Horizon 2020: Key Enabling Technologies (KETs), Booster for European Leadership in the Manufacturing Sector

Study for the ITRE Committee

EN 2014
Abstract

Key Enabling Technologies (KETs) are crucial for the competitiveness and renewal of European manufacturing. This study, prepared by Policy Department A at the request of the Committee on Industry, Research and Energy (ITRE), examines the nature of KETs, and the drivers and barriers to their deployment. It includes an assessment of the current KETs situation in the EU in a global perspective. A broad overview of European policies and financing instruments precedes an in-depth assessment of the role of KETs in Horizon 2020. The analysis continues with a look at their contribution to growth, impact on employment and skills requirements.
This document was requested by the European Parliament's Committee on Industry, Research and Energy.

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<tr>
<td>AIRI</td>
<td>Associazione Italiana Ricerca Industriale</td>
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<td>AM</td>
<td>Advanced materials</td>
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<td>AMT</td>
<td>Advanced manufacturing technology</td>
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<td>cPPP</td>
<td>Contractual public-private partnership</td>
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<td>CPR</td>
<td>COMMON Provisions Regulation, ESIF</td>
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<td>EARTO</td>
<td>European Association of Research and Technology Organisations</td>
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<td>ECSEL</td>
<td>Electronic Components and Systems for European Leadership</td>
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<td>EFFRA</td>
<td>European Factories of the Future Research Association</td>
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<td>EIB</td>
<td>European Investment Bank</td>
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<td>EIT</td>
<td>European Institute of Innovation and Technology</td>
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<td>ELAT</td>
<td>Eindhoven-Leuven-Aachen triangle</td>
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<td>ERDF</td>
<td>European Regional Development Fund</td>
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<td>ESF</td>
<td>European Social Fund</td>
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<td>ESIF</td>
<td>European Structural Investment Funds</td>
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<td>EU</td>
<td>European Union</td>
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<td>FET</td>
<td>future and emerging technologies</td>
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<td>FoF</td>
<td>Factories of the Future</td>
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<td>FP7</td>
<td>7th Framework Programme</td>
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<td>FTI</td>
<td>Fast Track to Innovation pilot action</td>
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<td>GBER</td>
<td>General Block Exemption Regulation</td>
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<td>GDP</td>
<td>Gross domestic product</td>
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<td>H2020</td>
<td>Horizon 2020</td>
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<td>HL(E)G</td>
<td>High-level (expert) group</td>
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<td>IB</td>
<td>Industrial biotechnology</td>
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<td>ICT</td>
<td>Information and communication technology</td>
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<td>IMEC</td>
<td>Interuniversity MicroElectronics Center, Leuven</td>
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<tr>
<td>IPCEIs</td>
<td>Important Projects of Common European Interest</td>
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</table>
IT  Information technology
ITRE  Committee on Industry, Research and Energy
JTI  Joint technology initiative
JU  joint undertaking
KET  Key enabling technology
KIC  Knowledge and innovation community
LEIT  leadership in enabling industrial technologies
mKPL  Multikets pilot lines
MNE  Micro- and nanoelectronics
NACE  Nomenclature Statistique des Activités Économiques dans la Communauté Européenne
NANO  Nanotechnology
OECD  Organisation for Economic Co-operation and Development
PHOT  Photonics
PPP  Public-private partnership
R&D  Research and development
RDI  Research, development, and innovation
RIS3  Research and Innovation Strategies for Smart Specialisation
RSFF  Risk-Sharing Finance Facility
RSI  Risk-Sharing Instrument for SMEs
RTO  Research and technology organisation
SMEs  Small and medium-sized enterprises
STEM  Science, technology, engineering, and mathematics
TFEU  Treaty on the Functioning of the European Union
TRL  Technology readiness level
UK  United Kingdom
UKCES  UK Commission for Employment and Skills
US  United States
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EXECUTIVE SUMMARY

Modernisation of the European industrial base is a crucial issue for future competitiveness and employment. A key question is how the deployment of key enabling technologies (KETs) can contribute to European re-industrialisation through the development of an integrated approach to the financing of KET-related research and innovation.

