awareness and maximise exposure of investment opportunities with potential investors. In addition to general market visibility efforts, this initiative could also entail better coordination between the EIB and ECSEL to ensure ECSEL-funded projects are adequately considered for follow-on support by the EIB, other public agencies and the private sector.

Recommendation 1: Strengthen existing indirect funding via VCs and banks to encourage more private financing for Deep Tech companies

While indirect financing mechanisms offered by the EIB Group and other promotional banks are seen as effective, these instruments are unfortunately insufficient to meet the specific difficulties encountered in KETs companies, in general, and photonics and semiconductor companies, in particular.

Indirect financing mechanisms could be adjusted, to **steer specific private venture capital activity to KETs companies including in the photonics and semiconductor segments**, and **overcome the obstacles** currently faced by private investment firms, including the **risk-return imbalance** of ventures in the sectors, and the **need for Deep Tech expertise** to effectively assess investment return potential.

The proposed adjustments could introduce a degree of **conditionality between public investment into private funds, and the allocation of these funds**. In other words, venture capital funds would need to deliver on specific funding goals related to the Deep Tech sectors in order to satisfy the mechanism's objectives. This conditionality could be linked to features that encourage investors to overcome the high risk of investing in Deep Tech. **Public investors could use asymmetric funds** offering **risk mitigation and/or return enhancement features for private limited partners** to encourage VC financing into these sectors.

Synergies with previous reports:

KETs I study findings:	▲▲	**KETs II study findings:**	▲▲▲

Recommendation 2: Adapt existing financial instruments and programmes to better fit the risk-return profile of KETs companies via dedicated resources to support these companies

Building on the findings of this study and the previous KETs I and II studies, this study identifies the need for **dedicated resources for Deep Tech companies**, which could potentially take the form of a **thematic investment platform** to overcome the specific financing difficulties encountered by these companies and to better fit the Deep Tech risk-return profile.

These dedicated resources **could boost existing venture debt or quasi-equity instruments,** as this would build on existing EIB experience with the European Growth Finance Facility (launched under EFSI) and would help achieve critical mass for the instrument in financing Deep Tech companies. From a market standpoint, the importance of non-dilutive financing to preserve the interests of founders is aligned with this proposed approach.

These dedicated resources for Deep Tech companies could further build on the experience from existing thematic instruments (i.e. InnovFin IDFF and EDP) and incorporate **risk-sharing features**. Given the characteristics of Deep Tech companies with high technological risk, high capital intensity and less attractive risk-return profile, these dedicated resources could require a structure capable of absorbing the potential higher losses with such investments. **The potential structure could include a first-loss piece from the central EU budget**, and **a second-loss piece from EFSI or European Structural and Investment Funds.**

Synergies with previous reports:

KETs I study findings:	▲▲▲	**KETs II study findings:**	▲▲

Recommendation 3: Develop blended financial instruments (combining public and private funding) including a conditional grant programme, a contingent grant programme, and a co-investment programme to better support KETs companies

Blended financial instruments leverage public funding with private financing in a combined financial product. Blended financial instruments typically have higher risk capacity than financial instruments offered by private and public financial institutions (such as EFSI), and bridge companies from the grant phase moving towards private financial products. This study recommends that the EC, national innovation agencies and national promotional banks consider **developing blended financial instruments dedicated to Deep Tech companies**. The development of a **conditional grant programme, a contingent grant programme or a co-investment programme (potentially**

structured with a central EU first-loss piece and EFSI or ESIF second-loss piece) could boost the funding available at the early stages and act as a strong signal to private VC investors. In conditional grants, the disbursement of a **grant (or part of it) is subject to the beneficiaries obtaining additional financing from third parties**. In contingent grants, **repayment of the grant is linked to the success of the underlying project**, while in co-investments, **a matching mechanism is in place, allowing a private investment in a company to be matched by a grant or equity investment with capped returns for the public investor**. The public component reduces the risk of the venture and helps it gain visibility and credibility for potential investors.

Synergies with previous reports:

KETs I study findings:	▲▲	KETs II study findings:	▲▲▲

Recommendation 4: Promote further coordination with national programmes to encourage more specific roll-out of funds to KETs companies

This recommendation proposes to **promote the expansion of financing programmes at national level and promote coordination with EC programmes**, with a specific focus on Deep Tech. The rationale for this proposition rests on the finding that national agencies bring specific advantages to companies (agility, flexibility) but (with some exceptions) generally lack focus to organise dedicated efforts in favour of the photonics and semiconductor sectors, in particular, and KETs in general.

To address this, **enhanced coordination could be introduced between EU and national agencies, as also reflected in the KETs II study promoting the development of enhanced and joined-up ecosystems of KETs innovation**. A joint plan could also be produced to leverage EU and national programmes' strengths with the specific purpose of bringing increased financing to the sectors in scope.

Under this line of action, it should be ensured that investment requests be detected at either national or EU level and that the formulation of **the most appropriate financing package be made considering the range of public funding instruments available** locally or at European level.

An a**dvisory platform would be an important complement** to the different agencies and ensure comprehensive support for investment requests.

The resulting benefits from this proposal would include potential financing execution for Deep Tech companies of higher magnitude, combining both national and EU resources, and ensuring commensurate impact on a company's visibility and credibility for other investors.

Synergies with previous reports:

KETs I study findings:	▲▲	KETs II study findings:	▲▲▲

Recommendation 5: Launch an EU initiative to improve the visibility of photonics and semiconductors, reduce information asymmetries, raise awareness and maximise exposure of investment opportunities with potential investors. Such an initiative should be launched in the context of a broader initiative for KETs.

This recommendation aims to **overcome the lack of general visibility of the photonics and semiconductor sectors, limited technological expertise among investors**, and the fact that the venture capital agenda tends to be occupied by more mainstream investment themes such as software or e-business.

First, an EU initiative on **general communication and visibility** should be considered, aimed at increasing awareness and understanding of the technologies among investment providers and changing the perception of investment challenges by presenting potential available solutions.

Second, **an EU technical support platform could be implemented**, offering technological expertise and knowledge to private investors so as to facilitate their investment activity. Such a technical support platform could potentially build on the expertise of knowledgeable partners such as Research and Technology Organisations.

Third, to bridge the lack of visibility in the sectors in scope, and information asymmetries, **more targeted advisory services to KETs companies including photonics and semiconductor companies** should be considered to help them pitch potential investors, whether public/EU or private. The EIB's advisory competences in this area could potentially be leveraged.

Fourth, the development of an information-sharing platform should be considered to provide easy access to information about funding programmes that support the KETs sector and individual companies. Efforts made in developing centralised KETs resources and market information (e.g. KETs Observatory) could be a good starting point to **improve the dissemination and availability of information on photonics and semiconductor companies.**

In addition to such general market visibility efforts, the EIB and ECSEL could improve coordination efforts in order to ensure that ECSEL-funded projects are adequately considered for follow-on support (advisory or lending) by the EIB, other public agencies and the private sector. For example, **ECSEL-funded projects and relevant contacts could be used for the origination of financing opportunities at the EIB.**

Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲▲

1.3 Conclusion

Companies in the photonics and semiconductor sectors along with other KETs companies are important drivers of innovation in Europe and contribute significant economic leverage. They represent important building blocks for the next wave of digital innovation based on Deep Tech, and they are key drivers if Europe is to remain at the forefront of innovation. However, these sectors respond to specific competitive and sectorial dynamics, which tend to make their financing a very challenging task.

Therefore, there is a clear need for EU intervention to improve access to finance for innovative companies active in these sectors through more targeted measures and more tailored financing mechanisms. While **Europe is well positioned in terms of technologies, expertise, skills and knowledge in these sectors, there is a need to better support Deep Tech companies in exploiting the full potential of the next wave of digital transformation**. This digital revolution will bring significant societal benefits and drive economic growth for years to come. Europe is at a crucial juncture and this opportunity cannot be missed.

Introduction

2.1 Context and objective of the project

The European Investment Bank and European Commission have commissioned this study on access-to-finance conditions in the photonics and micro-electronics/components sectors.

The objectives of this study are to:

- Collect information, map and review the access-to-finance conditions in the EU 28 countries for companies worki ng in micro-electronics/components and photonics sectors and;
- Identify problems and provide recommendations to further improve the access-to-finance conditions for the companies in the relevant sectors.

2.2 Background and prior KETs studies

This study is also a follow-up to the EIB InnovFin Advisory study of Access-to-Finance Conditions for Key Enabling Technologies Companies (the "KETs I study"). One of the objectives of the present work has been to explore to what extent conclusions drawn and recommendations made for KETs companies in general also apply to photonics and semiconductor companies.

The KETs study highlighted a number of findings, including:

- The banking sector does not cater to the specific needs of KET companies, and about 50% of companies find themselves severely struggling to obtain the finance needed to generate further growth and innovation.
- Europe's conservative financing ecosystem is not in favour of the most dynamic innovators. Most R&D-driven businesses find it hard to convince traditional banks to invest.
- Well-established instruments like public loan guarantees will continue to be cornerstones of KETs financing. However, such instruments alone are unlikely to make a significant difference to the European KETs sector.

- Promising innovative approaches for KETs financing include higher risk-taking debt instruments, specific equity-based programmes and the combination of financing instruments with advisory services. Furthermore, we consider the ability of financial instruments to attract private co-financing as a key element of successful public support to improve financing conditions for KETs companies.
- The EIB is already well-positioned in technology financing, with substantial funds available from EU programmes and financial instruments under the umbrellas of InnovFin and the European Fund for Strategic Investments. The existing programmes, however, do not fully meet the specific needs of many KETs companies.
- The significant amount of capital and flexibility provided by the currently available instruments should be exploited to better target the specific needs of KETs companies.
- Measures to significantly enhance the growth of the European KETs sector need to be simultaneously well-targeted and bold.

Based on these findings, a set of recommendations was devised as to how the EIB and EC can improve access-to-finance conditions for KETs companies. The recommendations were to:

- Implement measures to increase awareness among potential customers of the EIB and EC communication channels about the existing financial instruments and to continue being a stable KETs player in all phases of the market cycle.
- Expand the indirect equity approach. The EIB should increase its lending activities to public technology investors. Based on loans provided by the EIB, technology investors can effectively provide equity to KETs companies.
- Review existing internal lending processes and procedures to enhance responsiveness and maximise customer satisfaction.
- Set up targeted/specialised advisory services including the use of expert pools to assist in the assessment of new technologies and their market potential to help KETs companies prepare for financing. Such additional resources could bring "science to finance" and "finance to science".
- Leverage existing EFSI/InnovFin resources to develop targeted/bespoke financial mechanisms, including investment platforms that can provide:
- Equity and equity-type debt to companies on the verge of commercialisation of planned ambitious investments (venture debt to high-growth/young KETs).
- EIB to investigate the possibility of increasing the acceptance of intellectual property as collateral for debt financing.
- EC to review regulatory matters, potentially affecting KET investments and financing.
- EC to review content/user-friendliness of EIPP and to evaluate the launch of a platform on best fundraising practices.
- Promote the increase of resources for KET investment schemes/financial products at national levels.

Throughout this study, we attempt to provide insight into how each of these findings and recommendations apply to photonics and semiconductors.

In addition, this study also has a clear link with the EIB InnovFin Advisory study on "Financing the Deep Tech Revolution: How investors assess risks in Key Enabling Technologies (the "KETs II study" available at: *http://www.eib.org/attachments/pj/study_on_financing_the_deep_tech_revolution_en.pdf*) published in March 2018. The purpose of the KETs II study was to identify the bottlenecks in the due diligence process and technological assessment that KETs companies with revenues below €50 million encounter when seeking finance, and to explore potential solutions.

2.3 Scope of work

To achieve this objective, the scope of the work undertaken for this study includes:

For microelectronics/components (referred to in this report as semiconductors):

- A detailed review of a representative sample of companies in the sector selected across the semiconductor industry value chain.
- A review of investment dynamics in Europe and of expected returns.
- Conducting in-depth interviews with semiconductor companies.
- Conducting in-depth interviews with companies engaged in financing activities in Europe that have experience in investing in semiconductors.

For photonics:

- Providing a description/mapping of the main photonics activities taking place in Europe.
- A high-level review of the top 500 photonics companies.
- A detailed review of the top 100 photonics companies.
- Conducting high-level interviews with relevant photonics companies.
- Conducting in-depth interviews with relevant financial actors.

Methodology

3.1 Overall methodology for photonics sector review

The methodology employed is outlined in the chart below and consists of a combination of different activities:

- Desk research on industry trends and financing landscape.
- Structured approach to identify and filter photonics companies.
- Interviews with companies and financing players.
- Iterations with the EIB project team on the above.

In addition, the project team participated in a flagship photonics industry event (EPVF Dublin) and spoke with a large number of associations, clusters and experts who provided valuable input into the subject matter.

Approach Overview		
Scope of work	**1 Mapping of main photonics activities in Europe**	**2 High-level review of top 500 Photonics companies**
	Provide description / mapping of main photonics activities taking place in Europe - based on preliminary interviews with relevant experts and on access to resources (i.e. KETs Observatory, Photonics21, among others)	High-level review of top 500 Photonics companies • List of largest 500 photonics companies • Area of activity • Geographical distribution
Target Approach		100 photonics companies
	• Conduct desktop research to describe / map the main activities in Europe • Complement with content of interviews (Task 4) • Summarize the key findings to be presented in the Final Report	• Compile a list of 500 companies and validate with EIB • Conduct desktop research to carry out high-level review of 500 companies • Summarize the key findings to be presented in the Final Report

Approach Overview		
3 Detailed review of top 100 photonics companies	**4 Conduct interviews with key players**	**5 Conduct interviews with financial actors**
Detailed review of top 100 photonisc companies • List of largest 500 photonics companies • Area of activity • Geographical distribution • Revenues trend • Profitability level • Presence of debt	Conduct high-level interviews with companies • Investment dynamics and market perspectives / expected returns • Financing needs • Experience with raising debt / equity financing	• Conduct in-depth interviews with financial actors
100 photonics companies	At least 15 companies	At least 15 financing players
• Compile a list of 100 companies and validate with EIB • Conduct desktop research to carry out high-level review of 100 companies • Summarize the key findings to be presented in the Final Report	• Compile a list of companies to be interviewed and validate with EIB • Prepare questionnaire and validate with EIB • Conduct interviews / follow up • Summarize the key findings to be presented in the Final Report	• Compile a list of companies to be interviewed and validate with EIB • Prepare questionnaire and validate with EIB • Conduct interviews / follow up • Produce Final Report

Figure 1: Photonics sector review methodology
Source: Project team analysis

3.2 Overall methodology for semiconductor sector review

The methodology employed is outlined in the below chart and consists of a combination of different activities:

- Desk research on industry trends and financing landscape.
- Structured approach to identify and filter semiconductors companies.
- Interviews with companies and financing players.
- Iterations with the EIB project team on the above.

In addition, the project team participated in the ECSEL JU Symposium 2017 in Malta and spoke with a number of industry players and experts who provided valuable input into the subject matter.

Approach Overview

Scope of work	**1 Review of relevant companies across value chain**	**2/3 Conduct interviews with key players**	**4 Conduct interviews with relevant companies engaged in financing activities**
	Detailed review of a representative sample of companies - based on preliminary interviews with relevant experts and on access to resources (i.e. KETs Observatory among others) - in the sectors selected across the micro-electronics / components industry value chain • Semiconductor manufacturing – Fabless and Foundry • Chips packaging	Conduct in-depth interviews with companies to determine: • Investment dynamics and market perspectives in Europe / expected returns • Financing needs • Experience with raising debt / equity financing • Relevance of recommendations resulting from the EIB KETs study	Conduct in-depth interviews with companies engaged in financing activities in Europe with experience in investing in semiconductors
Target Approach		At least 15 companies	At least 10 financing players
	• Compile a list of companies to perform detailed review and validate with EIB • Conduct desktop research and interviews with experts for review of companies the sector • Summarize the key findings to be presented in the Final Report	• Validate the list of relevant companies with EIB • Prepare questionnaire and validate with EIB • Conduct interviews / follow up • Summarize the key findings to be presented in the Final Report	• Compile a list of companies to be interviewed and validate with EIB • Prepare questionnaire and validate with EIB • Conduct interviews / follow up • Summarize the key findings to be presented in the Final Report

Figure 2: Semiconductor sector review methodology
Source: Project team analysis

3.3 Methodology for identification of photonics companies

In order to identify the top 500 and then the top 100 photonics companies, we have defined a structured approach in collaboration and designed jointly with the EIB project team.

The list of companies identified is included in an appendix.

Key steps	Description	Entries	Tasks completed
Extraction	We extracted raw company information and names from recognized industry sources i.e., the members of EPIC and Photonics21.	**~3,000 entries**	• Conduct desk research • Extract data • Compile members list
Initial screening	From this list, we excluded any irrelevant actors including European institutions, non-European institutions / companies, universities, schools, institutes, government institutions, agencies, etc.	**~2,400 entries**	• Examine member status
In depth screening	We conducted, jointly with the EIB, a screening of Amadeus information available about these companies. Companies retained in this step were those with either: • Revenue information available or, • At least 1 patent (IP) or, any other criteria indicating high relevance (companies analysed on a case by case basis)	**792 matches**	• Conduct Amadeus screening • Apply a quantitative filter
Qualitative filtering	We carried out qualitative filtering and selected the most relevant companies in terms of their business description.	**450 matches**	• Carry out case by case analysis • Assess company relevance
Ranking	We ranked the top 450 companies into 4 tier groups based on their size in terms of revenue, staff, asset value or any other relevant financial information. Ranking criteria were chosen according to the EC SME definition.	**Tier 1: 95** **Tier 2: 74** **Tier 3: 117** **Tier 4: 164**	• Assess tier group criteria • Rank companies
Final filtering	To identify companies for the top 100 shortlist, we used the following criteria to narrow down our research: • Innovation / number of IPs • Previous experience with financing (debt, equity financing) • Actively seeking financing (participating in fundraising events) Based on this process, we identified 113 relevant companies of which we shortlisted 56.	**113 matches**	• Apply a final qualitative filter • Constitute a shortlist

Figure 3: Photonics companies identified
Source: Project team analysis

3.4 Methodology for identification of semiconductor companies

A similar approach has been employed to identify semiconductor companies.

Key steps	Description	Entries	Tasks completed
Extraction	We extracted raw company information and names from recognized industry sources i.e., the members of SEMI, DSP Valley, Silicon Saxony, Aeneas, Mi-Cluster, Distretto HTMB, Minalogic, etc.	**~1,255 entries**	• Conduct desk research • Extract data • Compile members list
Screening	From this list, we excluded any irrelevant actors including European institutions, non-European institutions / companies, universities, schools, institutes, government institutions, agencies, etc. and then conducted a screening of Amadeus information available. Companies retained in this step were those with either: • Revenue information available or, • At least 1 patent (IP) or, any other criteria indicating high relevance (companies analysed on a case by case basis)	**570 entries**	• Examine member status • Conduct Amadeus screening • Apply a quantitative filter
Qualitative filtering	We carried out a qualitative filtering and selected the most relevant companies in terms of their business description.	**450 matches**	• Carry out case by case analysis • Assess company relevance
Ranking	We ranked the companies into 4 tier groups based on their size in terms of revenue, staff, asset value or any other relevant financial information. Ranking criteria were chosen according to the EC SME definition.	**Tier 1: 38** **Tier 2: 57** **Tier 3: 52** **Tier 4: 60**	• Assess tier group criteria • Rank companies
Final filtering	To identify companies for the top 100 shortlist', we used the following criteria to narrow down our research: • Innovation / number of IPs • Previous experience with financing (debt, equity financing) • Actively seeking financing (participating in fundraising events) Based on this process, we identified 110 relevant companies of which we shortlisted 60.	**110 matches**	• Apply a final qualitative filter • Constitute a shortlist

Figure 4: Semiconductor companies identification methodology

Source: Project team analysis

3.5 Overview of interviews conducted

Overall we conducted over 50 interviews with relevant industry stakeholders, including:

- Photonics and semiconductor companies.
- Established corporates with interests and activities in photonics and semiconductors.
- Private venture capital firms.
- Commercial banks and venture debt funds.
- National agencies.
- Representatives of industry clusters.
- Industry experts and other players active in the sectors.

The table below gives a detailed breakdown of the interviews conducted, including the names of the stakeholders.

27 companies in the sectors in scope		24 financing intermediaries, experts and other relevant industry stakeholders		
Semiconductor players	**Photonics players**	**Venture capital firms**	**Large corporates**	**Clusters**
01. Mescap	01. Amplitude	01. Bullnet	01. Global Foundries	01. PhotonDelta
02. TTTech	02. Digitarena	02. Octopus Ventures	02. ST Microelectronics	02. Distretto HTMB
03. Hahn Schickard	03. Aledia	03. The Faktory	03. Lfoundry	
04. Anvo Systems Dresden	04. Fibercryst	04. Target Partners	04. NXP	
05. Greenwaves	05. Holoxica	05. Wellington Partners	05. Trumpf	
06. Anvil Semiconductors	06. Luxexcel	06. Kreos Capital	06. NXP Semiconductors	
07. Surecore	07. Pilot Photonics	07. Low Carbon Innovation Fund	07. Anonymous Corporate	
08. Novelda	08. Holografika	08. Seroba Life Sciences		
09. IDEAS	09. LUMEX			
10. Sicoya	10. Almakor			
11. Computek Solutions	11. Smart Photonics			
12. AlphaSIP	12. H + S Cube Optics			
	13. Lightmotif			
	14. GNA Biosolutions			
	15. Ithera Medical			

24 financing intermediaries, experts and other relevant industry stakeholders		
Banks	**National agencies**	**Experts and other relevant stakeholders**
01. European Investment Bank 02. Barclays	01. Bpifrance (Innovation) 02. Bpifrance (Grenoble regional office) 03. KfW 04. Finnish Funding Agency for Innovation 05. Netherlands Ministry of Economic Affairs 06. Enterprise Ireland 07. Japan Science and Technology Agency	01. EPIC 02. SEMI 03. GSA 04. ECSEL-JU 05. DG Research and innovation 06. Techtour 07. PNO Consultants 08. James Cogan 09. IMEC

Semiconductor players

Growth profile		Investment size		
Seed/Start-up	Scale up	< EUR 5m	EUR 5m to EUR 10m	> EUR 10m
70%	30%	30%	33%	37%

Company size				Investment size		
Micro	Small	Medium	Large	Equity	Debt	Grants
30%	48%	11%	11%	~95%	~20%	~80%

Photonics players

Growth profile		Investment size		
Seed/Start-up	Scale up	< EUR 5m	EUR 5m to EUR 10m	> EUR 10m
80%	20%	40%	20%	40%

Company size				Investment size		
Micro	Small	Medium	Large	Equity	Debt	Grants
30%	47%	7%	13%	~95%	~15%	~75%

Overview of sector and companies

4.1 Key sector specificities and trends in photonics and semiconductors

The following specificities and trends provide important context to understand the financing challenges discussed in the later chapters of this report.

Future growth potential in photonics and semiconductors

There is significant growth potential in both photonics and semiconductors. In photonics, technology maturity is still developing, and a number of end-market applications are expected to support demand growth; such applications include:

- Communications technology, with the need for faster, more energy-efficient data transfer.
- Medical technology, with the need for new sensing/measurement technologies to detect or treat certain pathologies.
- Photovoltaics, with the need for more efficient solar energy production technologies.
- In semiconductors, technology maturity is generally higher for mainstream applications; but a number of developments still require continued innovation; such developments include:
    - Internet of Things, with the need for new semiconductor solutions in a wide variety of devices and applications.
    - Automotive, with a growing need for semiconductors to enable smart applications and connectivity around cars.
    - Power electronics, with the need for new solutions to handle "Smart Grid" requirements, for example.

Underlying these potential applications, we note the constant and rapid technology evolution of the sectors.

Innovation dynamics between academia, early-stage ventures and established corporate players

At the more upstream stages, research and innovation opportunities often originate from the academic world, and can result, where potential value is perceived, in early-stage venture launches aimed at validating technology concepts and their potential market fit as well as prototype initial workable solutions. This part of the industry is largely fragmented across a number of small innovative companies.

Further down the line, the industry is much more integrated with the presence of large established corporates playing the role of "integrators" of multiple technologies into broader commercial applications. This is true in photonics, for example in optical communications innovations or in medical sensing devices, as well as in semiconductors where innovative fabless chip solutions typically need to be integrated into circuits and/or require the manufacturing capabilities of more established foundries.

4.2 Photonics sector overview

Photonics is a family of technologies based on the science of light including fibre optics, light emitting diodes, optical sensors, lasers, photonics chips and integrated circuits. The range of products and applications is vast and includes the displays and camera sensors on mobile phones, laser manufacturing and cutting equipment, super-fast computer and communications hardware, all kinds of lighting, medical equipment, robotics and other technologies[1].

The photonics sector is broken down under multiple fields of applications including:

- Production technology.
- Open measurement and machine vision.
- Medical technology and life sciences.
- Information technology.
- Optical communications.
- Flat panel displays.
- Lighting.
- Defence photonics.
- Optical systems and components.

1. James Cogan - Finance for Photonics in Europe (April 2016).

Among other key enabling technologies, photonics is an important sector for the European economy. Photonics-related technologies enable developments in many of the industries where they are used. The photonics industry is estimated to bring a positive leverage impact to 10% of the European economy, with leverage ratios that may go up to 50, between the photonics market size and the total market size impacted[2].

Photonics applications can be found in multiple end markets including retail, medical and healthcare, manufacturing of electronics and vehicles, transport and telecommunications[2].

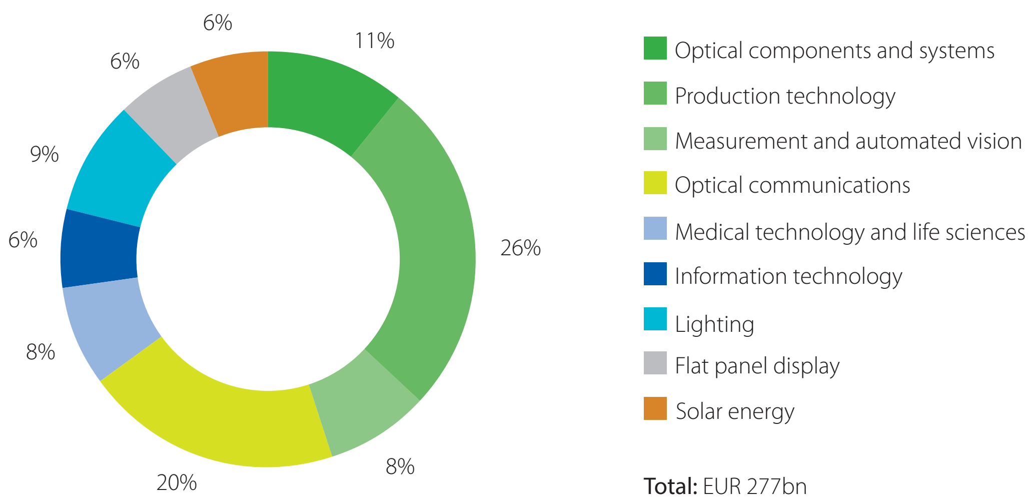


Figure 5: Breakdown of photonics production by application sector in %

Source: Photonics21, The Leverage Effect (March, 2011)

Because of their leverage effect and multiple applications across industries, photonics technologies are an important driver of growth, innovation, productivity and broader environmental benefits, and their development should therefore be encouraged as much as possible.

The European photonics market is estimated to be worth around EUR 70 billion, accounting for around 15% of the global photonics market of EUR 445 billion in 2015[3]. Growth averaged over 6% in the period from 2011 to 2015, and was strongest in the information and displays fields over this same period[4].

2. Photonics 21 - The Leverage Effect (March 2011).
3. James Cogan - Finance and Photonics in Europe (April 2016).
4. Photonics 21 - Market Research Study Photonics (2017).

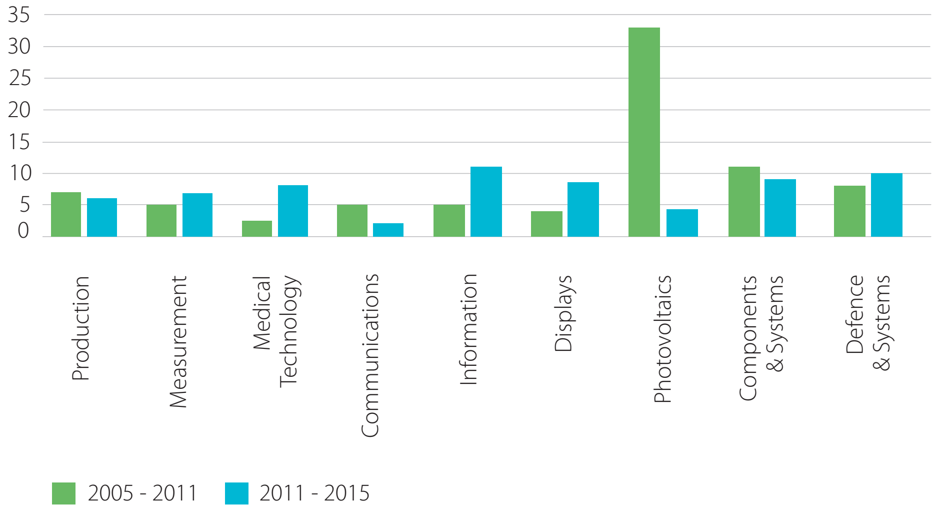


Figure 6: Growth of global photonics market on EUR-basis

Source: Photonics21, World photonics production by sector (2008)

The market share of European companies is around 15% on average across several of the key photonics application fields, but production has been growing more strongly in Asia and North America. As a result, European market share in the global photonics market fell from 19% in 2011 to around 17% in 2015 (excluding PV, 15% including PV). The market share of European companies is highest in the following application fields:

- Production technology (40-50%).
- Optical systems & components and measurement (30-40%).
- Medical technology, lighting and defence (20-30%)[5].

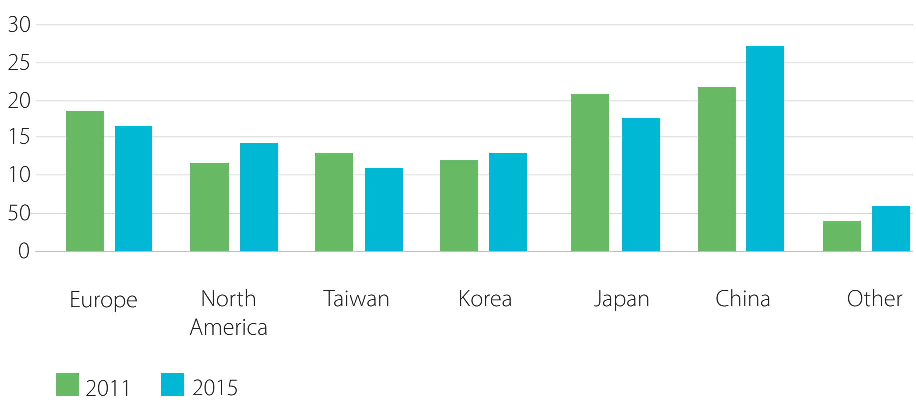


Figure 7: Photonics production by region in %

Source: Photonics21, World photonics production by sector (2008)

5. Photonics 21 - Market Research Study Photonics (2017).

Within the EU, an estimated 5 000 companies and some 1 000 to 2 000 organisational units (institutes, labs, university groups) are presently in the field of photonics. This assessment shows that the European photonics sector is almost half the size of the pharmaceutical industry. The relative number of SMEs and large companies in Germany is significantly higher than in the other countries. However, other EU countries also show a critical mass in the sector[6].

According to Photonics 21 estimates, European photonics production has increased by over 62% over the last 10 years.

4.3 Photonics market trends and key application areas

The global market for photonics products was EUR 445 billion in 2015. The market has grown substantially over the last few years. The market has grown at a CAGR of 6.2% (EUR) since 2011.

European photonics industry production in 2015 totalled EUR 69.2 billion, down from a production value of EUR 65.6 billion in 2011. During the 2011 to 2015 period, European photonics industry production grew at a CAGR of 1.3% versus a CAGR of 6.8% over the 2005 to 2011 period.

The difference between the growth rates over these periods is mainly due to the increase and subsequent decrease of the photovoltaics segment and increased overall competition by photonics manufacturers in China.

By 2020, the global photonics market is estimated to reach approximately EUR 615 billion[7]. This is equivalent to a growth rate of around 7% over the 2015-2020 period.

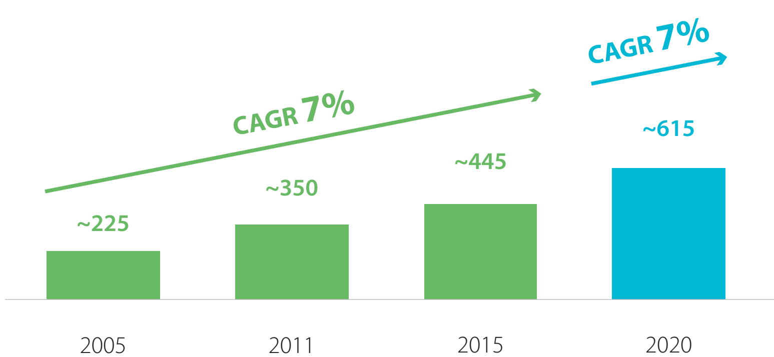


Figure 8: Global photonics market (EUR bn)

Source: Photonics21 - Market Research Study Photonics (2017), Photonics Public Private Partnership (2017)

6. Photonics 21 - The Leverage Effect (March, 2011).

7. Photonics 21 - Photonics Public Private Partnership (Heinz Seyringer, 2017).

Among the companies identified in this study, we note that three application sectors were represented in particular. These applications include production technology, medical technology & life sciences, and measurement & image processing[8]. The below paragraphs provide an overview of trends in these sectors.

Communications technology

- Optical networking employs light for the transmission of data in the long range (metropolitan to worldwide data transmission) and in the short range (local area networks). Data centre networks account for an increasing share and are considered to offer substantial growth potential[6].
- Global application areas are forecasted to keep growing exponentially due to multiple drivers:
  - Mobile and computer segments are generating direct demand for components such as displays, cameras and sensors, as well as indirect demand for wireless high-speed internet to support today's online services.
  - The internet is driven by light, not electronics, and fibre-optic cables coming to our houses are over 10 times faster than ADSL was a few years ago, generating the need for fibre-optic components.
  - In turn, this fuels the need to create efficient data centres and units that connect the "last mile" of fibre to our homes.

We are approaching the limits of how fast current electronic chips can process data using existing technology. Using photonics technology that works with light rather than electrons, data capacity, efficiency and transmission speeds are increased considerably[9].

Photovoltaics

- Despite the fact that the photovoltaic segment has seen a considerable slowdown in growth, the market reached an all-time high in 2015.
- Recent evolution has been characterised by price cuts in end-products driven by manufacturers in China, driving many manufacturers in Europe and the Far East out of business[8].
- Research shows that the use of solar energy will grow significantly over the coming years due to several drivers:
  - Progress in energy storage, which is expected to grow exponentially[10].
  - Adoption of new "building-integrated solar systems" that seamlessly integrate photovoltaics into existing building architectures, such as the use of photovoltaic roof tiles and organic photovoltaic window glass[11].

8. Photonics 21 - Market Research Study Photonics (2017).
9. PhotonDelta - Ensuring Photonics gets the investment it deserves (2016).
10. ElectroOptics - Guiding light, predictions for the future of photonics (2015).
11. LaserFocusWorld - Optics & Photonics sees nano and solar future (2007).

Tesla's Solar Roof and Heliatek's HeliaFilm are pioneers in this area, paving the way for the future of photovoltaic innovation.

Medical technology & life sciences

- Photonics 21 defines medical technology and life sciences as two different sub-sectors. Medical technology includes therapeutic medical systems. Life sciences includes analytical systems used in R&D in the pharmaceutical and biotechnology industry[12].
- The biggest growers are endoscope systems, therapeutic laser systems and analytical systems for the pharmaceutical and biotechnology industry. Moderate growth was observed for vision correction products and microscopes[13].
- Medical photonic diagnostics and photonics in therapy present strong growth opportunities over the next years. Notable drivers for future growth are:
  - Femtosecond laser products for ultra-precise surgery with minimal heat damage. (A femtosecond is one quadrillionth of a second).
  - Optical coherence tomography, which is no longer used exclusively for eye treatment and is moving into new fields of application at a rapid pace.
  - The growing activity of researchers to understand the brain will put ontogenetic science to work[14].

4.4 Typology of photonics companies identified

While a few large corporate players are active in photonics in Europe, the European market is still largely SME-based, with over 300,000 people employed. Previous research indicated that there are about 5,000 organisations in Europe that self-identify as belonging to the sector, of which about 10%, or 500, are producers of core photonics products and components[15].

Through our analysis, we identified 450 companies which present the following characteristics in terms of geography, size and photonics sub-sector.

In terms of geography: the top five countries represented are Germany, France, UK, Italy and Switzerland followed by a long tail of countries with smaller representation.

12. LaserFocusWorld - Optics & Photonics sees nano and solar future (2007).
13. Photonics 21 - Market Research Study Photonics (2017).
14. PhotonDelta - Ensuring Photonics gets the investment it deserves (2016).
15. Photonics 21 - Photonics -a Key Enabling Technology with enormous economic potential (2013).

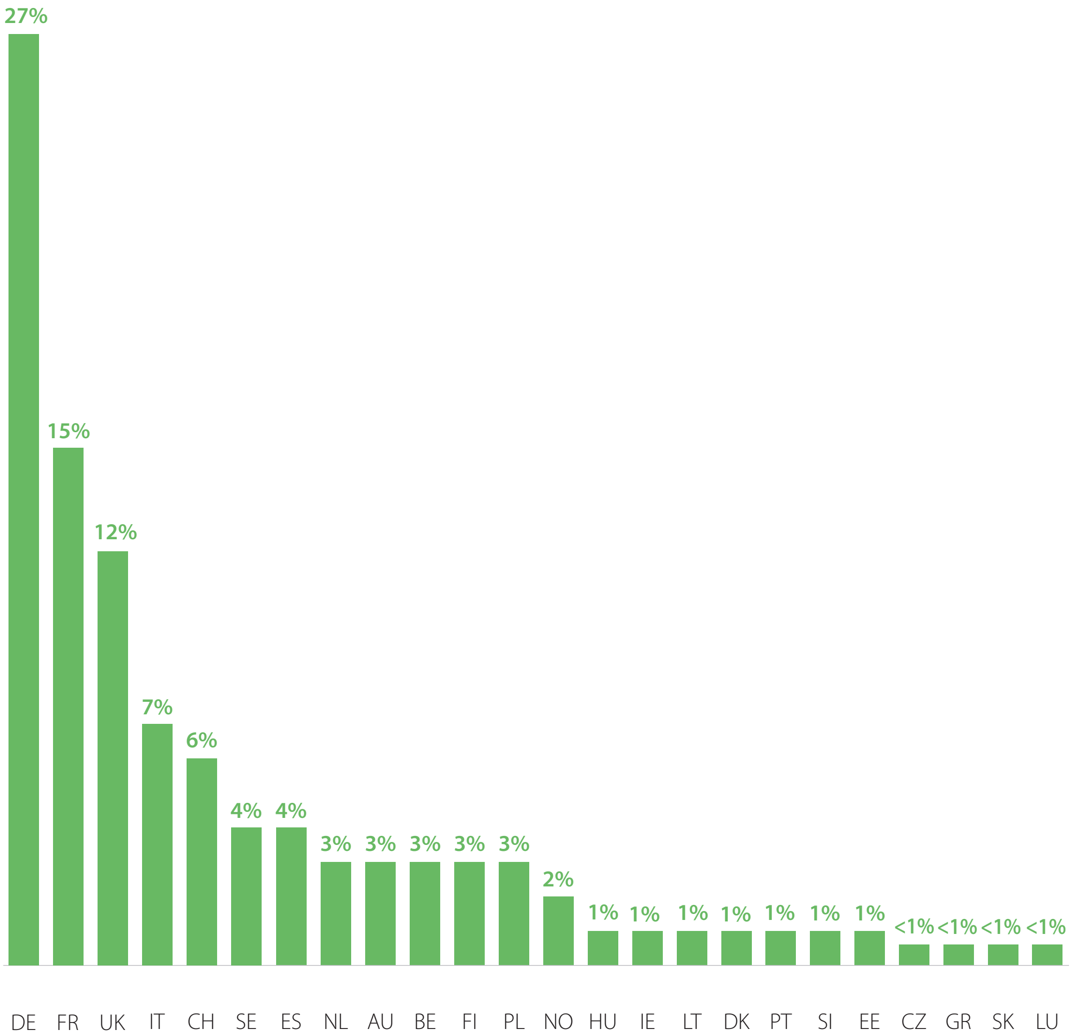


Figure 9: Distribution of photonics companies by country in %

Source: Project team analysis

In terms of company size, nearly 80% of the 450 companies identified are in line with the size criteria of micro, small and medium-sized companies. Only 21% are large companies.

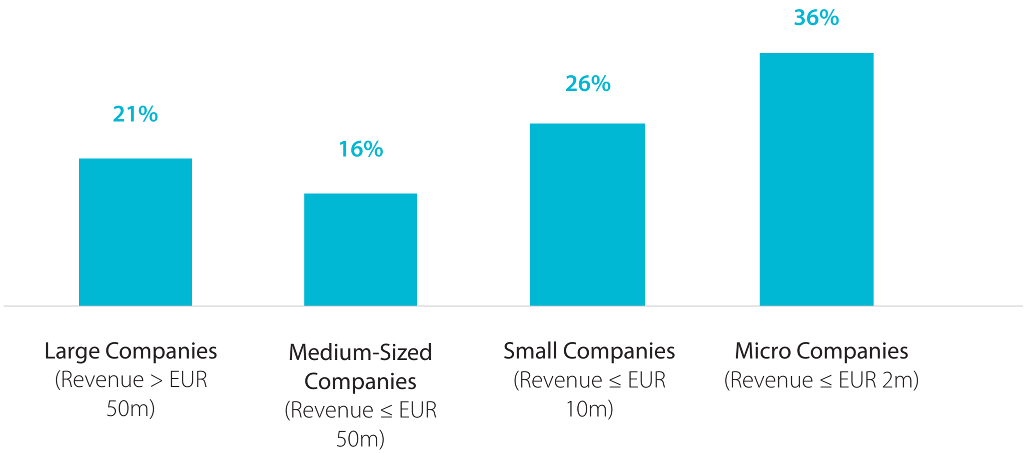


Figure 10: Distribution of photonics companies by size in %

Source: Project team analysis

In terms of sub-sector representation (based on the top 50), we note a strong representation of production technology, medical and life sciences, open measurement & machine vision and communications.

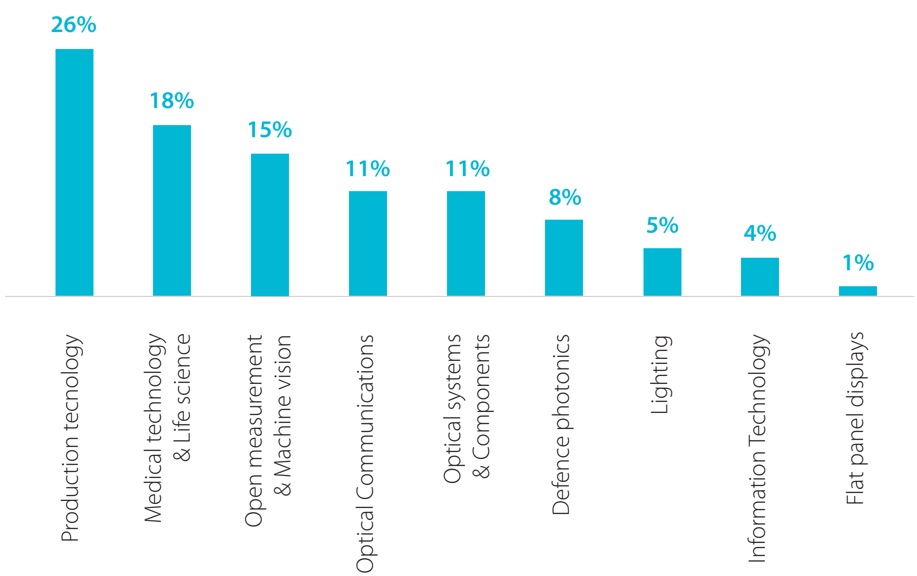


Figure 11: Distribution of photonics companies by sub-sector in %

Source: Project team analysis

4.5 Semiconductor sector overview

The Semiconductor Industry Alliance defines semiconductors as being essential for all goods and services which need intelligent control in sectors as diverse as automotive and transportation, aeronautics and space. Smart industrial control systems permit more efficient management of electricity generation, storage, transport and consumption through intelligent electrical grids and devices. Semiconductors are the "brains" of all modern electronics, from consumer electronics to aerospace systems, business operations, industrial applications and national defence. In 2017 global semiconductor sales revenue is forecasted to reach USD 378 billion compared to USD 339 billion the previous year.

In 2015, the European Union was the world's fourth-biggest semiconductor producer, representing approximately 9% of global production[16].

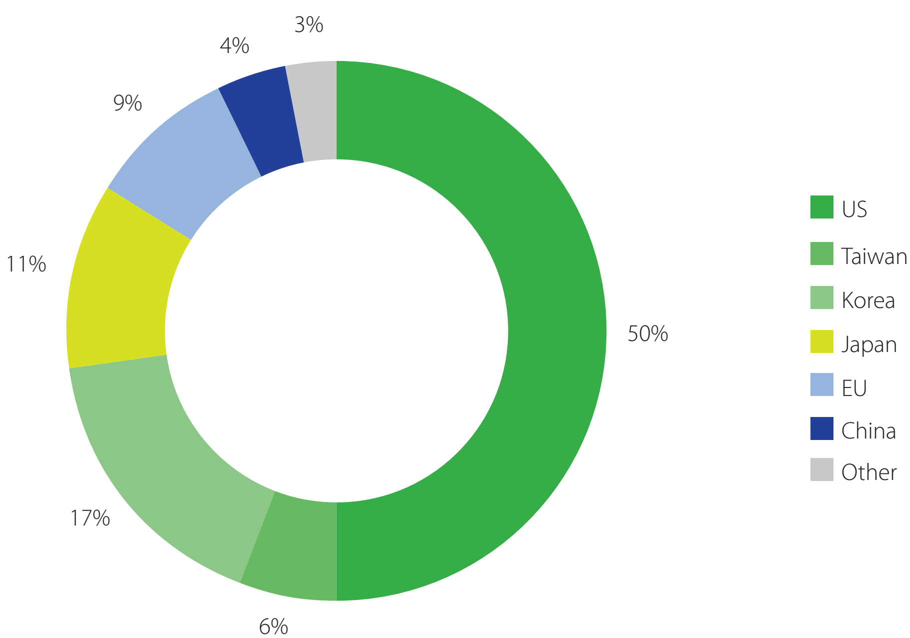


Figure 12: Semiconductor production by country in %

Source: US Department of Commerce, International Trade Administrataion, 2016 Top Markets Report: Semiconductors and Semiconductor Manufacturing Equipment (2015)

16. SIA - World Semiconductor Trade Statistics (WSTS)/IHS/PwC/IC Insights
Share based on headquarters of seller: Foundry output not included, fabless included.