The purpose of this study, which was requested by the Committee on Industry, Research and Energy (ITRE) of the European Parliament, is to provide an independent expert opinion that will enable members of ITRE to establish an own view on the contributions of research and innovation (specifically in relation to KETs) to European industrial development and capacities, and to (highly skilled) employment, as well as on the role of SMEs. Horizon 2020 (H2020) will be a key instrument in securing European competitiveness through the support of research and innovation to create growth and new jobs.

Section 2 starts with a discussion on the concept of KETs, a term that has been officially coined to develop a strategic, integrated approach to the development and deployment of new technologies. With their final report, the first High Level Group (HLG) KETs introduced the so-called “Valley of Death” as one of the central elements of the EU KETs strategy: to reduce the “Valley of Death”. The strategy combines the two issues of deployment and re-industrialisation into an approach that differentiates three fundamental stages in the innovation chain of KETs and KET-based products: technological research, product development, and competitive manufacturing. A closer look at KETs shows that they cover a wide variety of technologies, products, components, goods, and services, and they are often applied as multi-KETs or cross-cutting KETs: processes and products that involve a number of different KETs (e.g., nanobiotechnology and nanophotonics).

The HLG KETs suggested that the NASA-developed concept of technology readiness levels (TRLs), comprised of nine levels, and could be used as a tool to facilitate the characterisation of the maturity of projects. This made the concept of the Valley of Death more operational, as the tool could assess whether a product was about crossing the Valley of Death. In practice, the TRL concept is difficult to apply because each KET is very different from the others. This has implications for the policy and funding instruments that are linked to the TRLs.

Although many countries focus on critical and enabling technologies, only a few (Belgium, Germany, Austria) use the term KETs. And when it is used, they are referring to the EC KETs strategy in order to align their policies on research, development, and innovation with funding from the European level—leading to the conclusion that the KET concept is mainly used by the European Commission and some EU countries in its wake.

Section 3 presents—for each of the six KETs—an overview of EU performance in a global context, an assessment of how different European countries perform, and the main clusters where KETs play a major role. The assessment of the role that the different KETs play with regard to their contribution to the competitiveness of EU actors in a global context is not straightforward. As mentioned above, this is because of the fact that KETs, in the way they are defined, are of a very different nature: some refer to technologies, others to production processes or properties of materials. The definitions also refer to pervasive technologies that are deployed by different sectors and actors. And KETs are formulated such that they are not exclusive—i.e., there is a certain overlap. Furthermore, the concept of KETs was initiated by EU policymakers, but in practice, it has not yet been adopted by all stakeholders involved (industry, statistics offices, EU and non-EU national policymakers,
etc.), meaning that statistical information is not structured and available according to a KET classification.

Our analysis shows that Europe is leading in knowledge creation for most of the KETs, as reflected in, for example, patenting activity. But when it concerns the exploitation of this knowledge (i.e., the second and, especially, the third pillar), Europe falls behind its main competitors. In the mass manufacturing of KET-based products, Asia is leading (originally because of the cost of labour, but also because of industrial policies for mass manufacturing. Within Europe, Germany, which is a global leader in the production of machine tools for KET-based products, dominates the market for these products, followed by France, the UK, and Italy.

Specific clusters building on KETs are present in Europe, spread over different countries. While these clusters build on the proximity of leading actors, they do have a global scope in their activities, and rely on international counterparts for production.