Simple scaling and cost reductions will soon no longer be enough to improve device performance as they did in the past. However:

- The nonstop customer demand for more characteristics, capabilities, reliability and speed requires heavy investment in R&D, design and efficiencies throughout the supply chain (low-cost manufacturing, testing, assembling and packaging, and distribution).
- The industry is rapidly moving into new areas such as IoT, energy-efficient sensors, automated devices, robotics and AI.

These sectors therefore rely on a global supply chain including a set of key activities: R&D, design, manufacturing, assembly, testing, packaging, and distribution - as illustrated in the below figure.

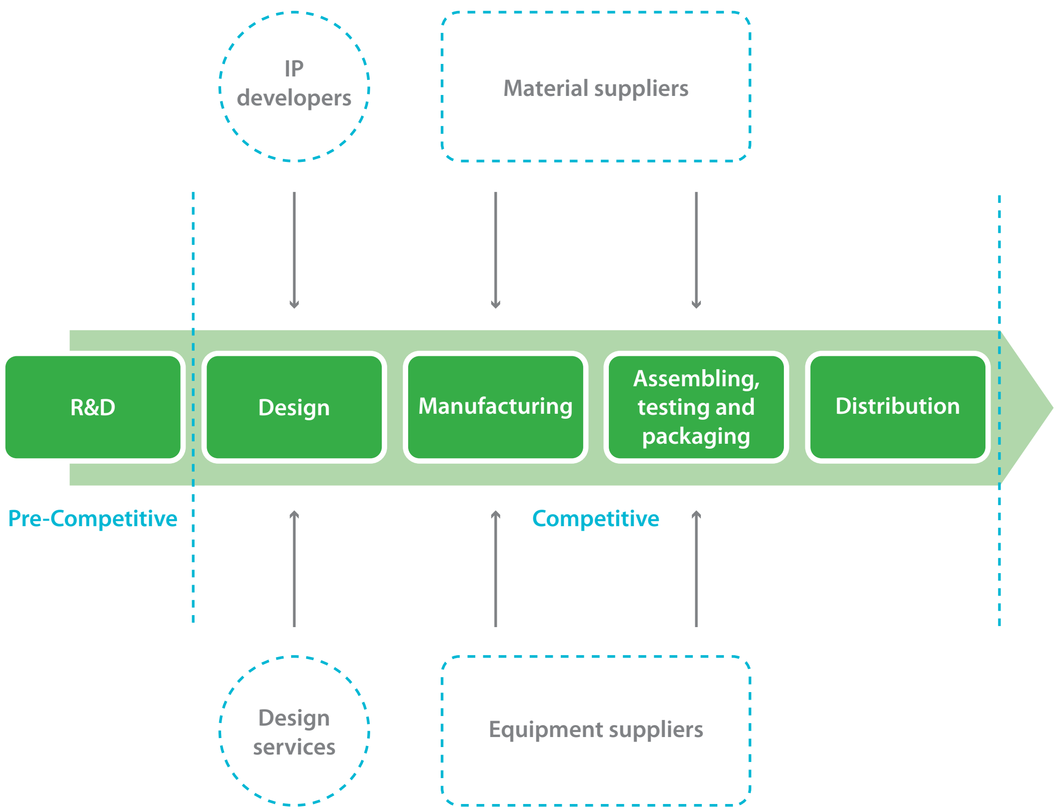


Figure 13: Summary of the semiconductor value chain

Source: SIA, Beyond Borders: The Global Semiconductor Value Chain (2016)

Each actor along the supply chain is highly specialised and therefore adds high value to its activity. According to the Semiconductor Industry Association: "R&D can be competitive and/or pre-competitive. R&D is pre-competitive when industry participants, governments and academia cooperate to promote technological innovation. Competitive R&D on the other hand comprises activities undertaken by individual companies in an attempt to innovate and compete in the market through better products. All other value chain activities are carried out by companies that actively compete with each other by pursuing innovation and efficiencies."

The actors above form part of the semiconductor ecosystem, along with materials suppliers, design service providers, developers of intentional programming cores/blocks and producers of semiconductor manufacturing equipment.

- Intentional programming developers create and licence pre-designed blocks of circuits that semiconductor companies integrate into their broader chip designs.
- Design service providers offer computer-aided design services among others.
- Materials suppliers produce materials for wafer fabrication and packaging.
- Equipment manufacturers produce specific equipment and tools essential for manufacturing, testing and packaging.

This ecosystem benefits the global economy significantly through employment, exports, incremental innovation, etc.

Europe is a fragmented market which is SME-dominated in terms of volume. Nevertheless, many large corporates have their roots in Europe and as a result, have high-end manufacturing activities located on the continent. However, European companies are mainly focused on the early stages in the value chain: pre-competitive R&D (Germany, UK), and design. To an extent, some countries are also specialised in the supply of equipment and materials.

4.6 Semiconductor market trends

We can distinguish two eras in recent semiconductor history: 1995 to 2008, and 2008 to the present. The first era was driven by high growth (7% CAGR) with rapid sales growth on the mobile and computer segments. In parallel, mobile devices became more innovative and complex and computers became more mobile. This required an increasing volume of semiconductors and ever-higher performance. The most successful players increased R&D investments during this period. The actors on the market therefore became increasingly specialised, obtaining most of their revenue from a specific component category. Leading competitors in each category were, therefore, different[17].

17. McKinsey & Co. - McKinsey on Semiconductors (December 2015).

During the second era, however, industry growth fell to 3% due to lower demand in key categories (e.g. mobiles and computers) that had fuelled demand in the previous era. No other major growth driver has emerged since, and competition intensified as system-level players (i.e. Samsung, Apple and hyper-scale players in datacentre management) took on a greater role in chip design. As a result, profits dropped, R&D spending decreased and industry consolidation gained strategic importance for players[18].

A new growth trend is expected to emerge in the near future due to the potential of a number of new segments (i.e. cloud infrastructure, security, next-gen memory, energy-efficient sensors, connected and automated devices, robotics, AI and IoT). In the following paragraphs, we discuss growth drivers in two of these application fields.

Internet of Things (IoT)

The Internet of Things is defined as the practice of capturing, analysing, and acting on information generated by networked objects and machines detecting action. While the technology is still in its early days, a growing number of companies are creating business value with IoT applications[19].

Multiple research sources suggest that IoT represents a major opportunity for semiconductor companies. That is because the creation of information from action is facilitated by the use of sensors, microcontrollers, modem chips, power sources, and other semiconductor-related devices.

Experts estimate that IoT products and services could generate between USD 4 trillion and USD 11 trillion in value globally by 2025. These large numbers reflect the IoT's transformational potential in both consumer and business applications[20].

Automotive

Many international automotive original equipment manufacturers (e.g. Bosch) have been introducing sensors, applications, connectivity platforms, and other technologies along the line of mobility solutions, passenger safety or autonomous driving.

These elements, combined with the potential of electric vehicles, presents a number of opportunities for semiconductors. As cars become even more electronics-based, including increasingly complex systems, demand for automotive semiconductors will continue to rise steadily and provide long-term growth.

Semiconductor companies today are aggressively pursuing strategic partnerships with automotive companies and taking up challenges along the supply chain[21].

18. McKinsey & Co. - McKinsey on Semiconductors (December 2015).
19. DUP - Inside the Internet of Things (August 2015).
20. McKinsey & Co. - McKinsey on Semiconductors (December 2015).
21. McKinsey & Co. - McKinsey on Semiconductors (December 2015).

4.7 Typology of semiconductor companies identified

A few large semiconductor corporates are based in Europe, operating foundry models, e.g. ST Microelectronics, NXP and Infineon. However, looking at the broader number of players active in the field, the European market is principally SME-based. Through our analysis, we have identified 207 companies which present the following characteristics in terms of geography and size.

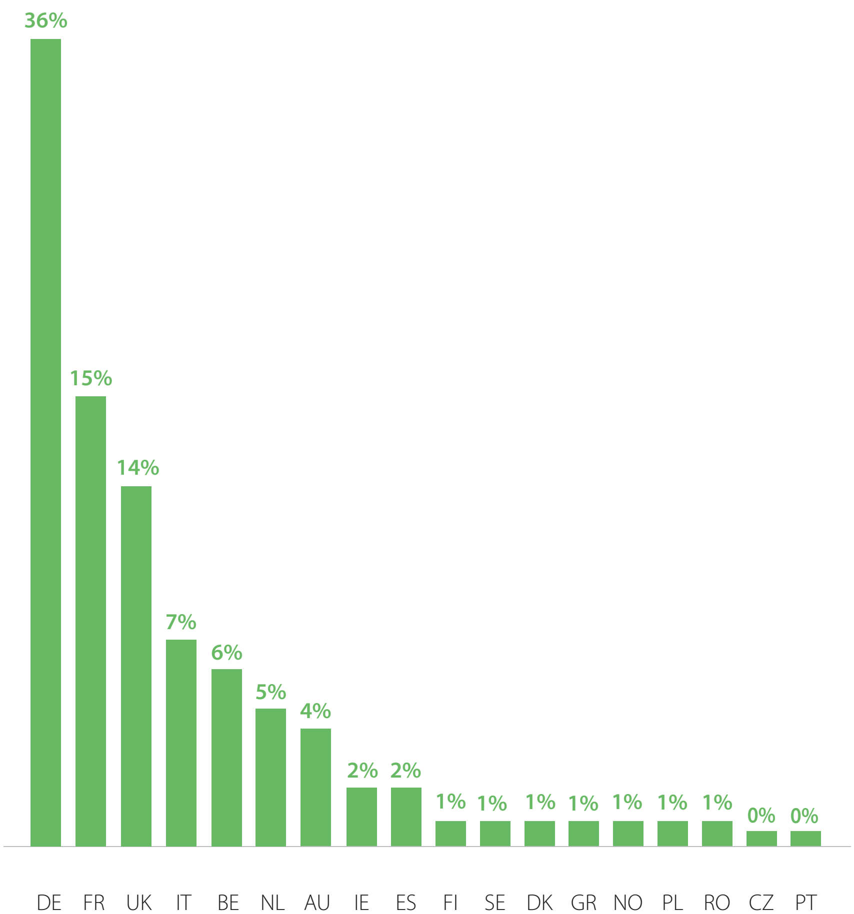


Figure 14: Distribution of semiconductor companies identified by country in %

Source: Project team analysis

In terms of geography, the main countries represented are Germany, France, UK, Italy, Belgium and the Netherlands followed by a chain of lesser represented countries.

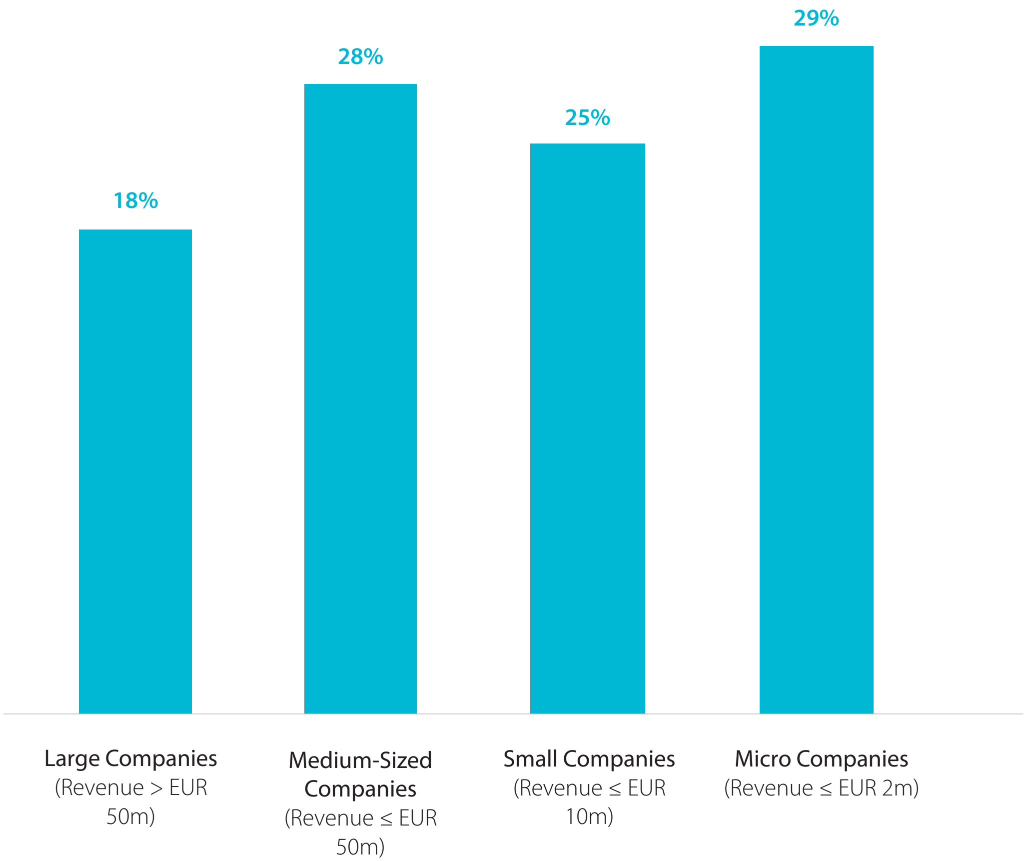


Figure 15: Distribution of semiconductor companies identified by size in %

Source: Project team analysis

In terms of company size, over 80% of the 207 companies identified are in line with the size criteria of micro, small and medium-sized companies. Only 18% are large companies.

Key findings

5.1 Summary of key findings

Overview of findings

Based on the more than 50 interviews conducted and the research performed in the context of this study, we identified nine key findings about the state of access to finance in the photonics and semiconductor sectors.

These findings cover a range of topics for the industries in scope, including:

- The specific financing challenges of photonics and semiconductors.
- The ability of photonics and semiconductor companies to access private financing (VC or commercial loans).
- The role of grants and that of national agencies.
- The role of EU direct and indirect financing instruments.
- The role of established corporates and the role of technology clusters.

Our findings are summarised in the table below and detailed in the following pages

			Sector		Lifecycle	
		Key findings	**Photo-nics**	**ECS**	**Early stage**	**Scale up**
Grants and national programmes	1	**Grant programmes are a key lever** for Photonics and Semiconductor companies at early stages **but often fail to be followed on by adequate financing** at later growth stages e.g., funding for pilot lines or commercialization.				
	2	National agencies are important financing players for Photonics and Semiconductor companies, in particular to facilitate access to grants at R&D stage and other financing tools at later stages.				
Corporates and clusters	3	**Clusters play a key role in supporting the sectors' companies** (network, financing guidance, infrastructure).				

		Key findings	Sector: Photonics	Sector: ECS	Lifecycle: Early stage	Lifecycle: Scale up
Corporates and clusters	4	Established corporates play an **important role to support** the development of Photonics and Semiconductor companies (sharing IP, access to equipment, financing) and are also a **key exit avenue** for innovative companies.	Highly relevant	Relevant	Highly relevant	Relevant
Specific financing challenges	5	Photonics and Semiconductor business models tend to be **complex and not fully understood**; the Photonics sector is also broadly perceived to **lack visibility** given its often enabling nature for other end applications.	Relevant	Highly relevant	Highly relevant	Highly relevant
	6	Photonics and Semiconductor companies tend to present **less compelling investment characteristics** vs. other industries (i.e., lower return vs. risk, longer time horizons).	Relevant	Relevant	Relevant	Relevant
"Funding gap" in private financing	7	There is a **shortage of venture capital and private funding gap** in Photonics and Semiconductors, and it is more pronounced than in other sectors due to complexity and return/risk specificities of these sectors.	Relevant	Relevant	Highly relevant	Relevant
	8	Commercial bank funding **is mostly not available where needed** in the Photonics and Semiconductor sectors; and difficult to obtain even for growth stage companies.	Highly relevant	Highly relevant	n/r	Highly relevant
EU financial instruments	9	01. Direct lending from EIB to the Photonics and Semiconductor sectors is limited but addressing a real market need.	Relevant	Relevant	Highly relevant	Relevant
		02. Indirect financing of VC funds is necessary but not sufficient to meet specific Photonics and Semiconductor market needs.	Relevant	Relevant	Highly relevant	Highly relevant
		03. There is insufficient awareness and understanding of EU financial instruments (EIB, EC, etc.).	Highly relevant	Highly relevant	Highly relevant	Highly relevant

Relevant   Highly relevant

Ranking of key access-to-finance levers

We gathered feedback from participants on the range of funding sources and levers that may be activated in support of a financing process.

In the chart below, we highlight the percentage of responses supportive of the importance of the key findings highlighted in this report. Please note that these numbers bear limited statistical significance given the semi-structured interview format used and the size of the sample. Nevertheless, these percentages are indicative of what respondents have agreed on explicitly when prompted or have mentioned proactively without prompting.

Several points emerge with above 50% response rates from the survey, including:

- The importance of clusters for the sectors, which was recognised by those prompted as an important enabling factor to access development resources, network with other companies and potential talent, and seek financing guidance.
- The importance of grants, in our view one of the most important factors in the list, as it often represents one of the first and only financing tools available to young ventures at early-stage.
- The importance of national agencies, which are often the first public point of contact for young companies and are often seen as responsive and flexible financing partners.
- The importance of VC funding, albeit in short supply and suffering from the funding gap noted below.
- The unavailability of commercial bank funding at early and growth stages, due to the intrinsic risk characteristics of photonics and semiconductor ventures, and commercial banks' general risk aversion.

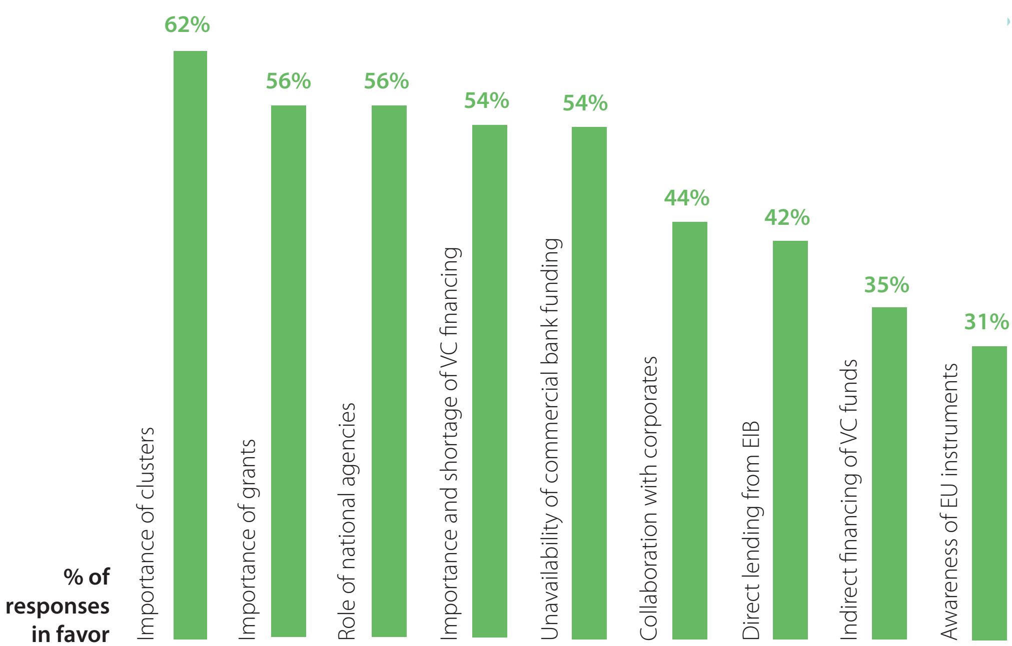


Figure 16: Percentage of interviews conducted making reference to key financing issues

Challenging access-to-finance conditions and a clear funding gap at both early-stage and growth-stage

Overall, we find that all companies and financing intermediaries and sector promoters interviewed expressed views underlining the difficulty of accessing financing for companies in the photonics and semiconductor sectors.

A number of factors contribute to the expansion of this funding gap and to making access to finance in general extremely difficult for photonics and semiconductor companies. These specific factors are highlighted in the first two findings of this chapter and relate to:

- The complexity of photonics and semiconductor technologies, requiring a high degree of technological expertise for the evaluation of investment opportunities, and resulting in those opportunities being only considered by a less extensive range of financing players versus more traditional ventures.
- The lower attractiveness of photonics and semiconductor investment characteristics, as the sectors tend to combine high technology and market risk with long development lead times and high capital requirements, resulting in an often less compelling proposition compared to more predictable and scalable VC alternatives.

Among the responses received, 48% of those interviewed underlined the complexity of the sectors in scope, and 54% discussed explicitly the intrinsic reasons that can reduce the investment attractiveness of photonics and semiconductors ventures.

Key specific financing challenges for photonics and semiconductor companies

	Description	Key sub-issues
Higher complexity, lower visibility **48%**	• Photonics and Semiconductor business models tend to be **complex and not fully understood**; the Photonics sector is also broadly perceived to **lack visibility** given its often enabling nature for end-market applications	**Technological complexity** – requiring deep expertise to be properly understood and factored into a business plan or investment model. **Lower visibility** – enabling technologies integrated in variety of end-market applications but lacking own identity (mainly applicable to Photonics).

	Description	Key sub-issues
Lower attractiveness of investment characteristics **54%**	• Photonics and Semiconductor tend to present **less compelling investment characteristics** vs. other industries • While not necessarily disqualifying factors for high quality ventures, these elements tend to make the **Photonics and Semiconductor return vs. risk equation less attractive to investors** vs. other investment alternatives e.g., in software or e-commerce	**High technology risk** – high uncertainty on the applicability of the technology to address a given objective/market need. **High market risk** – uncertainty on the ability to monetize the given technology due to the risk of substitutes, the threat of faster competitors bringing a workable solution to market. **Long development lead times** – multi-year R&D lead-times to bring a technology from lab concept to working prototype, taking into account ongoing technological evolutions. **Capital intensiveness** – significant investments required to fund prototyping efforts at early-to-mid development stages, and later medium-to-high volume production capabilities.

Source: Feedback from stakeholder interviews, Project team analysis

Applicability of findings to photonics and semiconductor companies and early-stage vs. growth-stage companies

Overall, we find that all findings presented are true for both the photonics and semiconductor sectors, and true for both early-stage companies and later-stage/scale-up companies. Nevertheless, we highlight a number of nuances in terms of the applicability of the findings:

- Technological complexity as a financing challenge is particularly true in the photonics sector, where the diversity of core technologies and potential applications is even higher than in semiconductors.
- The financing challenges observed in this study apply to both photonics and semiconductors in similar ways. However, while early-stage financing is already deemed more difficult than in other industries, it is particularly so for later-stage growth financing, where the funding gap identified is most pronounced due to the higher size of the investments retaining high-risk characteristics.
- With private financing sources not meeting market needs, the role of grants and national agencies is essential in funding technology development efforts. This is true for both photonics and semiconductors, in particular at early-stage.
- The importance of EU financial instruments is underlined for both sectors, but the relevance of the current direct lending instruments is higher for more established growth companies compared to early-stage start-ups.

- The role of established corporates in supporting companies is true in both sectors but particularly in semiconductors, where manufacturing capabilities are dependent on a few large players globally, and becomes particularly important at later stages when companies approach high-volume production.
- While applicable in both sectors, the role of clusters also tends to be more explicit and pronounced in semiconductors, with key clusters positioned mainly around this sector.

The table below summarises our views of the nuances discussed in this section.

	Photonics	**Semiconductors**	**Early-stage**	**Growth-stage**
Technology complexity	Limited sector identity / visibility Large array of complex, disruptive technologies	High complexity in emerging technologies Technology landscape mature	Complexity at both early-stage and growth-stage	
Less compelling investment character-istics	High risk, high investment and long development lead-times		Highest risk stage	Elevated risk, higher capital investments
Venture capital in-vestment	Extremely challenging conditions in both sectors		Very challenging conditions but amounts sought still may be found	Higher amounts required for development more difficult to access
Commer-cial bank funding	Generally not available except among few specialist providers		Not applicable for early-stage companies	Not applicable for early-stage companies
Grants	Grants critical for both sectors		Highly reliant on grants, often key source of funding post-lab phase	Reliance on grants remains but not principal source of funding

	Photonics	Semiconductors	Early-stage	Growth-stage
EIB direct lending	High need for financing support across both sectors		Existing instruments tend to be more geared to larger companies	Highly relevant instruments though still limited use cases
Role of corporates	Reliance on integrators key in some fields; some fields may require less integration	Reliance on foundries and integrators critical from early prototyping stage	Technology validation and prototyping carried out with partial corporate collaboration	Move to HV production requires robust production and commercialization capabilities
Clusters	Generally applicable and supportive to both sectors	Semiconductor clusters more developed and industry more standardized / integrated	Both early-stage and growth-stage to find benefits of leveraging clusters	

Relevant   Highly relevant

Differences between types of respondents

Feedback was collected from company/start-up respondents, financing intermediaries (VCs, banks) as well as sector promoters (clusters, associations, research technology organisations, national agencies). Overall, we find that feedback generally converges across these different types of stakeholders on most findings. In particular, there is broad consensus on:

- The intrinsic characteristics of the sectors, making financing difficult (long development lead time, high risk, capital intensiveness and lower scalability).
- The difficulty and reluctance of private players to provide risk financing in the face of these challenges, taking into account the opportunity for the private sector to look at alternative investment opportunities, as well as the relative lack of technological knowledge in the private sector required to properly evaluate opportunities.
- The importance of grants and other public funding mechanisms as bridges or complements to private financing, with caveats on the clarity and awareness of available financing solutions, and the complexity of application processes for young companies.

- The need for better visibility and awareness about the photonics and semiconductor sectors, as these remain insufficiently known and understood by the financing community.

Relevance of the findings from the KETs I and II studies for photonics and semiconductor companies

The tables below illustrate the key findings of the KETs I and II studies and examine their relevance for photonics and semiconductors based on the findings emerging from this study. As shown in the table, there are clear common characteristics between these two sectors and KETs. Photonics and semiconductor companies share very similar characteristics with KETs (such as high technology risk, capital intensity, etc.) resulting in the same issues and difficulties when looking at access-to-finance conditions, but this study also shows that these companies have specific characteristics and features that are unique to these sectors. In particular, photonics and semiconductor companies tend to be concentrated in technology clusters (where they can benefit from knowledge exchange and networking, access to equipment and infrastructure, etc.). Partnerships with large corporates are crucial for business development and bringing products to the market, and national funding agencies are key enablers for these sectors especially in the early stages.

	Previous KETs I study findings	Relevance for this study	Comments
1	Almost 30% of the KETs companies in our study fail to obtain adequate debt financing. Even more KETs companies (about 50%) find themselves severely struggling to obtain the finance needed to generate further growth and innovation.	✓	Commercial bank funding is generally difficult for photonics and semiconductor companies.
2	Europe's conservative financing "ecosystem" is not in favour of the most dynamic innovators.	✓	Not only lending is limited but there is a shortage of VC funding in the photonics and semiconductor sectors, due to the high risks presented by these sectors, and to a lack of players with sufficient focus and technological knowledge.
3	Profound knowledge of KETs and a cash flow-based lending approach are key for financing decisions but in short supply with many banks.	✓	The complexity of photonics and semiconductor technologies requires a high degree of technological expertise for the evaluation of investment opportunities, and results in those opportunities being considered only by a less extensive range of financing players versus more traditional ventures.

	Previous KETs I study findings	Relevance for this study	Comments
4	Big is beautiful – smaller KETs companies face more difficulties and require broader support beyond pure finance.	✓	Clusters contribute in a significant way to the development of photonics and semiconductor companies (especially SMEs), by facilitating knowledge exchanges and networking, and by providing access to equipment and infrastructure.
5	Public support is well-suited to compensate for specific market shortcomings.	✓	Grants are an essential funding lever for photonics and semiconductor companies, and national agencies are important financing and support providers for innovative companies.
6	Boosting the growth of the European KETs sector will require smart, well-targeted instruments.	✓	There are opportunities to improve EU financing tools supporting photonics and semiconductors.

	Previous KETs II study findings	Relevance for this study	Comments
1	High credit risk of KETs companies: KETs companies typically present a high credit risk for lenders, i.e. there is a higher risk for lenders to lose money on the loans they provide to KETs companies.	✓	Lending is limited for photonics and semiconductor companies due to the risks of these sectors (high capital intensity, intangible assets, long development and production lead time).
2	Information asymmetries: these prevent investors from adequately evaluating different technology solutions and recognising truly disruptive technologies that are likely to lead to important transformations in the design and development of consumer products and services.	✓	Due to the complexity and technological expertise required by semiconductor and photonics companies, financing options tend to be more limited compared to ICT companies, and only a limited number of financing players have the required knowledge for investing in these sectors.
3	Lack of access to the right funding: Beyond bank lending, other forms of financing are more adapted to the risk-return profile of KETs, however they are currently limited in scale and breadth in the EU.	✓	Existing financing programmes and financial instruments are important funding sources but insufficient for semiconductor and photonics companies.

5.2 Finding 1: Grants are an essential funding lever for photonics and semiconductor companies

Key takeaways

- Photonics and semiconductor companies rely heavily on grant programmes throughout the early stages of their development.
- There is limited "follow-on" financing available for growth investments.

As shown in the table below, 56% of respondents underlined that access to grants was a key issue in terms of access to finance for photonics and semiconductor companies. We also note that a large majority of the companies interviewed had also resorted to grant-based funding in the past (even if not commented on explicitly during interviews).

Segment	Photonics		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	**9** 75%	**1** 33%	**5** 71%	**3** 60%	**4** 57%	**0** 0%	**1** 71%	**5** 71%	**1** 33%	**29** 56%
Segment summary	Responses 18 (67%)				Responses 5 (33%)			Responses 6 (60%)		

Figure 17: Respondents mentioning the importance of grant programmes at early stages and the need for follow-on financing

Source: Project team analysis

Critical role of grant programmes for photonics and semiconductor company development

Access to grants is undoubtedly a critical factor supporting the development of companies in photonics and semiconductors. Virtually all of the companies surveyed throughout this study are or have been recipients of grant programmes from Horizon 2020 or from their respective national agencies. Grants are clearly seen as a principal source of funding in the very early stages of development for companies, i.e. during the technological research phase. Grants also remain very important alongside other forms of financing during the product design/ prototyping stages, and even throughout company life to fund research on new innovation.

Most companies interviewed shared positive feedback on the grant programmes to which they had access. However, some mentioned the complexity of the grant landscape and the related application processes. For example, the nature and fit criteria of certain programmes tend to be insufficiently clear, requiring guidance and extra work for applications. The sometimes complex requirements of certain programmes (consortium structure, cross-border collaboration, etc.) sometimes limit their relevance for young companies with a need for fast and agile tools.

Of particular interest, the ECSEL JU programmes stand out for their ability to direct funding to large cross-border projects in the field of semiconductors, which is seen as an important driver of research funding in the area of semiconductors, as well as a vehicle to encourage collaboration between research start-ups or labs and established corporates.

Overview of ECSEL JU

Objective: the Electronics Components and Systems for European Leadership (ECSEL) Joint Undertaking's main mission is to contribute towards keeping Europe at the forefront of technology development and addressing capabilities of essential systemic and strategic importance for the EU.

Approach: the Joint Undertaking brings together both the public and private sectors, joining forces between participating national authorities and the European Commission, and aligning academics and industry across a very wide and complex supply chain.

Positioning of ECSEL and H2020 on the development cycle and the lack of follow-on financing at later stages

When looking at the adequacy between grant programmes and company financing needs, we note the following about the different grant programmes under review:

- Horizon 2020 programmes tend to focus on early-stage R&D efforts.
- ECSEL focuses on larger projects, typically between the end of the technological research phase and the product design and demonstration phase.
- National grant programmes may cover the entire spectrum described above.

As companies mature past the prototyping and demonstration phase, the need for new and larger-scale investment to fund manufacturing equipment appears. We note that there are limited programmes in place to support the financing of such investments as the follow-on to grants provided previously in a company's development.

As a consequence of this lack of growth financing, companies with a viable and demonstrated product proposition may end up being taken over or enter into an exclusive partnership with more established corporates.

“National and H2020 grants are an essential source of funding for us.”

Small photonics company

“Grant programmes are an excellent support to our R&D investments.”

Medium-sized, scale-up stage photonics company

“Many European initiatives are very time-consuming to apply for and the process is slow compared to the fast-moving market.”

Small semiconductor company

Synergies with previous reports:

KETs I study findings:	▲▲	KETs II study findings:	▲

Note: ▲ = Low ▲▲ = Medium ▲▲▲ = High

5.3 Finding 2: National funding agencies are important providers of financing and support for innovative companies, but they lack dedicated support programmes for photonics and semiconductors

Key takeaways

- National agencies play an important role for photonics and semiconductor companies, and are praised for their proximity and agility.
- While some programmes of relevance for photonics and semiconductors exist, generally speaking there is a limited number of dedicated programmes in place for the sectors in scope.

As shown in the below table, 56% of respondents recognised the importance of national agencies to support access to finance for photonics and semiconductor companies.

Segment	Photonics		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	6 50%	3 100%	4 57%	2 40%	4 57%	0 0%	2 33%	6 86%	2 67%	29 56%
Segment summary	Responses 15 (57%)				Responses 6 (40%)			Responses 8 (80%)		

Figure 18: Respondents mentioning the importance of national agencies for photonics and semiconductor companies

Source: Project team analysis

Proximity and agility as key benefits for photonics and semiconductor companies

Through our interactions with photonics and semiconductor companies, we find that more than half of them received support from their respective national agencies. In our sample, support generally took the form of grants, or some form of forgivable loan instrument.

Entrepreneur respondents shared generally positive to very positive feedback concerning the national agencies they had been working with. In practice, respondents praised the ease of access to and proximity of these agencies, as well as the agility of their decision-making processes and ability to respond to company needs relatively quickly.

We also find that photonics and semiconductor companies at different stages of development are receiving support from national agencies. Multiple start-ups interviewed were recipients of grants or loans from their local partners, but some more developed players also mentioned active relationships with their national agency.

> "Our local agency has been tremendously helpful for our de velopment, providing funding rapidly and with more flexibility than we expected."

Start-up stage photonics company

A limited number of dedicated programmes in place for the photonics and semiconductor sectors

In spite of this very positive feedback, we note that still too few programmes are in place at national agency level to specifically promote the development of the photonics and semiconductor sectors.

Commercial success in the photonics and semiconductor sectors often requires the integration of selected technologies into a broader commercial value proposition. As such, this process of integration requires coordination across countries, clusters, as well as national and regional development agencies. Increased support to photonics and semiconductors may be of help to bring about additional coordination, which is key in these sectors. In this respect, the importance of cross-border initiatives such as ECSEL becomes apparent.

The table below lists examples of national programmes applicable to photonics and semiconductor companies. Over the past decade, KETs-specific programmes have begun to emerge. While some are relevant, none are specific to the photonics and/or semiconductor sectors.

Member state		Programme
France	Bpifrance	**Fonds SPI: Investment fund for industrial projects** Bpifrance invests as a minority shareholder in project companies created in partnership with industrials, in order to transfer projects to their phase of industrialization.
		Garantie de caution sur projets innovants (Guarantee on intonative projets) Bpifrance will guarantee bank loans for innovative SMEs to the height of 80% and up to EUR 300k (for companies seeking to access a first market or a contract in a sector considerably different than that of their previous activity).
		Aide au partenariat technologique (Technological partnership support) Bpifrance invests as a minority shareholder in project companies created in partnership with industrials, in order to transfer projects to their phase of industrialization.
Germany	KfW	**ERP-Mezzanine for Innovation** KfW finances a project up to 100% of the investment costs through debt capital or a financing package out of debt capital and subordinated capital with a 10-year fixed interest rate and repayment-free start-up period (up to EUR 5m per project).
		ERP-Digitalisierungs- und Innovationskredit KfW finances a project up to 100% of the investment costs through loans with a 10-year fixed interest rate and repayment-free start-up period (up to EUR 25m per project).

Member state		Programme
Netherlands	Netherlands Enterprise Agency	**Innovation credit** The Netherlands Enterprise Agency Innovation Credit facility is a risk-bearing loan. Based on the realization of milestones of the project the credit is paid as an advance. Small businesses can finance 45% of project development costs, SMEs 35% and large companies 25%. The credit amount is up to EUR 10m. In the case of a collaboration, the maximum credit rate can be increased.
Belgium	Sowalfin (Novallia)	**NOVALLIA Accélérateur de projets innovants** Novallia finances a project up to 40% of the financing needs (max EUR 500k) through subordinate loans. The interest rate is fixed at a minimum of the Euribor-IRS rate depending on the duration of the project. The duration of the loan can be up to 10 years.
	VLAIO	**VLAIO SME Innovation project** VLAIO funds a Flemish SME's innovative project (max EUR 250k). This may involve the development of a completely new or significantly innovative (improved) product, process, service or concept. The amount of funding is calculated on the basis of the acceptable costs. **VLAIO Industrial R&D projects** VLAIO provides funding to any Flemish company's R&D project (from EUR 100k to 3m) carried out by one or several enterprises, sometimes in collaboration with research partners. The applying enterprise(s) must exploit the result to a sufficient extent in Flanders and hence create enough economic impact in the form of employment and investments.
	PMV	**PMV Innovation Mezzanine** PMV finances a small enterprise's innovative project (max EUR 500k) through subordinate loans (provided the company is no older than 6 years, in no difficulties and with a set of operations in Flanders).

Synergies with previous reports:

KETs I study findings:	▲	KETs II study findings:	▲▲

5.4 Finding 3: Technology clusters are key supporting players for the photonics and semiconductor sectors

Key takeaways

- A number of clusters operate across Europe with a specific focus on supporting photonics and/or semiconductor companies.
- The contribution of clusters is important in terms of networking, financing guidance and access to infrastructure.
- We find evidence of the positive impact of clusters, namely through the geographic location of photonics and semiconductor companies and examples of corporate investment (e.g. Bosch).

Based on the interviews conducted, we note 62% referencing the important supporting role of technology clusters.

Segment	Photonis		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	**6** 50%	**2** 67%	**4** 57%	**4** 80%	**3** 43%	**1** 50%	**5** 83%	**4** 57%	**3** 100%	**32** 62%
Segment summary	Responses 16 (59%)				Responses 9 (60%)			Responses 7 (70%)		

Figure 19: Respondents mentioning the supporting role of clusters to photonics and semiconductor companies

Source: Project team analysis

A number of clusters operate across Europe with a focus on the sectors in scope

The clusters identified have been found to have a focus on either one or both of the photonics and semiconductor technology categories, as well as potentially other deep technologies.

- Silicon Saxony: Located in the region of Saxony in Germany, this cluster defines itself as a network. It coordinates networking between the members of the cluster, fostering innovation, enabling knowledge transfer and synergies.

- Minalogic: A French high-tech cluster located in Grenoble, Minalogic addresses a wide array of industries from ICT and healthcare to energy and advanced manufacturing. The cluster has a total of 335 members with over 500 certified R&D projects and has spent EUR 2 billion spent in the field of R&D.
- PhotonDelta: Active across Belgium and the Netherlands, in particular northern Belgium and southern Netherlands, PhotonDelta aims to put together a network of small companies and connect them with research institutes and corporates.
- DSP Valley: This cluster is also active throughout Belgium and the Netherlands. Defining itself as one of the top clusters in Europe, DSP Valley has a network of more of 100 members including research institutes, universities, start-ups and corporates.
- Distretto HTMB: Located in the north of Italy and set up by public as well as private partners, Distretto HTMB focus part of its resources on semiconductors.

The contribution of clusters is important in terms of networking, financing guidance and infrastructure

Based on these discussions, including those with cluster representatives themselves and companies associated with such clusters, we find that the contribution to the sector takes multiple forms. First, clusters (and more broadly industry associations) play a role in networking, i.e., connecting entrepreneurs with other entrepreneurs, corporate players, financing partners, potential talent, etc.

Beyond networking, certain clusters provide specific guidance and advice in terms of financing, for example by helping companies understand which public grants or other financing programmes they may be entitled to.

Last but not least, clusters provide companies with preferential access to valuable infrastructure and equipment, to support their research efforts (e.g. lab access), their day-to-day-management (e.g. office space) or shared production capabilities.

We note that clusters can be of value to early-stage companies in need of guidance and support, but also to more established players seeking connections/access to niche solutions and talent. For financing intermediaries, we note that clusters provide more centralised access to potential opportunities in a single industry.

To further demonstrate the positive impact of clusters, we analysed the geographical location of photonics and semiconductor companies identified in this study compared to that of the main sector clusters. As illustrated in the maps below, we find that there is an apparent link between the presence of clusters and the location of companies. Of note:

- The identified photonics companies are reasonably spread across Europe with minor concentrations around key cities and clusters.

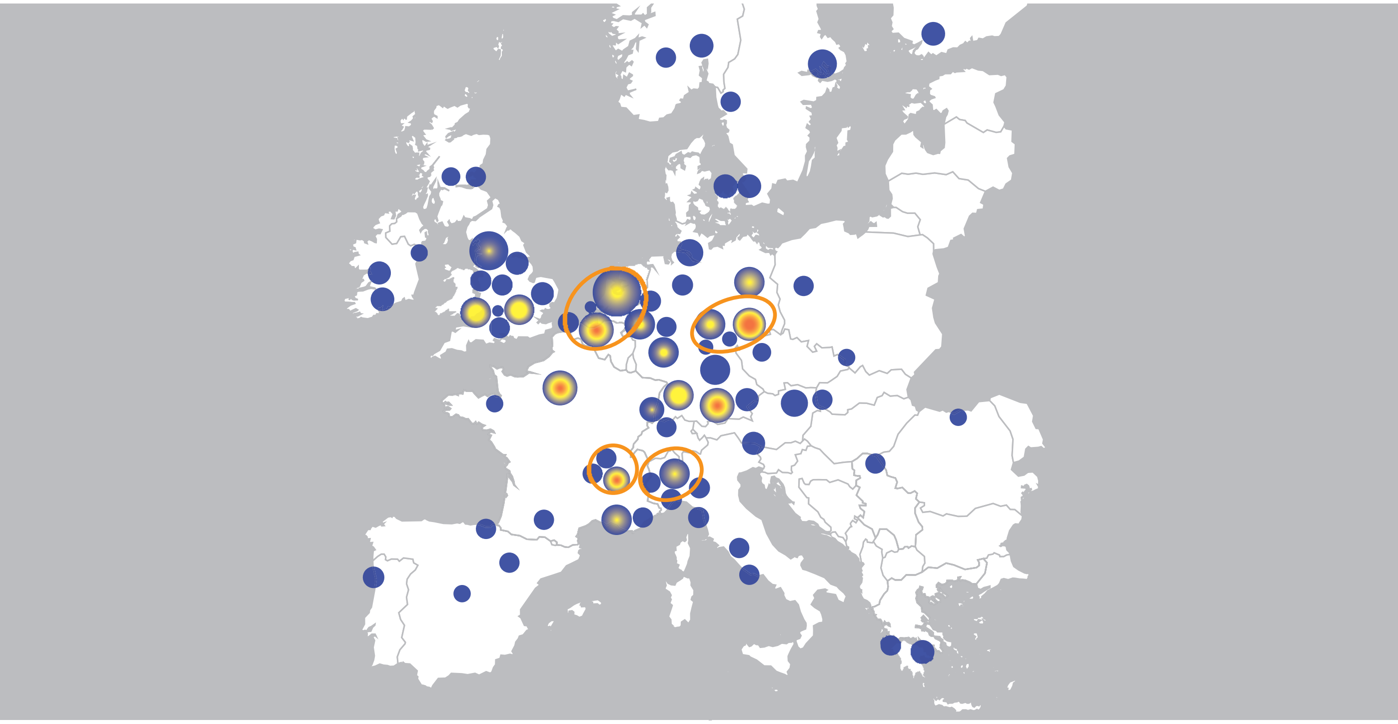
- Not surprisingly, on the semiconductor side, companies tend to be somewhat less widely spread across Europe and are more concentrated around the several clusters which clearly stand out.

In addition, we note that this analysis illustrates a degree of concentration of companies identified around a belt from northern Italy and southeast France to Germany, the Benelux countries and the United Kingdom.