Section 4 focuses on Horizon 2020. It starts with an assessment of the three pillars in H2020 and their relevance for KETs: Excellent Science, Industrial Leadership, and Societal Challenges. It discusses in detail the acceleration of KETs through Horizon 2020, the creation of synergies between EU policies, the stimulation of cross-fertilisation between KETs, and their exploitation: crossing the Valley of Death. As a rationale for policy intervention, it is argued that Europe does not fully exploit its potential with respect to KETs. As indicated in the policy document “A European Strategy for Key Enabling Technologies—A bridge to growth and jobs” (European Commission 2012a), Europe is a global leader in KET development but a follower in subsequent commercialisation into KET-based goods and KETs have become a fundamental part of Horizon 2020, with an allocation of about EUR 30 billion. Horizon 2020 pays significant attention to KETs and pilot lines, where activities to translate prototypes into low-rate mass manufacturing will be supported. About 30% of the budget for leadership in enabling industrial technologies (LEIT) will be allocated to cross-cutting KETs, focusing on activities where more than one KET are integrated, and the focus will be on activities in TRL 4 to 8. Although Horizon 2020 does not fall under State Aid rules, the rules can complicate the support of higher TRLs because the new combined funding mechanisms can lead to problems, for example when structural funds are used to support higher TRL activities that ask for strong industrial participation but less government support because of market distortion. Research and technology organisations (RTOs) have a relevant role during all stages of innovation. Multi-user technology platforms can provide technological infrastructure and expertise to stimulate pilot production in SMEs and large enterprises.

Within H2020, the concept of multi-KETs pilot lines (which originated in EU policy from HLG KETs) is also used to focus funding. Some EUR 600 million has been allocated for projects in this category. H2020 also provides access to risk finance on proven FP7 activities: the Risk-Sharing Finance Facility (RSFF) and the Risk-Sharing Instrument for SMEs (RSI). The dedicated SME instrument will be funded from H2020 second and third pillars. New in H2020 is the Fast Track to Innovation pilot action (FTI), a separate instrument, which aims to support innovation under LEIT and Societal Challenges, relating to any technology field.

KETs are about the re-industrialisation of Europe, which, by definition, is about industry participation. One of the key changes of H2020 with regard to KETs and industrial leadership is that a shift can be seen in the focus of the framework programme towards higher TRLs. Partnerships are important in deploying KETs, and H2020 supports public-public partnerships and joint technology initiatives (JTIs), implemented by joint undertakings (JU) as a legal body. Two initiatives explicitly focus on KETs: The new JTI Electronic Components and Systems for European Leadership (ECSEL) and Factories of the
Future (FoF), a contractual EU public-private partnership supported through the H2020 research programme.

In addition to the roles of industry, the KET discussion also needs to address the role of RTOs. Although often not optimally used, institutionally, RTOs play a crucial role in the valorisation of research into economic applications. They are especially important for hosting the multi-user technology platforms.

Section 5 discusses other EU policies, programmes, and financing instruments that play a role in the development and deployment of KETs. It specifically addresses the role of cohesion funds and smart specialisation in KETs, and it addresses the possibilities for financial engineering (i.e., combining different types of funding for KETs).

The roll-out and uptake of KETs is regarded as key to the future of manufacturing in Europe. In order to cross the existing Valley of Death in KETs, three main pillars need to be strengthened. These relate to (1) technological research, (2) product and product development, and (3) manufacturing. For constructing these pillars, sufficient investment and adequate financing mechanisms, both public and private, are needed. The HLG KET Working Group on Financial Instruments estimated in 2011 that, with a future European investment portfolio of 20 globally competitive manufacturing sites and 100 pilot lines in KETs in Europe over the oncoming years, the overall financing needs in this alone would amount to roughly EUR 60 billion for manufacturing sites (EUR 3 billion per site) and another EUR 60 billion for pilot lines (EUR 600 million per pilot line). If the existing JTIs are taken as illustrative, having a relative contribution of private and public funding of, respectively, two-thirds and one-third (the latter to be divided between Europe and the Member States/regions), this would lead to a European public investment ambition of approximately EUR 20 billion for the current programming period 2014–2020.