Figure 20: Geographical mapping of photonics & semiconductor companies versus key sector clusters

Location of semiconductors in Europe

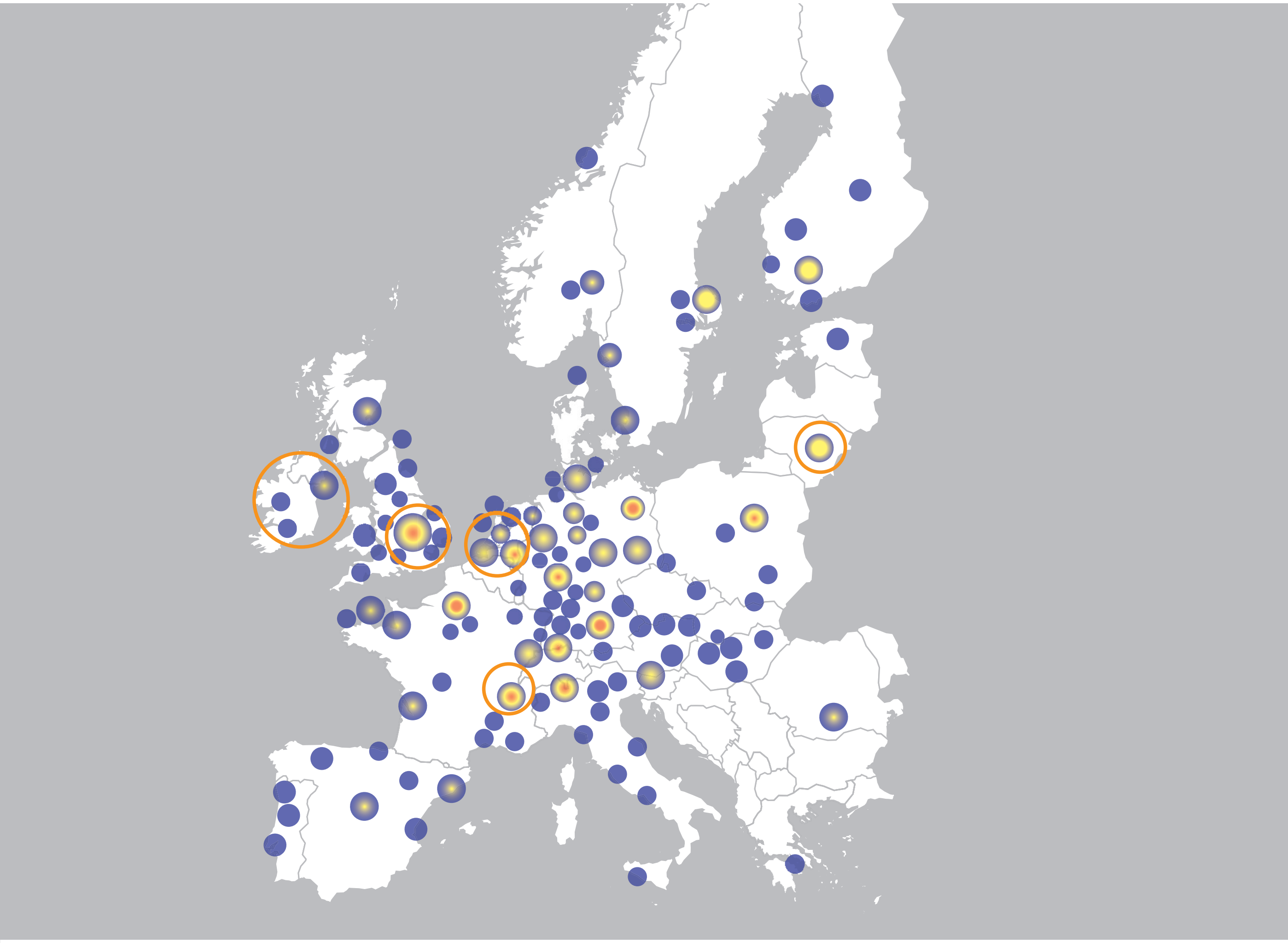
Key semiconductor clusters are concentrated in Germany, France, Netherlands, Belgium and Italy. Most of these clusters are built around large companies such as ST Microelectronics in Grenoble (France) or Globalfoundries and Infineon in Saxony (Germany). Moving towards Central and Eastern Europe, there is a less concentrated presence and a smaller number of companies operating in these sectors.



Colour code: Higher concentration — Lower concentration

Location of photonics in Europe

Key photonics clusters are located in Germany, the UK and France. There are also smaller clusters in Ireland and Lithuania. Geographic proximity between photonics companies offers clear advantages in terms of knowledge exchange, networking, etc.



Colour code: Higher concentration [colour scale] Lower concentration

Source: Project team analysis

A cluster success story: Silicon Saxony

Silicon Saxony

Silicon Saxony is a German cluster/trade association for the semiconductor, electronic, microsystems and software industries. The cluster is based in **Dresden**, Saxony at the heart of the Semiconductor ecosystem.

Dresden has historically been a **major microelectronic hu**b even prior to Germany's reunification. Industry suffered in East Germany after the collapse of the Soviet Union, but the microelectronics industry was, with support from the **German state**, one of the first industrial sectors in Saxony to recover.

Today, the number of cluster members has risen to approx. **300**, many (but not all) situated in the **Dresden Chemnitz** area.

Location: Dresden, Germany

Members: approx. 300

ECEI GOLD label for Cluster management Excellence

Key Achievements and Success factors

- The **historic implantation** of microelectronics in the Dresden area; the pre-existing skill set and infrastructure
- The ideal geographical situation:
  - In the **heart of Europe**, no longer than 24h drive from all the major technology hubs and capitals
  - **Neighbouring** Czech Republic and Poland
  - Having a **population** over 4m inhabitants
- The local, national and European **support** to the region and cluster and the close cooperation between Silicon Saxony and public entities
- The identification of Semiconductors as **KETs**
- **Competence** for high volume **production** by Infineon and Globalfoundries (most powerful chip production in Europe)
- 9 **universities**, over 100,000 **students** and many **research** institutes

Key Challenges

- Lack of **corporate headquarters** in the region, and the local economy is SME based
- There is a visible **lack of VC** and business angels in the area
- Knowledge transfer structures are **underused**
- The current trend is leading to a production, product development and research relocation to **East Asia** and a local **dependency** on Asian foundries
- **Energy** costs are at a stage of **uncertainty** due to the national low carbon energy policy (Energiewende)
- The current **demographical shift** is leading to decreasing **start-up** activities and a lack of **skilled labour**

An innovative collaboration model: LITEK

LITEK

Laser & Engineering technologies cluster (LITEK) was established in 2011 but cooperation between science and SMEs goes back over 20 years.

It all started when manufacturers of laser systems in cooperation with scientific institutions began to develop unique products in the field of photonics in joint efforts.

These two players understood that combining different areas of knowledge, cooperating closely and sharing ideas are a main growth drivers.

LITEK

Founded: 2011

Location: Vilnius

Members: 10

Operating model

- Being a part of the cluster allows its members to combine resources and knowledge, carrying out joint R&D and Innovation oriented projects in order to remain competitive in international markets and efficiently enter new ones
- Various seminars and other events are regularly organized. The aim is to help the companies learn, share their experiences, discuss problems but also help each other to find technological partners
- Members of LITEK cluster members benefit from business support services. Members are advised on matters relating to research, development and innovation activities, their initiation, documentation, market trends and prospects, usage of R&D infrastructure etc. Consultations are also provided for partnerships, EU fund-raising and other development questions relevant for companies
- LITEKs goal is to become a dynamic center of activity, comprising a fully integrated value chain of researchers, suppliers, manufacturers and sellers

Training & research center

- The infrastructure of LITEK training and research center was established using European Union Structural funds:
- Cleanrooms equipped with research and prototyping equipment have been created for the joint use of the clusters members
- More than 500 people are working in LITEK companies, of who 20% hold a doctoral degree and more than EUR 1.6m per year are spent on implementation of R&D activities
- Today, annual sales volume of LITEK members is over EUR 50m and increasing

Evidence for the impact of clusters: Bosch's manufacturing facility

Bosch Chip Manufacturing Plant

Bosch announced the construction of a new semiconductor plant in 2017. The company is traditionally known as a maker of **mechanical automotive parts** such as braking systems and combustion engines, but is also a long-time **software developer** and is increasingly investing in **innovative technologies** to keep up with the changing nature of **driving**.

For almost 50 years, Bosch has been developing and manufacturing **microelectronic components** and systems. Bosch developed the microfabrication technique for microelectromechanical systems (**MEMS**) and today is the global **market leader**. According to the German company, every car sold globally contained an average of nine **chips** made by Bosch in 2016.

Why Dresden?

- Heart of Silicon Saxony cluster, part of Silicon Europe
- Cluster covering the whole value chain
- Core of the ICT Saxony Cluster (2,100 enterprises and 51,000 employees)
- Strong research and university landscape (13 Fraunhofer Institutes and 9 universities) suppling the region with skilled potential employees
- Functioning technology transfer structure
- Strategic cooperation with local, national, and European authorities
- Key area in "High-tech Strategy for Germany" and "Innovationsstrategy" and in high propriety foe EU-funding focused on "smart specialization"

"As an industrial location, the state of Saxony offers excellent conditions for enhancing our semiconductor expertise"

Dirk Hoheisel
Member of the Board

Plant key figures

- Location: Dresden, Germany
- EUR 1.1bn investment (largest in Bosch's history)
- Majority of the investment from Bosch and the rest from national and European Union subsidies
- Approx. 15,000 m^2 shopfloor space
- Up to 700 collaborators working on site
- Bosch holds more than 1,000 patents and patent applications related to MEMS technology
- Built to satisfy the demand generated by the growing number of internet of things (IoT) and mobility applications

Case of international collaboration: Silicon Europe

Silicon Europe Initiative

Silicon Europe is the brand under which the leading **micro-** and **nano-electronics clusters** in Europe collaborate to represent, support and promote companies and organizations belonging to their ecosystem both on **European and global level**.

The organization acts as **intermediary** between all the relevant **partners** from research and academia, public authorities and the industry.

The Alliance, an association **welcoming** other European micro- and nano-electronics clusters, **unites currently 13 European MNE clusters** with approx. 2,000 cluster partners.

This "**cluster of clusters**" stands for a new level of transnational **collaboration** and a combined innovative strength that is forecasted to significantly contribute to the future **competitiveness** of the European **economy**.

Strategic Objectives:

01. **Knowledge and technology transfer**
Clusters support exchange throughout Europe

02. **Smart Specialisation**
R&D along the Regional strongholds and markets

03. **SME Funding**
Clusters liaise SMEs to sources of capital

04. **International business development**
Increase international visibility and consequently detect and create opportunities for the (SME) members

05. **Promotion of micro- and nano-electronics**
Communicate at large the indispensable role in today's and future society

SILICON EUROPE

- **Silicon Saxony**
- **Minalogic**
- **DSP Valley**
- **High Tech NL**
- **Mi-Cluster**
- **Distretto HTMB**
- **MIDAS**
- **Silicon Alps**
- **GAIA**
- **NMI**
- **SCS Cluster**
- **Mesap**
- **Business Cluster Semiconductors**
- **Growing…**

Key success factors in three successful clusters

Among the most successful clusters, we find a combination of actors in the academic and research spaces closely collaborating with local authorities and industrial corporates. All are closely linked with financing intermediaries. This ecosystem creates synergies and contributes to the establishment of efficient clusters.

Cluster	Key success factors	Additional facts
France MINALOGIC	**Academic & research landscape** • Large number of internationally recognized higher education institutions • Focus on sciences and engineering contributing to the knowledge base • Skilled labor for the business and research landscape **Social capital** • Strong, efficient stakeholder collaboration • Frequent interaction between the public, private, research and industrial sectors **Financial support** • High investments in structural projects from the local, national and European authorities • Large investments in local research organizations and universities **Corporate presence** • Multiple corporates (STMicroelectronics, Schneider Electric, HP, Soitec, Siemens…) are based in the region	• The French government launched the "**pôle de compétitivité**" initiative in 2004 in order to take advantage of local partnerships between the private, public and research sectors • Minalogic was founded in 2005 and focuses on three strategic areas: **Micro-nanoelectronics, Photonics & Software**

Cluster	Key success factors	Additional facts
Germany SILICON SAXONY	**Academic & research landscape** • Large number of universities with a tuition focus on microelectronics • Strong presence of research institutes including Fraunhofer Institutes **Social capital** • A large population of over 4m people • Historic regional specialization and expertise in microelectronics • Close collaboration between the cluster governance and public authorities **Financial support** • Large investments from the local, national and European authorities **Corporate presence** • Competence for high capacity for production with due to the presence of Infineon and Globalfoundries fabs in Dresden	• The German State developed an "**Innovationsstrategie**" in 2013, set up for establishing **priorities for EU-funding** with a focus on "smart specialization" in Saxony • Silicon Saxony is the coordinator of **Silicon Europe**, which aims to unite clusters in an **alliance** with access to advanced technologies across the value chain

Cluster	Key success factors	Additional facts
Belgium & Netherlands	**Academic & research landscape** • In the heart of the largest Dutch and Belgian university and research ecosystem (KU Leuven, IMEC, High Tech campus…) **Social capital** • Tightly woven ecosystem of high-tech economic and social actors who collaborate frequently on multiple projects **Financial support** • Receives financing from multiple regional agencies, local provinces and European institutions to promote its objectives and support its projects **Corporate presence** • Concentration of corporates with a wide range of production lines including Philips, NXP, ASML…	• DSP Valley was founded in 1994 with Belgium's "**cluster policy**". Throughout the country thirteen 'clusters' are recognized through **bilateral agreements** between the government and the cluster organization, allowing specific support to set-up **infrastructure and targeted schemes**

Synergies with previous reports:

KETs I study findings:	▲	KETs II study findings:	▲▲▲

5.5 Finding 4: Corporates are important business development partners and often end up acquiring successful ventures

Key takeaways

- To support their development, photonics and semiconductor companies tend to depend on corporate collaborations, which can bring both financing resources and intangible support (e.g. networking, access to complementary intentional programming, infrastructure and commercial synergies, etc.).
- Large corporate players often become exclusive commercial partners or acquirers of photonics and semiconductor companies.

Based on the interviews conducted, we note 44% of respondents referenced the key role of corporates.

Segment	Photonis		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	**4** 33%	**2** 67%	**3** 43%	**4** 80%	**1** 14%	**0** 0%	**5** 83%	**2** 29%	**2** 67%	**23** 44%
Segment summary	Responses 13 (48%)				Responses 6 (40%)			Responses 4 (40%)		

Figure 20: Respondents mentioning the key role of corporates in supporting development of photonics and semiconductor companies

Source: Project team analysis

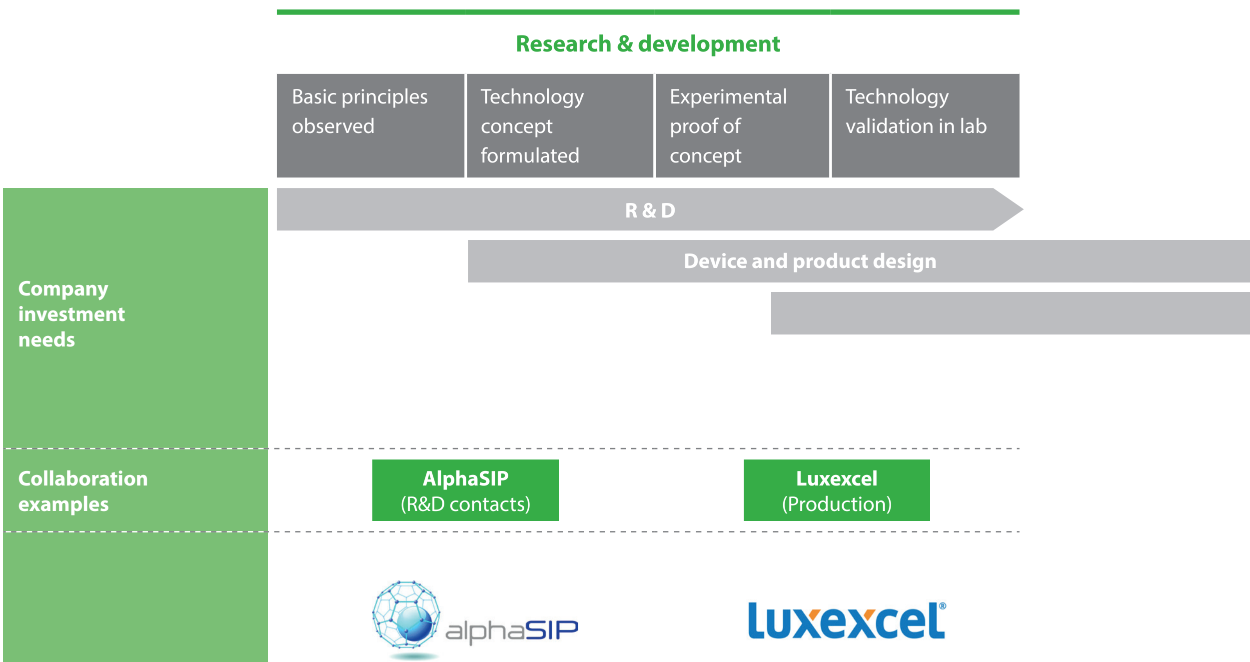
Collaboration, financing and strategic partnerships

To support their development, photonics and semiconductor companies tend to depend on corporate collaborations, which can bring both financing resources and intangible support (networking, access to complementary intentional programming, infrastructure and commercial synergies, etc.).

Specifically in semiconductors, fabless players (that is, companies that design microchips but do not have production facilities) involved in chip design activities typically rely on a few large corporate players worldwide (foundries) to proceed with prototype and proof-of-concept development, and later full-scale production. These interactions are often expensive and time-consuming for small companies.

Similarly, in photonics technologies linked to telecommunications, the avenues for commercialisation typically involve the large equipment providers to the industry.

In this context, several respondents mentioned that they are actively pursuing corporate collaborations or are already involved in them. Respondents also highlighted the need to align strategy and the overall terms and conditions to remain independent and competitive.



Collaboration through R&D contracts

LuxExcel enters in strategic partnership with KLA Tencor.

KLA Tencor participated in USD 10m series C funding round both **financially** and through **in-kind** industrial cooperation.

LuxExcel is now preparing a 3D-printing **platform** for global shipments to clients.

Collaboration through R&D contracts

AlphaSIP collaborates with large corporates (Bosch, NXP, J & J, STMicroelectronics, and Atmel) through **PPP projects** at national and European level worth over EUR 50m.

Figure 21: Corporate collaboration landscape

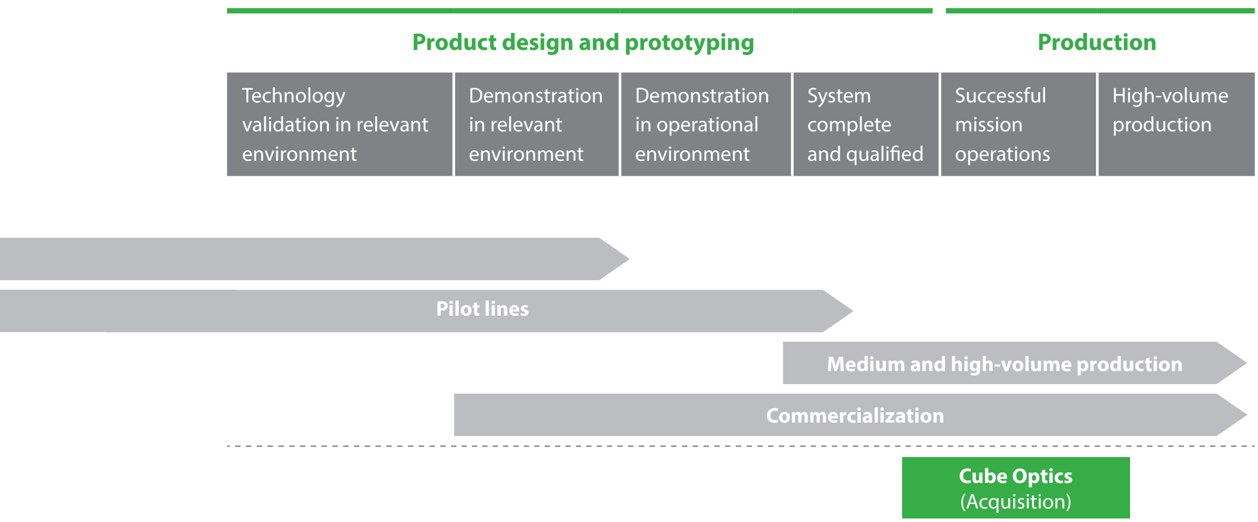
Source: Project team analysis, ECSEL, Free State of Saxony

Corporate exits a key avenue for many photonics and semiconductor companies

We note that a number of corporates monitor the photonics and semiconductor sectors on a structured basis through business development or VC arms. At the same time, takeover by a large corporate often imposes itself as one of the most viable options for entrepreneurs.

Indeed, large corporate players active in photonics and semiconductors tend to have an established presence in broad commercial applications where new technologies can be integrated. These often represent the preferred path to monetization of their technology.

The chart below illustrates interactions between photonics and semiconductor SMEs and corporates taking the shape of collaborations or financial exits.



HUBER+SUHNER

Acquired by corporate

HUBER+SUHNER acquires Mainz based **Cube Optics** for an undisclosed amount in 2014.

Cube Optics reported **revenues** of EUR 18.9m for the year ended 2013.

The goal was to enhance H+S's **position** in fiber optics and broadband communication and enter the **strategic market segments** of data centers and Fiber to Home.

As an additional note, we find that corporates play an important role in both sectors. Multiple sub-segments of photonics (telecommunications, media and technologies, health, industrial applications) as well as late-stage semiconductor manufacturing typically rely on large, established capabilities. As discussed in other sections, corporate collaborations are important at earlier stages, and barring the possibility of stand-alone development, may result in a strategic partnership or exit at later stages.

Synergies with previous reports:

KETs I study findings:	▲	KETs II study findings:	▲▲▲

5.6 Finding 5: Insufficient financing available for companies in the photonics and semiconductor sectors, with financing difficulties most pronounced at early-stage and growth-stage

Key takeaways

- Financing for companies in the Photonics and Semiconductor sectors is insufficient and the funding gap is particularly evident at growth stage.
- Difficulties for companies in both sectors are the result of supply-side risk aversion and lack of technology savviness, as well as less favourable investment characteristics of the sectors in scope.

This situation holds true for the KETs sector in general, confirmed by the findings of the KETs I and II studies.

Virtually all of the more than 50 respondents surveyed agree that **access-to-finance conditions in photonics and semiconductors are challenging**. We find that companies in both sectors face these difficulties, which we see as the result of both supply-side risk aversion and lack of technology savviness, as well as less favourable investment characteristics of the sectors in scope.

These difficulties equate to a funding gap in photonics and semiconductors, and are **most concentrated around two stages of company development** (see also, picture below):

- **At early-stage** after the initial seed phase: this is when **risk is high and investment requirements begin to rise** (typically around €1-5 million). At this stage, companies are essentially seeking to graduate from grant financing to private financing to support the product design phase.
- **At the growth stage of company development**: this is when industrialisation of technology and commercialisation require much larger investments (potentially above €10 million), while risks tend to remain elevated. At this stage, companies are essentially trying to launch medium- to large-scale production of a product proven viable based on earlier investments. Given short technology cycles and constant innovation in the sector, a viable product only remains so for a limited period of time, which tends to exacerbate the need to find commercial applications at this stage. This finding is also emerging from the KETs II study, which highlights the lack of financing options better fitted to the risk-return profile of KETs companies.

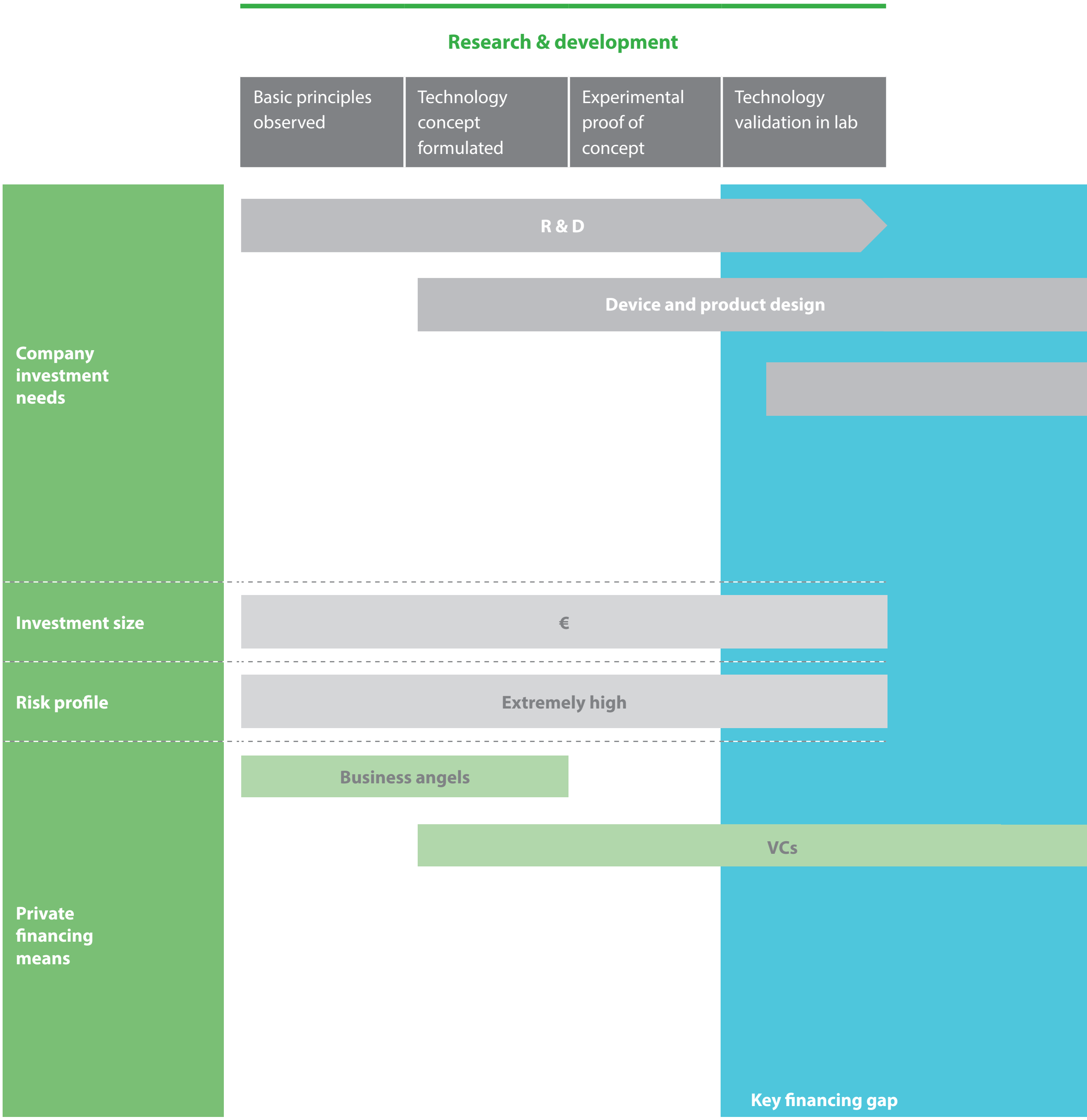
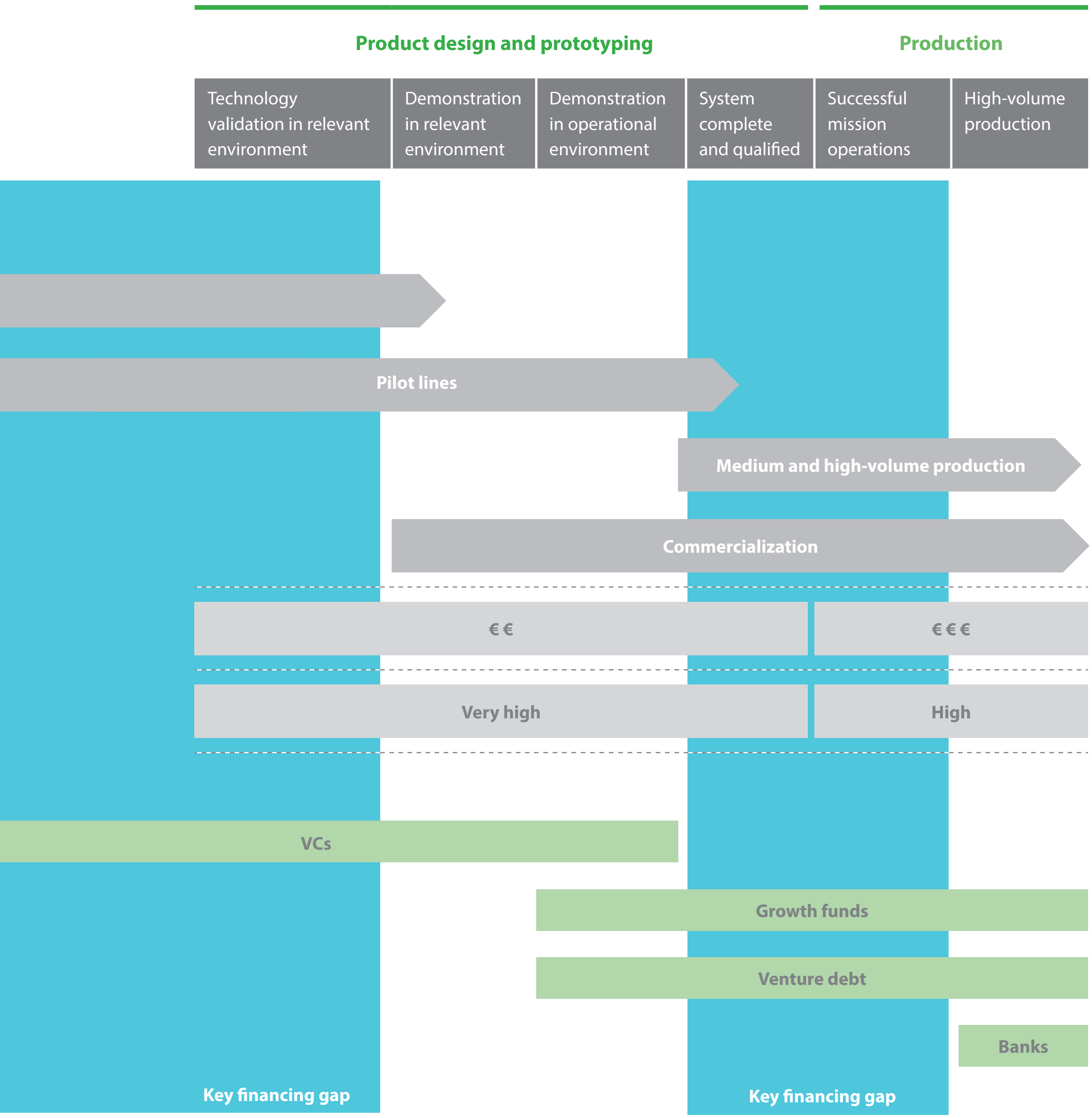


Figure 22: Photonics and semiconductors funding gap versus technology readiness level

Source: Project team analysis, ECSEL, Free State of Saxony


Product design and prototyping
Production
Technology validation in relevant environment
Demonstration in relevant environment
Demonstration in operational environment
System complete and qualified
Successful mission operations
High-volume production
Pilot lines
Medium and high-volume production
Commercialization
€€
€€€
Very high
High
VCs
Growth funds
Venture debt
Banks
Key financing gap
Key financing gap

Rounds of financing can also prove to be difficult when established photonics companies develop technologies to target new markets, as there is little proven track record. New markets require more time to penetrate; therefore, companies targeting such markets are often perceived as too risky by would-be investors despite their potential.

When the risk profile is too high for traditional private investors, capital still lies with corporates through strategic alliances. Collaborations are a way for companies (subject to alignment of objectives and subject to finding the right partner) to enable future growth.

"There is a stage at which companies struggle to obtain any type of financing. For example, our company is today too mature to attract business angels and at too early a stage for VCs."

Small start-up company

"The EU lacks when it comes to capital to invest and VCs to invest it. Many middle-tier companies seek financing from overseas nowadays."

Specialised VC

"One of the key challenges companies face is to finance the development of their product from proven technology to prototype and then production."

Multiple company and institutional responses

"There is a lot of European and public money in grants and loans, but not in equity. Equity is what most start-ups actually need in order to obtain loans."

Small start-up company

Synergies with previous reports:

KETs I study findings:	▲▲▲	**KETs II study findings:**	▲▲▲

5.7 Finding 6: Technological complexity and less compelling investment characteristics are key issues limiting access to finance for photonics and semiconductor companies

Key takeaways

- The core underlying technologies are highly complex and require a high level of technological education to be properly understood.
- Most private investors do not have the technical background and capabilities to assess investment opportunities from a technical standpoint.
- As a result, the potential commercial applications are not always evident to potential investors, in particular in the case of photonics, which also lacks visibility.
- Companies in the photonics and semiconductor sectors tend to present intrinsic characteristics that make it harder for them to attract investor interest compared to technology sectors such as software or e-business. These characteristics include high-risk and technology uncertainty, long R&D development lead times and capital intensiveness.
- Integration across the value chain poses an additional challenge for certain developing companies which need to find the right commercial partners to position themselves with an integrated customer proposition in order to unlock the value of their technology.

Segment	Photonics		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	**7** 58%	**1** 33%	**2** 17%	**2** 40%	**3** 43%	**2** 100%	**2** 33%	**3** 43%	**3** 100%	**25** 48%
Segment summary	Responses 12 (44%)				Responses 7 (47%)			Responses 6 (60%)		

Figure 23: Respondents mentioning complexity and lack of understanding of photonics and semiconductor business models

Source: Project team analysis

Feedback from interviews highlights the technological complexity of the photonics and semiconductor sectors as one of the reasons limiting private investor interest in the sector. In addition to the inherent complexity of technological topics, the fast and frequent technology evolutions were mentioned as an additional difficulty for non-specialists to appreciate the technical relevance of investment opportunities presented.

On the financing side, we find that investors, whether venture capital providers or banks, tend not to have sufficient technical capability to assess photonics and semiconductor investment opportunities. Through the study, it appears that even specialised providers may not have all the in-house technology resources required. Some of them rely on third party technical evaluations, others on evaluations of other financing providers (e.g. debt providers relying on equity provider assessment).

In the case of photonics in particular, lack of visibility was also mentioned as a key constraint. Photonics ventures tend to be very quickly associated with the end market where the initial technology tends to present potential (e.g. healthcare). This is seen by some as curbing the transversal application of photonics technologies across multiple end markets and, as a result, limiting the development of photonics as a stand-alone, bona fide sector in the mind of private investors.

Technological complexity as a financing challenge is also particularly true in the photonics sector, where the diversity of core technologies and potential applications is high. Financing intermediaries surveyed, who tended to be specialised in the sectors, also clearly recognised the uniqueness of their approach and the general lack of understanding of the sectors in scope.

"Many financial players do not understand hardware companies and products. This makes it difficult to benchmark, compare and carry out due diligence."

Small early-stage semiconductor company

"What we really need is an investor or a set of investors who can appreciate the long-term disruptive potential of our semiconductor technology."

Small early-stage photonics company

"The sector is a complex one that you need to understand before making a move. However, many investors do not try to understand the fundamentals when looking at it."

Large commercial bank telecommunications, media and technology division

"VCs tend to look for "low risk = high return" profiles, which are almost non-existent in these sectors."

Small seed-stage photonics company

Intrinsic characteristics posing specific financing challenges

As shown in the table below, 54% of respondents mentioned investment characteristics of the sectors as a key issue impacting access-to-finance conditions.

Segment	Photonics				Semiconductors				Financing Intermediary						Sector promoters				Total	
Respondent type	Seed / Startup		Scale Up		Seed / Startup		Scale Up		VCs		Banks		Corporates		National Players		Clusters		Total	
Number of respondents	12		3		7		5		7		2		6		7		3		52	
Number and percentages of responses in favour	4	33%	1	33%	6	86%	2	40%	6	86%	2	100%	2	33%	3	43%	2	67%	28	54%
Segment summary	Responses 13 (48%)								Responses 6 (40%)						Responses 4 (40%)					

Figure 24: Respondents mentioning less compelling investment characteristics for private investors versus other growth technology business models

Source: Project team analysis

Photonics and semiconductor technologies are also in many cases potentially disruptive technologies carrying intrinsically higher risk and uncertainty about their potential to gain traction and generate demand in their respective end markets compared to other technology-driven opportunities. The risks inherent to photonics and semiconductor companies are twofold:

- Technology risk, i.e. uncertainty on the applicability of the technology to address a given objective/ market need.
- Market risk, i.e., uncertainty on the ability to monetise the given technology (even if it proves to be an effective solution) due to the risk of substitutes, the threat of faster competitors bringing a workable solution to market, etc.

During early stages, material investments are required to develop photonics and semiconductor technology with uncertainty on the technological outcome. At later stages, further investment, usually of even higher magnitude, is required to fund production and commercialisation, with uncertainty around the market and demand. The combination of these two risks, high reinvestment requirements and long development lead times from early stage make it difficult for many private investors to fund the sectors in scope.

Another consideration is that most companies in the photonics and semiconductor sectors tend to be focused on hardware technologies i.e., representing a physical product or playing a role in the production of a physical product such as an integrated circuit, an imagery device, a measurement device, etc.

As a result, the development of these companies is typically capital-intensive, because it requires investments in research & development and also in the making of prototypes, which are needed to demonstrate the viability of the technology in scope. When a prototype's viability is demonstrated, manufacturing and commercialisation of the early-stage versions of the product also require substantial investment due to the complexity and specificity of the technologies.

For semiconductors, a complicating factor is that prototyping and manufacturing capabilities are typically concentrated in the hands of a few large global players such as Globalfoundries, Infineon and ST Microelectronics, so requiring high fees to secure production rounds. Development lead times and time to revenue generation also tend to be long, with multiple financing rounds typically necessary to support the development of the technologies up to commercial viability.

Because of the capital-intensive nature of these businesses, photonics and semiconductor businesses tend to be less scalable businesses compared to other technology ventures, and therefore present less potential for high/multiple payback at exit for private financing firms.

Integration across the value chain an additional challenge for developing companies

More generally, photonics and semiconductors face the question of technology integration. Young ventures in these sectors are perceived in many cases as promoters of focused technology blocks, or elements of a broader value chain. These individual pieces gain commercial relevance only when integrated into a consistent customer proposition. This implies a higher degree of complexity for investors when it comes to value creation, as the success of the integrated whole dictates the success of the individual piece.

> "Hardware is capital-intensive, and requires larger investments than traditional VCs offer. There are not as many big hits in hardware as in e-commerce or software, which have higher margins, require less capital and are more familiar to investors."

High tech specialised VC

"There is an extremely long sales cycle and the activity of these companies is very capital-intensive."

International VC

"Finding commercial partners to integrate a technology into a commercially viable whole is often a challenge for developing photonics companies."

Established national funding agency

As an additional note, we find that the issue discussed in this section is equally important in photonics and in semiconductors. Multiple company respondents have mentioned the difficulty of convincing private investors about the viability of their business, although all those interviewed were ultimately successful in funding at least part of their early-stage requirements. Similarly, financing intermediaries surveyed were generally very clear and explicit about the reasons why the sectors compare less favourably to other risk financing opportunities. We also note from one of the private investors interviewed (a serial semiconductor entrepreneur) an upbeat view on investment potential in the sectors, on the condition that investors possess the right level of knowledge and expertise to understand the risks and support the venture adequately.

Synergies with previous reports:

KETs I study findings:	▲▲▲	**KETs II study findings:**	▲▲▲

5.8 Finding 7: There is limited VC funding with sufficient focus and technology expertise to target the photonics and semiconductor sectors

Key takeaways

- There is a lack of private investor interest and few specialised investors willing and able to provide risk financing to photonics and semiconductor companies.
- We observe a private funding gap for photonics and semiconductor companies, which is concentrated around two critical life cycle moments of company development, i.e. early-stage financing and growth financing.

As shown in the below table, 54% of respondents mentioned the shortage of venture capital as a key issue in terms of access to finance for photonics and semiconductor companies.

Segment	Photonics		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	**5** 42%	**3** 100%	**4** 57%	**3** 60%	**4** 57%	**2** 100%	**3** 50%	**2** 29%	**2** 67%	**28** 54%
Segment summary	Responses 15 (56%)				Responses 9 (60%)			Responses 4 (40%)		

Figure 25: Respondents mentioning a shortage of venture capital and private funding gap in the photonics and semiconductor sectors

Source: Project team analysis

Lack of private investor interest and few specialised investors

Due to the combination of these factors, and the technical complexity described previously, private financing firms generally show limited interest in the photonics and semiconductor sectors. We find that only a limited number of funds, typically those with a degree of specialisation in technology, are willing and able to provide risk financing to the photonics and semiconductor sectors.

Through our research and identification of financing intermediaries, we have identified approximately 150 funds (~14% of the total number of funds in the EU) with past or present activity in the photonics space. Of these, only 18 can be described as having primary investment focus on these sectors (which we defined as "specialised").

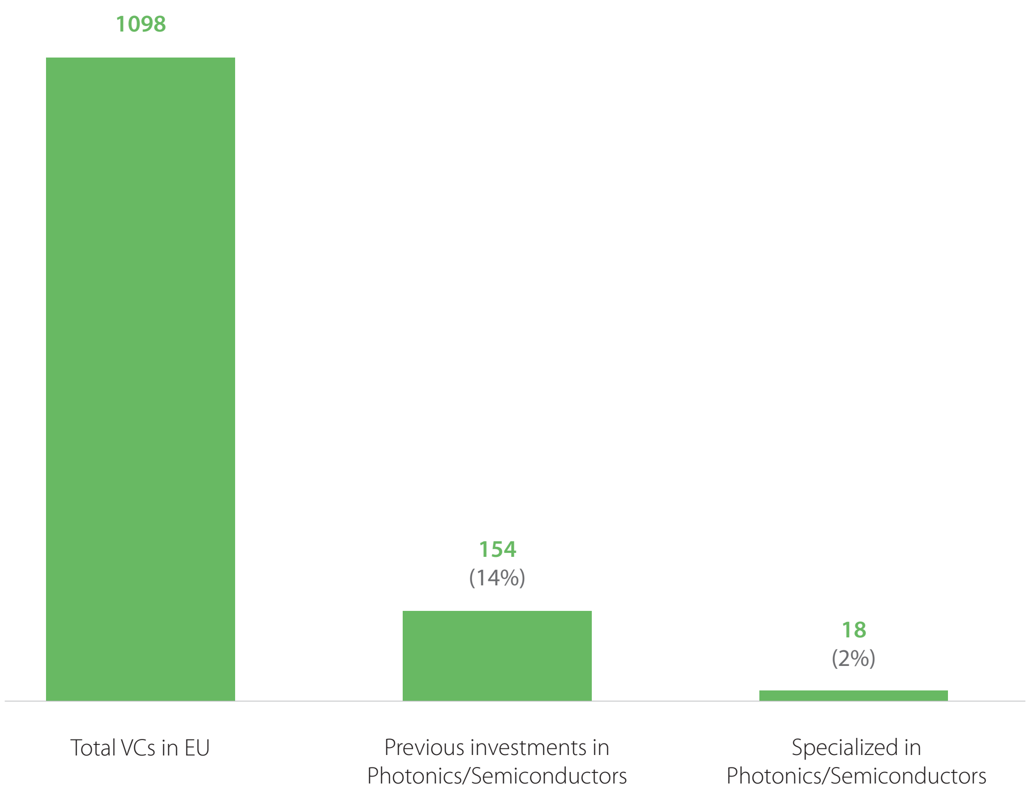


Figure 25: Number of specialised VC funds in the EU

Source: Project team analysis

Examples of such players with a focus on the sectors in scope encountered through this study include Target Partners and Bullnet Capital, as detailed in the table below.

TARGET PARTNERS	• **Country:** Germany • **Assets under management:** EUR 300m • **Founded in:** 2000 • **Geographical exposure:** Germany, Austria, Switzerland • **Photonics investment examples:** Sicoya, Cube Optics…	• Target Partners targets have activities in the IT domain • Target Partners benefits from a tech savvy team some with a background in photonics • The fund provides financing during the whole development cycle of the company
Bullnet capital	• **Country:** Spain • **Assets under management:** EUR 98m • **Founded in:** 2001 • **Geographical exposure:** Spain, Portugal • **Photonics investment example:** Anafocus	• Bullnet targets IP companies and those of R&D background • Bullnet Capital benefits from an extensive experience in investing in semiconductors companies due to the engineering background of the founders • The fund is EIF backed

Feedback from interviews underlined a very pronounced funding gap in terms of private capital for photonics and semiconductor companies. Financiers themselves acknowledged the difficulty of overcoming sector characteristics to find attractive investment propositions. Entrepreneurs interviewed cited a number of financing success stories but also detailed the difficulties to get traction with potential investors.

As observed in other sectors, we find that the funding gap for photonics and semiconductor companies is particularly pronounced at a couple of key moments in their development:

- At early-stage after the initial seed phase: this is when risk is still very high and investment requirements begin to rise (typically around €1-5 million). At this stage, companies are essentially seeking to graduate from grant financing to private financing to support the product design phase.
- At later "growth" stages of company development: this is when industrialisation of technology and commercialisation require much larger investments (potentially above €10 million), while risks tend to remain elevated. At this stage, companies are essentially trying to launch medium- to large-scale production of a product proven to be viable based on earlier investments. Given short technology cycles and constant innovation in the sector, a viable product only remains so for a limited period of time, which tends to exacerbate the need to find commercial applications at this stage.

Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲▲

5.9 Finding 8: Commercial bank funding is generally not available to photonics and semiconductor companies

Key takeaways

- Many photonics and semiconductor companies are focused on intangible technology developments and have no or limited tangible assets that can be pledged as collateral in deals with potential financing partners.
- With some rare exceptions, commercial banks tend to have very limited activity in the photonics and semiconductor space, mainly due to risk considerations.

As shown in the table below, 54% of respondents recognised the shortage of bank funding as a key issue in terms of access to finance for photonics and semiconductor companies.

Segment	Photonics		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	9 75%	2 67%	5 71%	1 20%	4 57%	2 100%	0 0%	3 43%	2 429%	28 54%
Segment summary	Responses 17 (63%)				Responses 6 (40%)			Responses 5 (50%)		

Figure 26: Respondents mentioning that commercial bank funding is generally not available where needed in the photonics and semiconductor sectors

Source: Deloitte analysis

High risk aversion limiting bank lending availability

According to our conversations with financing professionals, commercial banks tend to be extremely risk-averse and to avoid sectors where risk cannot be quantified and projected with confidence. As a result, commercial banks are generally not even active in the photonics and semiconductor spaces, unless dealing with larger established players with secure financial flows. This is mostly due, once again, to the intrinsic characteristics of the sectors and their technical specificities, which make it complicated for banks to evaluate the risk profile of potential loan candidates.

Limited collateral available during companies' development

In addition, despite the fact that photonics and semiconductor companies tend to focus on the development of hardware, they typically have little or no hard assets to pledge during their development phase.

In fact, none of the companies surveyed in this survey had access to commercial bank lending in the early to mid-stage of their development. Only those companies (e.g. Amplitude) that have attained a much more stable market position and revenue stream tend to enjoy access to commercial loans.

In this aspect, we don't find that access to finance for photonics and semiconductor companies differs from that of other KETs. It is generally accepted that bank funding is not easily available or is largely non-existent for most high-risk ventures. Nevertheless, we note that the factors mentioned previously exacerbate this limitation for photonics and semiconductors, because of the technological complexity (requiring special know-how for evaluation), the long development lead times and the high level of capital investment required.

The use of intellectual property as potential collateral, which has been mentioned in previous projects as a potential solution, does not yet appear as a convenient solution for the companies and professionals interviewed, who cited legal and valuation complexity as limitations, among other factors.