Unlike the previous programming period, the new multi-annual financial framework 2014–2020 foresees the allocation of EU resources to all different RDI stages, from TRL 3-4 to 8, involving funding from Horizon 2020, European Structural Investment Funds (ESIF), and actions of the European Investment Bank (EIB). Although KETs play an important role in Europe 2020’s sustainable competitiveness and growth agenda, there is no distinct or separate EU budget support line for KET-related activities and investment at the EU level. Funding is spread over different instruments, of which the H2020 Industrial Leadership pillar is the largest in terms of funding (with KET-specific support of EUR 5.9 billion foreseen in LEIT, and (although not KET-specific dedicated support) access to EUR 2.7 billion in risk finance and ditto EUR 0.6 billion on innovation in SMEs). H2020 funding also applies to establishing a new knowledge and innovation community (KIC) on value-added manufacturing in 2016 as well as activities in the Future and Emerging Technologies programme under the H2020 Excellent Science pillar. As regards access to risk finance, several instruments are available, such as loans and guarantees for investments in research and innovation of EUR 7.5 million and higher, targeted in particular at innovative midcaps and larger organisations ("RSFF II"), an SME & small midcaps research and innovation loan service ("RSI II") up to EUR 7.5 million, and a special SME initiative (following the June 2013 European Council) including a joint guarantee instrument/securitisation for loans to innovative SMEs and small midcaps. The European Commission and the EIB are working closely together to facilitate further investment in KETs by enlarging the available EIB capital to EUR 65 billion. Last but not least are the JTIs and the contractual public-private partnerships (cPPPs). With the agreement of the 2013 Industrial Investment Package, the Commission, the Member States, and European industry have agreed to invest more than EUR 22 billion over the next seven years, which includes a proposed EUR 8 billion investment from H2020, EUR 10 billion from industry, and close to EUR 4 billion from EU Member States. Part of the investment package goes to KETs, e.g., to
the new ECSEL and the FoF initiative from the European Factories of the Future Research Association (EFFRA).

Section 6 discusses the contribution of KETs to economic growth and trade and goes into the issues of employment and skills. KETs are generic technologies that, alone or more often in combination with other technologies, form the basis of a range of new products and processes used in manufacturing. While manufacturing as a share of the economy has declined in the EU and the US, it remains of crucial importance to the economy because it makes “outsized contributions to trade, research and development (R&D) and productivity” (McKinsey 2012, p3). The role of manufacturing changes with economic development: in low-wage countries, it generates employment; in more mature economies, its contributions are to innovation, productivity, and growth, far beyond the limited direct employment generated in factories. Advanced manufacturing forms the basis of an ecosystem of production of goods and services with the result that over time the “distinction between manufacturing and services has blurred” (McKinsey 2012).

With regard to trade, the different KETs show a mixed picture. Industrial biotechnology and exports of advanced materials show a high and increasing technology content with international competition on price. For nanotechnology, European products show a low and decreasing technology content with international competition. In micro- and nanoelectronics (MNE), Europe has a weak position with low and decreasing technology content, strong international price competition, and no price advantage for European products. In photonics, Europe shows stronger performance, with high and growing technology content of the products exported. International competition is mainly on price with no price advantages for European products. Finally, in AMT for other KETs, Europe holds a strong position in exports: technology content is high and increasing and European products compete mainly on quality.

KETs are expected to be a major source of new employment in the European Union, although direct employment in high-tech industries is usually limited. Additional employment will emerge in KET-based services. Shortages of skilled labour have been predicted but they are more a question of quality than quantity, related mostly to the qualifications needed for KET-based jobs rather than to the numbers of engineers available. While Europe is still a global leader in KET research, other regions are catching up fast. To remain at the science forefront globally, European countries need to give a high priority to science education, notably the science, technology, engineering, and mathematics (STEM) skills that are crucial for KETs. In addition, and as Europe is lagging in skills related to the commercial deployment and exploitation of KETs, a considerable effort will be needed in business skills (e.g., entrepreneurship) and soft skills (e.g., problem solving, communication).
1. INTRODUCTION

1.1. Context
Europe is slowly recovering from a deep recession and is urgently in need of new sources of economic growth and employment to improve the EU’s competitiveness in a rapidly changing global environment. To remain at the forefront of international developments, it is important to strengthen and revitalise the European industrial base. There is a new awareness and recognition of the fact that industrial development makes “outsised contributions to trade, research and development (R&D), and productivity” (McKinsey Global Institute 2012, p.3). The contributions of manufacturing go far beyond the modest direct employment generated in highly automated and robotised high-tech factories (McKinsey Global Institute 2012, p.7).