Through our research, we attempted to evaluate whether programmes such as the SME Guarantee were seen as effective mitigation of the risk constraints encountered by banks. Feedback from financing professionals, however, suggests that such guarantees are not sufficient to overcome risk aversion in these high-risk sectors. One bank executive commented that the bank looks at each deal's fundamental prospects, and that a public guarantee on the part of the total facility would be welcome, but not sufficient, to fulfil the bank's risk criteria.

We note a few exceptions of banks or debt-funding entities active in the technology field:

SVB Silicon Valley Bank	• **Country:** United States • **Founded in:** 1983 • **Geographical exposure:** Global • **Type of financing:** Venture debt • **Photonics investment example:** Sabeus Photonics…	• Innovative companies are privileged targets without any restriction on their activity sector • SVB is known for being able to deal with complex tech companies and offer financing where classical commercial banks do not
Kreos Capital	• **Name:** Kreos Capital • **Country:** United Kingdom • **Founded in:** 1998 • **Type of financing:** Venture debt and growth capital • **Geographical exposure:** Europe, Israel • **Photonics and semiconductors investment examples:** Rockley, Crocus…	• Kreos Capital is investing in startup, early stage, mid stage and late stage companies. • The firm seeks to invest in companies that are backed by an established VC • The firm can provides up to EUR 30m per investment
Barclays	• **Name:** Barclays TMT • **Country:** United Kingdom • **Founded in:** 1896 • **Type of financing:** Debt financing • **Geographical exposure:** United Kingdom, Europe	• As a leading bank, Barclays finances KETs companies through its TMT department • The TMT department is made up of processionals with a tech background • Barclays TMT operates a GBP 100m fund in collaboration with the EIF • The bank claims to be the largest lender in Europe

"Most Photonics and Semiconductor start-ups have little capital or collateral, which creates complications when they approach commercial banks for loans."

Semiconductor research technology organizations

"Commercial banks are not interested in lending cash to photonics and semiconductor companies. Companies, however, need loans to cover their development needs in a non-dilutive way."

Sciences specialised VC

Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲▲

5.10 Finding 9: There are opportunities to improve the awareness of and roll-out of EU financing tools to photonics and semiconductor companies

Key takeaways

- Direct lending from the EIB to the photonics and semiconductor sectors is limited, but it addresses a real market need.
- Indirect financing of VC funds is necessary but not sufficient to meet specific photonics and semiconductor market needs.
- There is insufficient awareness and understanding of EU financial instruments (EIB, EC, etc.).

There is insufficient awareness and understanding of EU financial instruments (EIB, EC, etc.)

As shown in the below table, 31% of respondents underlined a lack of EU instruments among photonics and semiconductor companies.

Segment	Photonics		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	8 67%	0 0%	5 71%	2 40%	1 14%	0 0%	0 0%	0 0%	0 0%	16 31%
Segment summary	Responses 15 (56%)				Responses 1 (7%)			Responses 0 (0%)		

Figure 27: Respondents mentioning the complexity, insufficient awareness and understanding of EU financial instruments

Source: Deloitte analysis

We note the lack of awareness and the perceived complexity of public programmes and instruments that companies may benefit from.

The majority of start-ups made reference to the need for more clarity and easier application processes. Some companies, in their own words, went as far as spending significant amounts of time and energy on preparing complex applications only to realise down the road that they were not eligible for the programme considered.

Based on the interviews conducted, about one third of respondents mentioned the complexity, insufficient awareness and/or understanding of EU financial instruments. A majority of these responses came from companies. On the whole, this feedback reflects a general impression among respondents that there are many instruments potentially available to companies, and that evaluating which of those are worth investing time in is a challenging task for entrepreneurs who are usually fully engaged in the development of their product and business. What this feedback also underlines is the potential for more consolidated financing guidance at international or European level about the instruments on offer, eligibility criteria and practical aspects required to be able to apply for these programmes. Beyond this, several participants mentioned that the application processes themselves tend to be complex and time-consuming.

"EU financing initiatives are of great help to companies like us, but have become less and less accessible over the years."

Seed-stage photonics company

"There is a lack of specialised VC funds. The EC could encourage the creation of specialised funds managed by industry experts."

Medium-sized scale-up stage semiconductor company

"The EUREKA grant application was very time-consuming and we received a negative first feedback. Grant applications are often unaligned with start-ups."

Small start-up photonics company

Direct lending from the EIB to the photonics and semiconductor sectors is still limited although the instruments are positioned against a real market need

As shown in the below table, 42% of respondents recognised the importance of EU direct financing to support access to finance for photonics and semiconductor companies.

Segment	Photonics				Semiconductors				Financing Intermediary						Sector promoters				Total	
Respondent type	Seed / Startup		Scale Up		Seed / Startup		Scale Up		VCs		Banks		Corporates		National Players		Clusters		Total	
Number of respondents	12		3		7		5		7		2		6		7		3		52	
Number and percentages of responses in favour	4	33%	0	0%	4	57%	3	60%	4	57%	1	50%	3	50%	2	29%	1	33%	22	42%
Segment summary	Responses 11 (41%)								Responses 8 (53%)						Responses 3 (30%)					

Figure 28: Respondents mentioning the importance of direct lending for photonics and semiconductor companies

Source: Deloitte analysis

In terms of direct financing, we found limited evidence of loans issued by the EIB specifically to the photonics and semiconductor sectors. Some exceptions are worth noting, however. For example, the case of Heliatek stands out. The company, active in organic photovoltaic and solar film manufacturing, was able to secure a financing package of €80 million, including €20 million in loans from the EIB, €42 million in equity, and about €18 million in subsidies.

In the sample of companies surveyed, we found no respondents were recipients of direct loans from the EIB. One company, Smart Photonics, mentioned it had received a loan from the Netherlands Investment Agency with secondary backing from the EIB. Anecdotal evidence and observations made in previous studies support a similar finding. We note that we could not access the EIB's transaction database to further substantiate this finding.

Nevertheless, feedback from multiple financing players and entrepreneurs indicates a need for non-dilutive instruments to complement private equity financing. Having to go through multiple rounds of equity financing, founders typically find themselves diluted to a significant extent. Anecdotal evidence indicated that it is common for photonics and semiconductor company founders to be diluted down to 1% or less of the firm they founded. As such, instruments that may support the development of the business while protecting the motivation of the founders are critical.

Several financing players also shared feedback on the guarantees provided by the EIB to encourage loans to SMEs. Based on these discussions, it appears that such guarantees are seen as insufficient to compensate the very significant risks inherent to the photonics and semiconductor sectors and the general aversion to such risk that most commercial banks tend to have. In fact, those financing players with active relationships in photonics or semiconductors (e.g. Barclays, Kreos) tend to do so mainly based on the intrinsic merits of the ventures, which they as credit specialists focus on assessing. Financial guarantees are seen as welcome by such investors but are not judged to be the primary criteria to support investment decisions.

Indirect financing of VC funds is necessary but not sufficient to meet specific photonics and semiconductor market needs

As shown in the below table, 35% of respondents recognised the importance of EU indirect financing to support access to finance for photonics and semiconductor companies.

Segment	Photonics		Semiconductors		Financing Intermediary			Sector promoters		Total
Respondent type	Seed / Startup	Scale Up	Seed / Startup	Scale Up	VCs	Banks	Corporates	National Players	Clusters	Total
Number of respondents	12	3	7	5	7	2	6	7	3	52
Number and percentages of responses in favour	3 25%	2 67%	3 43%	1 20%	2 29%	2 100%	1 17%	2 29%	2 67%	18 35%
Segment summary	Responses 9 (33%)				Responses 5 (33%)			Responses 4 (40%)		

Figure 29: Respondents mentioning the importance of indirect financing of VC funds for photonics and semiconductor companies

Source: Deloitte analysis

In terms of indirect financing in the form of investment into venture capital funds, we note generally very good feedback from financing players interviewed. Such investment is seen as a way to enhance investment capacity while allowing private risk capital specialists to handle the investment process, with the intention of allocating capital efficiently to companies presenting sufficiently attractive propositions.

Our observation is therefore that such indirect support is necessary to support the European venture capital industry. However, we also note that few specialised photonics and semiconductor funds exist, and that generalist funds generally don't invest actively in these sectors due to a lack of familiarity, but also due to specific risk/return profile as discussed in 4.2.

Based on this, and as corroborated by several discussions with financiers, we note that general indirect financing support is not sufficient to ensure these funds are effectively deployed to the photonics and semiconductor sectors. This will be the subject of a proposed action in the next chapter.

Synergies with previous reports:

KETs I study findings:	▲▲▲	**KETs II study findings:**	▲▲▲

Key recommendations

6.1 Review of the applicability of KETs I and II recommendations to photonics and semiconductor companies

The key findings of this study confirm the conclusions of the previous KETs I and II Studies and show that semiconductors and photonics share common characteristics and features with other KETs companies. The tables below depict the relevance of the recommendations from the KETs I and II Studies for photonics and semiconductor companies

	Previous KETs I study findings	Relevance for this study	Comments
1	Implement measures to increase potential customers' awareness of the EIB and EC communication channels.	✓	Multiple comments made about need for more awareness and better understanding of EU financing offerings.
2	Through the existing financial instruments: • Continue being a stable KET player in all phases of the market cycle • Expand indirect equity approach: the EIB should increase its lending activities to public technology investors. Based on loans provided by the EIB, technology investors can effectively provide equity to KET companies	✓	Multiple comments made on the relevance of indirect funding by the EIF; and potential for further and more targeted measures for photonics and semiconductors. Existing instruments targeted at market needs exist but do not appear to reach many photonics and semiconductor companies.

	Previous KETs I study findings	Relevance for this study	Comments
3	Review existing internal lending processes and procedures to enhance responsiveness and maximise customer satisfaction.	✓	Feedback from multiple stakeholders indicates a need for debt instruments with supportive risk-sharing mechanics, as an alternative to equity and its impact on founders' interests.
4	Set up targeted/specialised advisory services including use of "expert pools" to assist in the assessment of new technologies and their market potential to help KET companies prepare for financing. Such additional resources could bring "science to finance" and "finance to science".	✓	Photonics and semiconductor technologies and business models tend to be complex and are generally not understood well by the financing community.
5	Leverage existing EFSI/InnovFin resources to develop targeted/bespoke financial mechanisms, including investment platforms that can provide: • Equity and equity-type debt to companies on the verge of commercialisation of planned ambitious investments - "venture debt" to high-growth/young KET companies	✓	Broad-based consensus from respondents about the need for more, and more targeted measures by EU institutions to promote photonics and semiconductors
6	EIB to investigate the possibility to increase the acceptance of intellectual property as collateral for debt financing.	✗	Limited relevance. Multiple comments made about the complexity of intentional programming-based collateral solutions with a clear preference for fast and agile tools of most companies surveyed
7	EC to review regulatory matters, potentially affecting KET investments and access to finance.	–	No comments received
8	EC to review content/user friendliness of EIPP and to evaluate the launch of a platform on best fundraising practices.	–	No comments received

	Previous KETs I study findings	Relevance for this study	Comments
9	Promote the increase of resources for KET investment schemes / financial products at national levels.	✓	Multiple comments on positive role of national players which could be further supported.

	Previous KETs II study findings	Relevance for this study	Comments
1	Reduce information asymmetries about KET companies by developing a European Information Sharing Platform and, in the medium term, a technology credit assessment tool to support public decision-making processes.	✓	While the credit assessment tool for KETs was not explicitly covered in this study, the report identifies a need to improve information flow, visibility and awareness of photonics and semiconductor companies.
2	Fine-tune existing financial instruments and programmes to better fit the KETs/Deep Tech risk-return profile, including dedicated instruments: 1) contingent grants or forgivable debt facilities, 2) equity financing, 3) hybrid instruments, and 4) supply chain financing.	✓	The study identifies the need for financing blended instruments and more targeted financial instruments for photonics and semiconductor companies.
3	Enhance the enabling environment for KET companies by fostering "joined-up" innovation ecosystems and regional clusters.	✓	The study identifies the need for better coordination among national funding agencies and clusters.

6.2 Overview of key recommendations

The recommendations which follow draw on the previous KETs I and II studies. Given the clear similarities, it is important to take a systemic approach in addressing access-to-finance issues that embraces not only semiconductors and photonics but covers the entire spectrum of KET companies. Such an approach should benefit from a more efficient deployment of resources, avoiding excessive fragmentation.

The rationale for such measures finds its root in the strategic and crucial role that KETs companies have in the next wave of digital innovation based on Deep Tech. Europe is well-positioned to reap the benefits of this digital revolution in terms of technologies, expertise, skills and knowledge. However, improving access-to-finance conditions for European KETs companies is an important step if Europe is to be at the forefront of the next wave of innovation based on Deep Tech, which will drive economic growth by improving current products and services, creating new markets, and solving major societal and environmental issues.

We propose **five recommendations to improve access-to-finance conditions in the photonics and semiconductor sectors**:

01. **Strengthen existing indirect funding mechanisms** for private financing, to encourage private investment firms to allocate more attention and funds to Deep Tech companies including in the photonics and semiconductor sectors.

02. **Adapt existing financial instruments and programmes** to better fit the risk-return profile of KETs companies via **dedicated resources** to support these companies.

03. Develop blended financial instruments (combining public and private funding) **including conditional grant, contingent grant and co-investment programmes** to better support Deep Tech/KETs companies, encouraging businesses to build on the momentum around grant issues and secure additional third party financing.

04. Promote further **coordination with national programmes**, to encourage more specific roll-out of funds to Deep Tech/KETs companies involving collaboration between national funding agencies and European entities.

05. Launch an i**nitiative to improve the visibility of photonics and semiconductors**, to raise awareness and maximise exposure of investment opportunities with potential investors. In addition to general market visibility efforts, this initiative could also entail better coordination between the EIB and ECSEL to ensure ECSEL-funded projects are adequately considered for follow-on support by the EIB, other public agencies and the private sector.

Premise for our recommendations: the case for targeted measures in support of KETs companies

Several of the recommendations outlined in this chapter based on the feedback gathered from market participants have in common the introduction of a degree of "targeting" toward KETs.

Most financing instruments in place today tend to be transversal and to apply across multiple industries. It is our view that more sector-specific measures should be considered for a number of reasons.

First and foremost, there are a number of factors intrinsic to the sectors in scope, which exacerbate financing scarcity for KETs companies, including photonics and semiconductor companies. As discussed in previous sections, those factors include:

- The inherent complexity of the technologies at hand, requiring significant technological knowledge and experience to be evaluated from an investor standpoint.
- The investment characteristics including high uncertainty and risk, long development lead times and higher capital intensity.

Second, we observe a lack of relevant technology expertise in the investment community. This is true on the private sector side, where we observe that a small percentage of the VC funds in Europe have a dedicated focus on these sectors. This is also true among public investors, although certain institutions (e.g. EIB, ECSEL) have assembled technical expert panels to address the need for strong technological assessments. Nevertheless, with high-end photonics and semiconductor technologies evolving rapidly and constantly, sound technological judgement is a scarce resource and accessing it with the agility required to capture an investment opportunity is particularly difficult.

Looking at international benchmarks, we also note that several other countries or regions outside Europe have developed sector-specific financing initiatives to support strategically important sectors for their respective economies. Such initiatives provide relevant examples and may contribute to other countries gaining market share and competitiveness compared to EU-based photonics and semiconductor companies.

Programme	Description	Targeted companies
USA **SBIR**	• The Small Business Innovation Research (SBIR) program is a highly competitive program that encourages small businesses to engage in Federal Research/Research & Development that has the potential for commercialization • By reserving a specific percentage of federal R&D funds for small businesses, SBIR protects the small business and enables it to compete on the same level as larger businesses • SBIR funds the critical start-up and development stages and it encourages the commercialization of the technology, product, or service which are often beyond the means of many small businesses	**Research intensive** **Engineering** **Technology** **Science**

Phase I	Phase II	Phase II
Establish the technical merit, feasibility, and commercial potential of the proposed R/R&D efforts and to determine the quality of performance of the small business.	Funding is based on the results achieved in Phase I and the scientific and technical merit and commercial potential of the project proposed in Phase II.	Where appropriate, allow the small business to pursue commercialization objectives resulting from the R&D activities.

Success stories: Apple, Compaq, Intel …

Programme	Description	Targeted companies
Israel **Yozma**	• Until the 1990's, Israel had very little venture capital activity. Today, it hosts a local VC community which invests almost twice as much (per capita) as that in in the US. VC emergence in Israel, however, was a policy-enhanced process; triggered by a targeted government policy (Yozma) • The objective was to create a solid base for a competitive domestic VC industry with a critical mass of capital and activity • The program was based on a USD 100m government owned VC fund (called Yozma) oriented to two functions: **1** **Indirect investments in 10 private VC funds – USD 80m** **2** **Direct investments in high tech companies -USD 20m** **"Yozma Fund" characteristics** • Each 'Yozma Fund' had to engage as an LP together with a well-established Israeli financial institution • Government would invest 40% (up to USD 8m) of the funds raised through Yozma. Each Yozma fund had a call option on Government shares, for a period of five years (risk-sharing incentive for investors, as well as leverage for profits through potential acquisition of government shares) • Planned 'Privatization' of Yozma Venture Fund and its Hybrid Funds took place in 1998 and government returns exceeded the USD 100m invested **Success stories:** BioSense, Oramir, AG Israel …	**High-tech focused start-ups and early stage companies**

Targeted measures are also important to support a crucial European sector and one of the key building blocks of the next digital revolution based on Deep Tech. Europe cannot miss out on the potential and opportunities offered by the next wave of digital innovation. Examples of high-potential emerging companies suggest there is indeed the possibility for such companies to emerge, in particular because most of these players have benefited from public funding throughout their development.

	Company	Description
Proven unicorns	Amplitude	• Amplitude was identified by Techtour as a European Unicorn and figures in the "Growth 50" (list of 50 of Europe's fastest growing pre-exit investor backed companies) • The company has raised over EUR 30m in capital and benefited from Bpifrance financing
	ASML	• ASML Holding was founded in 1983, just over 10 years later it launched an IPO on the NASDAQ, and today, is one of the largest semiconductor companies in the world • The company was among the first to co-develop in a network of partners, universities, and institutes
	Crocus Technologies	• Crocus was also identified by Techtour as a European Unicorn and figures in the "Growth 50" • The French stat-up founded in 2004 has raised over EUR 180m to date including EUR 19m in its last series E round. Kreos Capital, the growth debt provider also backed the round
	Sigfox	• Sigfox is internationally recognized as France's IoT unicorn and also figures in the "Growth 50" • The Toulouse based stat-up is the world's leading provider of connectivity for IoT. The company has raised almost EUR 300m to date from a wide range of investors including corporates and Bpifrance
High potential companies	Aledia	• Aledia figured in the "Barometer of highest valued French start-ups" - Cambon Partners & Challenges (2016) and their technology has obtained Nobel prize laureate appraisal • The company raised a total of EUR 28,4m in its previous round of which Bpifrance contributed EUR 7m
	Chronocam	• Chronocam figures in the "EE Times Silicon 60: Emerging companies to watch 2016" • The company recently raised over EUR 15m in a Series B financing round with Intel and Bosch and the company is part of Bpifrance and Business France's "UbiMobility" exclusive export accelerator

Finally, the EIB already has experience with targeted measures, through two thematic funding pilots: InnovFin Infectious Diseases Finance Facility (IDFF) and InnovFin Energy Demonstration Projects (EDP). This experience provides a basis on which to build for the introduction of financing instruments targeted at KETs companies.

Pros and cons of transversal instruments versus targeted measures

Transversal instruments	Targeted measures
• Provide flexibility to allocate resources across multiple sectors, potentially resulting in higher deal flow • Less focus on achieving specific policy objectives in certain strategic sectors • Lower visibility by target companies in evaluating their own eligibility for such instruments	• Less flexibility to allocate resources across multiple sectors; potentially lower deal flow • Specific focus on achieving particular policy objectives in targeted sectors • Higher visibility by target companies in evaluating their own eligibility for such instruments • Potentially more focused investment prospection approach

6.3 Recommendation 1: Strengthen existing indirect funding mechanisms for private financing via VCs and banks

Indirect financing mechanisms could be adjusted, to **steer specific private venture capital activity to KET companies including in the photonics and semiconductor segments**, and **overcome the obstacles** currently faced by private investment firms, including the **risk-return imbalance** of ventures in the sectors, and the **need for Deep Tech expertise** to effectively assess investment return potential.

The proposed adjustments could introduce a degree of **conditionality between the public investment into private funds, and the allocation of these funds**. In other words, venture capital funds would need to deliver on the specific funding goals related to Deep Tech in scope to satisfy the mechanism's objectives. This conditionality could be linked to features to encourage investors to overcome the high risk of investing in Deep Tech ventures. **Public investors could use asymmetric funds** offering **risk mitigation and/or return enhancement features for private LPs** to encourage VC financing in the sectors.

Rationale

This recommendation aims to catalyse the activity of private venture capital firms to generate higher funding for KETs companies.

Market feedback indicates that private financing firms have difficulties and/or limited interest in dedicating funds and attention to the photonics and semiconductor spaces. As described in the earlier sections of this report, technology complexity and the often less compelling investment characteristics of the sectors (capital intensiveness, risk, long time horizons) result in few funds showing active interest. Past investment experience in the sectors is also seen as an additional constraint to the risk appetite of VC funds for photonics and semiconductors.

The majority of financing players interviewed comment that the indirect funding programmes currently at their disposal are a significant enhancement to the scale of their potential investments.

However, indirect financing tools in their current form appear to be insufficient to overcome the specific financing challenges encountered by KETs companies, suggesting an opportunity to adjust existing instruments to incentivise fund behaviour in support of the sectors, or alleviating some of the risk issues faced by funds investing in these sectors.

Feedback indicates that the capital intensiveness and risk-return profile of KETs companies including photonics and semiconductor companies require a more tailored approach to ensure private investor interest proportionate to the complexity and risk of the projects presented.

Key success factors

Based on our conversations with financing firms and related stakeholders, the following key factors would contribute to supporting private investment activity:

- Dedicated sector focus: a degree of conditionality would need to be introduced, in relation to meeting certain investment criteria in KETs companies;
- Asymmetric return profile: public limited partners could accept non-pari passu terms from the funds, with the goal of enhancing investment conditions for private investors into KETs companies including photonics and semiconductor companies, compensating for risk, long time horizons and the capital intensiveness of the sectors;
- Oversight: of deployed funds versus investment objectives.

Potential implementation

Instrument: Public investment in VC funds focused on Deep Tech ventures.

- Develop a specific targeted indirect funding facility: with funds invested in VC funds under specific conditions.
- Introduce incentives through risk/return proposition: e.g. risk absorption incentive associated with public investment (which could be associated with proportional return conditions).

Form of financing: equity

Target companies: all companies in the sectors in scope, both early-stage and growth stage

Targeted use of funds: general corporate purposes

> "Encouraging the creation of specialised funds in the hardware/photonics industries is a relevant area to explore for the EIB."

International VC

> "There is a real need for the creation of specialised funds. To invest in photonics and semiconductors spaces, we need expertise within funds to understand the technologies."

High-tech specialised VC

Synergies with previous reports:

KETs I study findings:	▲▲	**KETs II study findings:**	▲▲▲

6.4 Recommendation 2: Adapt existing financial instruments and programmes to better fit the risk-return profile of KETs companies via dedicated resources to support these companies

Building on the findings of this study and the previous KETs I and II studies, this study identifies the need for dedicated resources for Deep Tech companies, which could potentially take the form of a thematic investment platform to overcome the specific financing difficulties encountered by these companies and better fit the Deep Tech risk-return profile.

These dedicated resources could boost existing venture debt or quasi-equity instruments, as this would build on existing EIB experience with the European Growth Finance Facility (launched under

EFSI) and would help achieve critical mass for the instrument in financing Deep Tech companies. From a market standpoint, the importance of non-dilutive financing to preserve the interests of founders is aligned with this proposed approach.

Rationale

There is a need for greater and easier access to financing for KETs companies. These companies face specific challenges in accessing capital, including the complexity of the underlying technologies and generally less compelling investment characteristics, such as capital intensiveness, long time horizons and high risk. Direct financing instruments from the EIB could be an effective way to address the funding gap.

Most current financing instruments are transversal and not specific to any sector. As such, we find that insufficient direct financing reaches KETs companies, other than through grant programmes such as Horizon 2020 or ECSEL.

As discussed in the previous section, dedicated measures should be considered namely to overcome sector difficulties, and to be ready for the next digital revolution based on Deep Tech. Given the characteristics of Deep Tech companies with high technological risk, high capital intensity and less attractive risk/return profiles, these dedicated resources could require a structure able to absorb the potential higher losses involved with such investments. The potential structure could include a first-loss piece from central EU budget, and a second-loss piece from EFSI or European Structural and Investment Funds.

Key success factors

A successful dedicated support facility for KETs companies would comprise at least one or more of the following elements:

- Specific sector focus: on a broader sector base (e.g. KET) helping to achieve critical mass and visibility in the market;
- Tailored risk-management criteria: given the high risk profile of KETs companies, risk sharing mechanics such as first-loss tranches or guarantees are seen as important requirements. In addition, the instrument's risk criteria should ideally allow for the support of companies at early stages of development, including those companies that are loss-making or have limited or no revenue;
- Venture debt or quasi-equity: this approach should build on EIB direct financing capabilities and should help build critical mass for the instrument. From a market standpoint, the importance of non-dilutive financing to preserve founders' interest also justifies a venture debt approach;
- Accelerated financing process: agility and time-to-market are important factors for KETs companies, so a successful instrument should provide the possibility of financing acceptance under lead times comparable to those of private finance firms (e.g. less than six months);

- **Collaboration with private sector**: given the importance private financing players can have in the development of companies through the contribution of expertise and networking and through their positive influence on business credibility, attention should be given to the possibility of opening up the instrument to collaboration with private investors, for example by reserving certain tranches for co-investment by private funds or lenders;
- **Supportive of specific investments**: investments in items such as R&D, the development of prototype models and manufacturing could respond to market needs for KETs companies.

Potential implementation

Instrument: dedicated support to ensure a better fit with the risk-return profile of KETs companies, even those with limited financial capacity.

Sector focus: Deep Tech, including but not restricted to photonics and semiconductors.

Risk-sharing: investment platform with a first-loss piece from EU central budget and second-loss piece from EFSI or ESIF to facilitate access to financing for high-risk companies.

Forms of financing: venture debt.

Financing counterparty:

- EIB
- Guarantee from EC on junior tranches.

Target companies: all companies in the sectors in scope.

Target use of funds:

- Both start-up phase and scale-up phase should be encouraged, but the depth of the funding gap is highest at later growth stages, and investment sizes are likely to yield a more productive investment approach at such a later stage.
- Specific use of funds could be encouraged, such as funding for pilot lines, prototyping investments, and commercialisation efforts.

> "Targeted debt financing is important as founders of photonics and semiconductor companies need to remain incentivised and should not dilute their economic interests away."

Sciences and technology specialised VC

“There is a need for a short-term loan instrument to support companies struggling with liquidity.”

Medium-sized,
research-based semiconductor company

Case study on EDP

InnovFin Energy Demo Projects

InnovFin Energy Demo Projects facility targets innovative, first-of-a-kind energy technologies. Very much like the photonics and semiconductor industries, these technologies face a financing "**valley of death**" from demonstration to commercialisation. The goal of the EDP is to **provide risk finance** in order to bridge the valley, supporting the further rollout of low-carbon energy technologies to the market.

The programme enables the **EIB** to **provide** financing to **innovative** projects that would not have previously been **bankable**.

Eligibility criteria:

- **Innovativeness:**
  - The project/investment shall demonstrate for the first time the commercial viability of pre-commercial technologies.
  - Technologies should be innovative and not be commercially available yet.
- **Replicability:**
  - The project/investment should have the potential to be replicated elsewhere with convincing market opportunities.
  - The project/investment should offer prospects for cost-efficient CO2 reduction both in the EU and globally.
- **Readiness for demonstration at scale:**
  - The project/investment should be sufficiently mature for demonstration at the proposed scale (technologies validated and demonstrated through previous testing) with reasonable prospects of successful demonstration.
  - The proposed scale of demonstration should be equal to that of future commercial applications.
- **Timeline:**
  - At the time the project/investment is included under the facility, the projected start of the commercial operation of the whole plant is expected to take place within a maximum period of 4 years.
- **Bankability prospects:**
  - The project/investment shall have the potential to be or to become bankable by the guarantee release date.
  - This requirement relates to all aspects of the project/investment that are relevant for future project performance and debt service.
- **Commitment:**
  - Promoters, sponsors or operators must be willing to co-fund the project.

InnovFin
Energy Demo Projects

Instrument: loans/guarantees

Loan size: EUR 7.5m to 75m

Tenor: max. 15 years

Sectors: Renewable energies, Fuel cells, Hydrogen

Projects: First of a kind, commercial scale (TRL 7-8)

Covenants & security: Transaction-specific

Key issued tackled:

- Energy technologies face a "**valley of death**" on the way from demonstration to commercialisation
- **Project size** is often too **large** to satisfy exclusively with grants
- Traditional EIB debt facilities support R&D investments with a high risk profile **provided** they are "bankable"
- Energy technologies are considered as a **risky investment**, meaning private investment is limited

Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲

6.5 Recommendation 3: Develop blended financial instruments (combining public and private funding) including conditional grant, contingent grant and co-investment programmes to better support Deep Tech/KETs companies

Blended financial instruments leverage public funding with private financing in a combined financial product. Blended financial instruments typically have a higher risk capacity than financial instruments offered by private and public financial institutions (such as EFSI), and bridge companies from the grant phase to moving towards private financial products. This study recommends that the EC, national innovation agencies and national promotional banks consider developing blended financial instruments dedicated to Deep Tech companies.

Rationale

This recommendation aims to address the specific financing needs found in KETs companies, while building on the success and importance of grant programmes provided by the European Commission and related entities.

The objective of such a programme could be to enhance the leverage over public money that the European Commission or other institutions provide, with a specific focus on KETs. This proposed instrument should draw on the experience and lessons learned from the Connecting Europe Facility, which offers financial support to selected transport, energy and telecoms projects through guarantees and project bonds designed to attract further funding from the private sector and other public-sector players.

This proposition also builds on previous KETs I and II recommendations advocating new financial mechanisms in support of developing KETs companies. As such, conditional grants, contingent grants or co-investments have the potential to bring about the construction of multi-layered financing packages for KETs companies, including:

- The conditional grant piece, provided by a public institution, and based on its conditional nature bearing similar characteristics as the first loss tranche of a broader financing package.
- The co-investment from a public institution, with capped returns reducing the private investors' risks and enhancing returns.
- The contingent grants, only repayable in the event of success.
- Complementary debt or equity financing, through public or private commercial loans.

Key success factors

- **Specific sector focus**: on a broader sector base (e.g. KET), enabling the achievement of critical mass and visibility in the market.
- **Flexible timing and broad eligibility**: a broad range of third-party investors and investment types qualify, maximising the opportunity for companies to succeed in meeting required conditions.
- **Coordination of and eligibility of other public and private investor**s: with multiple financing sources involved around the concept of conditional grants, contingent grants, or co-investment, ensuring that effective coordination of other potential financing providers during and/or after the evaluation process is an important consideration. For example, such coordination could be provided by a dedicated agency or undertaking within the landscape of EU financing institutions to ensure the effective inclusion of both public and private financing partners in funded projects.
- **Supportive of specific investments**: investments in items such as R&D, the development of prototype models and manufacturing would respond to market needs for KETs companies.

Potential implementation

Instrument: Conditional grant facility provided by EC, ECSEL or other European entity.

Sector focus: Deep Tech, including but not restricted to photonics and semiconductors.

Grant structure:

- Multi-tranche approach: e.g. with unconditional first tranche and later tranches conditional to raising additional third-party financing.

Appointment of dedicated agency or undertaking: to drive coordination and support companies in obtaining additional financing and meeting grant conditions.

Instrument: Co-investment provided by EC, ECSEL or other European entity.

Sector focus: Deep Tech, including but not restricted to photonics and semiconductors.

Co-investment structure:

- Matching approach: private investment matched at a pre-determined ratio by an investment from a public entity.
- Capped return: investment from public entity is pari passu with the private investors, but with capped returns (enhancing returns for the private sector).

Appointment of dedicated agency or undertaking: to drive coordination and support companies in obtaining additional financing and meeting co-investment conditions.

Instrument: Contingent grant facility provided by EC, ECSEL or other European entity.

Sector focus: Deep Tech, including but not restricted to photonics and semiconductors.

Grant structure:

- Grants only repayable in the event that the underlying project is a success. The repayment of the grant could take the form of royalties on the revenues generated by the project.

Example of conditional grant programme in other sectors: CEF

Connecting Europe Facility (CEF)

The Connecting Europe Facility (CEF) is an EU **funding instrument** to promote growth, jobs and competitiveness through targeted infrastructure investment at European level. CEF investments aim to **fill the missing links** in Europe's energy, transport and digital backbone.

The CEF also offers **financial support** to projects through financial instruments such as **guarantees** and **project bonds**. These instruments create significant **leverage** in their use of EU budget and act as incentives to attract **further funding** from the private sector and other public sector actors.

Eligibility criteria:

- Applications **must be presented** by: Member States, international organizations, JUs, public/private undertakings or bodies/entities established in Member States
- The project must **contribute** to the **objectives** set out in the guidelines
- The project must be **economically viable** on the basis of a socio-economic cost-benefit analysis
- The project must demonstrate European **added value**
- The project's financial and legal structure should allow for **private sector involvement** whenever possible and to maximize the mobilization of private capital
  - The applicant shall submit a **letter of support** from one or several **public or private financing institutions** evidencing the financial readiness of the project and should indicate the **level of finance** that it/they could provide:
  - Identify the **public or private** entity established or to be established and which **will raise the financing** for the project
  - Cover the **financial capacity** and **business plan** of the grant applicant, grant beneficiary and borrowing entity as appropriate given the relevant responsibilities of the different parties
  - Evidence that the **stage of preparatio**n of the project is consistent with a **financial close** by 12 months

Budget: EUR 30.4bn

Sectors: Transport, Energy, Telecom

Selection:

- The applicant(s), beneficiary, and borrowing entity must have access to solid and adequate funding sources, so as to be able to maintain activities for the period of the project funded and to co-finance the project
- The applicant must also have the appropriate legal power, corporate structures, resources, professional skills and qualifications required to complete the proposed action

Award criteria

- **Relevance**. European added value, cross-border impact, contribution to innovation …
- **Maturity**. Maturity of the project in the level of development, financial readiness …
- **Impact**. Stimulating effect of EU support, need of the grant to overcome obstacles, economic and societal impact …
- **Quality**. Soundness of the financial, technical and operational plan as well as control, monitoring and audit…

"EIB should try to stimulate collaboration between public and private financing players."

International semiconductor corporate

"When a company obtains a European grant, it is more credible to an investor's eyes but a grant doesn't always imply that the company will find an investor."

Large commercial bank's Technology,
Media and Telecommunications (TMT) Division

"Conditional grants could be a way for companies and investors to leverage their funds and work together strategically."

International venture debt provider

Synergies with previous reports:

KETs I study findings:	▲▲	**KETs II study findings:**	▲▲▲

6.6 Recommendation 4: Promote further coordination with national programmes to encourage more specific roll-out of funds to KET companies

This recommendation proposes to promote the expansion of financing programmes at national level, with a specific focus on Deep Tech. To address this, enhanced coordination could be introduced between EU and national agencies, as also reflected in the KET II study promoting the development of enhanced and joined-up ecosystems of KET innovation.

Rationale

This proposition aims to build on the proximity and agility of national financing and development agencies, to introduce financing programmes targeted for KETs companies including in the photonics and semiconductor sectors. Similarly to their European peers, national agencies have a large array of financing programmes, including grants, equity financing and debt financing. In general, such innovation programmes tend to be transversal and not specific to a sector. Indeed, most national agencies have limited specific measures in place for the benefit of KETs, including the photonics and semiconductor sectors.

Recently, however, certain programmes of relevance to KETs have been developed at certain agencies. For example, in Germany, the State of Saxony has introduced a "KETs Pilot Line" scheme for the benefit of young companies active in KET, including in the photonics and semiconductor sectors. In Sweden, the VINNVÄXT programme for pilot production activities covers biotechnology and photonics, in particular.

As discussed earlier in the document (see the finding on the importance of clusters), the success of key cluster initiatives around Europe is in part to be found in their ability to provide coordination and guidance to companies to connect them with multiple potential financing partners, at both national and EU level.

This recommendation proposes to promote the expansion of targeted programmes at national level, with a specific focus on KETs companies through enhanced coordination between EU and national agencies. Such a plan would leverage both EU and national programmes strengths, with the specific purpose of bringing increased financing to the sectors in scope. Resulting benefits would include potential financing execution to KETs companies of higher magnitude combining both national and EU resources, supported by potential risk-sharing mechanisms provided by EU institutions and ensuring commensurate impact on companies' visibility and credibility for other investors.

Key success factors

The following key factors would need to be considered as part of the development of national measures for the photonics and semiconductor sectors:

- **Development of new instruments or programmes at national level, which could follow the following principles:**
  - **Dedicated sector focus**: explicit focus toward KETs companies would need to be one of the collaboration criteria to ensure that the instrument or programme is fit for purpose.
  - **Supportive of specific investments**: investments in items such as R&D, the development of prototype models and pilot manufacturing would respond to market needs for KETs companies.

  - A range of asset classes including debt (with a form of guarantee or forgivability) and venture debt: the long development lead times and multiple financing rounds often required to bring KETs companies to maturity often result in substantial dilution of the founders' interests. Mechanisms which help limit such dilution would respond to market needs.
- Involvement of national agencies in broader coordinated undertakings (e.g. ECSEL).
- Coordination platform between EU and national agencies: EU and national entities would need to work together, with the specific objective of delivering increased financing resources to KETs companies.
- Collaboration with private financing firms: given the positive impact on firms that national agency financing can have, close collaboration should be ensured between public financing sponsors and potential private partners.

Potential implementation

Introduce a coordination platform: involving both EU and national players to define and execute a common agenda in favour of KETs companies.

Leverage this coordination platform to:

- Encourage the development of targeted financing programmes at national level.
- Promote the coordinated roll-out of funds under existing programmes to KETs.
- Exchange investment leads and opportunities.

> "Our co-investments with our local agency work very well. We gain in efficiency, rapidity for deals and it makes sense to work hand in hand with such actors in the ecosystem."

Hybrid VC/incubator

> "Bpifrance-backed loans seem to encourage banks to lend due to the reduced risks."

Small start-up company

A successful joint financing effort: Heliatek's series D

Heliatek case

Heliatek is a worldwide leader in organic photovoltaics and a large manufacturer of solar films.

The Dresden based company is a spin-off from the Technical University of Dresden and the University of Ulm. The opening of the first production line in 2012 enabled the company to roll out production of it's innovative "HeliaFilm".

Founded: 2006

Raised to date: ~ USD 156m

Joint financing:

- In September 2016, Heliatek raised EUR 80m round to finance the expansion of its HeliaFilm manufacturing capacity by one million m^2. The series D round is a perfect example of joint financing efforts between private financing players, corporates, local authorities and European institutions
- The financing round is a perfect example of funding cooperation between the three major players in the financing landscape (EU, national agencies and private actors)
- Today, investors include international corporates and financial companies such as BASF, HTGF, Innogy Venture Capital, Wellington Partners, eCAPITAL and AQTON SE. New investors include innogy SE, ENGIE (leading European energy companies), BNP Paribas and CEE Group. R&D, as well as the installation of production technology in the past has been financed by the State of Saxony, the German government and the EU

"This €20 million loan supported under Horizon 2020, the EU's research funding programme, illustrates how the public and the private sector collaborate to keep Europe in a leading role..."

Carlos Moedas
EU Commissioner for Research

Deal structure:

Equity Capital EUR 42m

EIB Loan EUR 20m

State Subsidies EUR 18m

A relevant national funding initiative: Saxony KETs Pilot Lines

Saxony KET pilot lines programme

SAB
Sächsische AufbauBank

The KETs-Pilotlinien initiative is a **funding measure** for selected projects with **high demands** on the degree of **innovation** and **sustainable** economic exploitation. The programme serves as a springboard to enable the **transfer** of particularly promising **R&D** results into an industrial **production**.

Companies are to be supported by setting up pilot lines using key technologies in order to promote the **transfer of research results** into their economic exploitation.

The Development Bank of Saxony allocates subsidies (e.g., European Regional Development Fund) in the form of grants, sureties and loans to various sectors of the economy, as well as for residential and municipal construction.

Costs covered:

- Costs for **researchers, technicians** and other **personnel**
- Costs of **instruments** and **equipment**, in the amount of the impairment determined according to the principles of proper accounting during the duration of the project
- Costs of **buildings**, in the amount of the impairment determined according to the principles of proper accounting during the duration of the project
- Costs of **contract research, knowledge** and **patents** acquired directly or under license from third parties on the market conditions, **advice** and **equivalent services**
- Other **operating costs** (including, but not limited to, materials, articles of consumption, etc.)
- On request, **overhead costs** are only eligible as a lump sum of **25%** of the eligible individual costs for **personnel, instruments** and **operating** costs

Conditions

- The **prerequisite for support** is the participation of a company that bears the main responsibility for the project result and is entitled to exploit it
- Companies can carry out projects either **individually or in cooperation** with other companies or research institutes. A co-operation **agreement** must be in place, which regulates the cooperation and the distribution of tasks
- Ideally, the applicant should also be the future **operator of the pilot line** and use it for the production of their products
- The **project** must be able to be **assigned** to a Key Enabling Technology

Synergies with previous reports:

KETs I study findings:	▲▲	KETs II study findings:	▲▲▲

6.7 Recommendation 5: Launch an EU initiative to improve the visibility of photonics and semiconductors, reduce information asymmetries, raise awareness and maximise exposure of investment opportunities with potential investors.

This initiative should be launched in the context of a broader initiative for KETs.

This recommendation aims to overcome the lack of general visibility of the sectors in scope, limited technological expertise among investors, and the fact that the venture capital agenda tends to be occupied by more mainstream investment themes such as software or e-business.

First, a general communication and visibility EU initiative could be considered, aiming at increasing awareness and understanding of the technologies among investment providers, and changing the perception of investment challenges by presenting potential solutions available.

Second, an EU technical support platform could be implemented, offering technological expertise and knowledge to private investors in order to facilitate their investment activity. Such a technical support platform could potentially build on the expertise of knowledgeable partners such as research and technology organisations.

Third, to bridge the lack of visibility in the sectors in scope, and information asymmetries, more targeted advisory services to KETs companies including photonics and semiconductor companies should be considered in order to help them pitch to potential investors, whether public/EU or private. The EIB's advisory competencies in this area could potentially be leveraged.

Fourth, the development of an information-sharing platform should be considered to provide easy access to information about funding programmes that support the KET sector and individual companies. Efforts made in developing centralised KETs resources and market information (e.g., KETs Observatory) could be a good starting point to improve the dissemination and availability of information on photonics and semiconductor companies.

In addition to such general market visibility efforts, the EIB and ECSEL could improve coordination efforts in order to ensure ECSEL-funded projects are adequately considered for follow-on support (advisory or lending) by the EIB, other public agencies and the private sector. For example, ECSEL-funded projects and relevant contacts could be used for the origination of financing opportunities at the EIB.

Rationale

Deep Tech themes such as photonics and semiconductors tend to be considered by specialised investors, while non-specialists shy away from opportunities they may have difficulties in understanding.

In the case of photonics, the nature of the sector as an enabler of applications in multiple end markets tends to blur its identity and make it difficult for entrepreneurs to position themselves as photonics players, as opposed to healthcare or telecommunications players, for example.

Finally, with the presence of corporate players as a typical exit route for successful companies, there are very few examples of highly successful photonics and semiconductor companies breaking through to become large global players.

General communication and visibility EU initiative

The following key factors should be considered to improve photonics and semiconductor visibility (in the context of a broader action for KETs):

- Creating awareness and understanding: through branding, communications and outreach to key financing players, the creation of an industry nomenclature.
- Reaching key investment players: communications efforts should target private financing players, commercial banks and national agencies.
- Promotion of photonics and semiconductor associations and communities: to increase their visibility to the financing community.
- Potential communications campaign: targeted at private financing players, for example, through broadly communicated success stories.
- Communication around photonics and semiconductor investment characteristics and how public financing tools may help mitigate issues.
- Promotion of industry events as well as other community-type activities.

Establish EU technical support platform

- Access to expert knowledge: for funds with limited expertise in KETs, an indirect financing mechanism could be accompanied by a "technical support" programme, ensuring technological expertise is provided to private investors in order to facilitate their investment activity.

Leverage advisory services in support of sector companies

Another opportunity to bridge the lack of visibility in the sectors in scope would be to provide more targeted advisory services to KETs companies to help them raise their profile in the eyes of potential investors, whether public/EU or private.

Create an information-sharing platform in support of sector companies

Efforts made in developing centralised KETs resources and market information (e.g., KETs Observatory) could also be built on, for example to ensure that information on photonics and semiconductor companies is available and disseminated through such tools.

Improve follow-on coordination of ECSEL-funded projects

In addition to general market visibility efforts, the present recommendation could also include actions to improve the visibility of ECSEL-funded projects to facilitate their potential access to follow-on support (advisory or lending) by the EIB or by other financing providers.

To do this, a coordination mechanism could be introduced between the EIB and ECSEL to ensure ECSEL-funded projects are considered for follow-on financing by the EIB, and/or that financial advisory competences available at the EIB be leveraged to direct key projects toward appropriate sources of funding.

In keeping with this line of thought, ECSEL-funded projects and relevant contacts could be used for the origination of financing opportunities at the EIB.

> "Lack of visibility and understanding from the financing community is among the primary constraints for innovative photonics companies."

**Medium-sized,
scale-up stage photonics company**

> "Branding photonics is also an idea and should be focused on demonstrating that good returns can be made (i.e. promoting success stories in the industry)."

International VC

Synergies with previous reports:

KETs I study findings:	▲▲▲	KETs II study findings:	▲▲▲

INNOVATION FINANCE ADVISORY STUDIES

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print: QH-BG-18-006-EN-C ISBN 978-92-861-3639-9 ISSN 2599-7068 doi:10.2867/24995
digital: QH-BG-18-006-EN-N ISBN 978-92-861-3638-2 ISSN 2599-7076 doi:10.2867/509133