Leadership in enabling industrial technologies (LEIT) is therefore crucial for the future of European economies and societies. Six key enabling technologies (KETs) have been selected by the European Commission to play a leading role in establishing this leadership and to contribute to addressing the grand challenges that Europe is facing. To advance to a position of industrial leadership through the development and deployment of KETs, the European Union (EU) is supporting the development of KETs in Horizon 2020 (H2020) and in other EU programmes.

1.2. Aim and scope of the study
This study, requested by the European Parliament’s Committee on Industry, Research and Energy (ITRE) addresses the renewal of the European industrial base through the development and deployment of KETs. The study aims to enable members of the ITRE Committee to establish their own view of the contributions of KET-related research and innovation to strengthening European industrial capacities, including those of small and medium-sized enterprises (SMEs). The study reviews the current situation in Europe regarding KETs, in a broad international context, and presents the contribution of collaborative European research (with emphasis on, but not limited to Horizon 2020) to new manufacturing technologies and to new high-tech employment.

1.3. Methodology and approach
The data available on KETs are limited as the concept is relatively new and not yet widely adopted by statistics offices and policymakers outside the European Commission, but this study is based on an in-depth review of the available literature on KETs, manufacturing, innovation, clusters, smart specialisation employment, and skills. It includes the policy literature, scientific literature (mainly on individual KETs), and reports and papers on a wide variety of KET-related issues. In addition, the study team has drawn on its extensive experience in a number of European KET projects. To complement the information from secondary sources, we have interviewed 10 leading experts in the field, especially on their views on KETs in Horizon 2020 and in other European initiatives (Annex 2).

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1 The EU has identified the following six grand challenges: (1) climate action, resource efficiency, and raw materials; (2) secure, clean, and efficient energy; (3) food security, sustainable agriculture, marine and maritime research, and the bio-economy; (4) health, demographic change, and well-being; (5) inclusive, innovative, and secure societies; and (6) smart, green, and integrated transport.
2. BACKGROUND TO KEY ENABLING TECHNOLOGIES

KEY FINDINGS

- Manufacturing is crucial to the European economy and society, and KETs have the potential to play an important role in the re-industrialisation of Europe.
- KETs typically are an EU policy concept. As such, KETs have not yet been widely adopted in Member States; however, in many Member States, individual KETs play a role in innovation policy.
- One key element in crossing the Valley of Death is commercialisation, which, apart from getting technologies and their manufacturability right, also requires organisational developments and skills as well as active market deployment.
- Technology readiness levels (TRLs) are used as a policy tool in assessing eligibility in Horizon 2020, among other things. The TRL scale needs further adaptation to the needs of EU policy.
- KETs apply to the development and manufacturing of KETs-based components, which are subsequently used to produce KETs-based products. It is in this latter phase that most jobs are created. KETs-based products should therefore get a more prominent position in EU policy.
- The definition and demarcation of the six KETs is not clear. Software, moreover, is missing as a KET and should be integrated into the KETs.

2.1. The importance of key enabling technologies

In 2009, the European Commission published the first Communication on Key Enabling Technologies, stating that they were "indispensable" to creating a competitive high-tech European industry and to ensuring the “welfare, prosperity and security of its citizens”. The question is, what is the reasoning behind the concept of key enabling technologies as being core to the further development of our economy and society?

We depend highly on technology to ensure that the limited resources of our planet can support our ever-growing population. During the first industrial revolution, technology was placed at the core of our society, transforming the industry from a manual production system to one that was machine based. It had a disruptive impact on the standard of living, income and overall population. The second industrial revolution in the early 20th century introduced manufacturing based on electrical power and scientific research as the basis for further industrial development. In the 1970s, the developments in information technology (IT) and electronics initiated the third industrial revolution, which introduced technological “brainpower” into the production process. Based on the Internet of Things (Figure 1), and before it reached its full impact, Germany announced that a fourth revolution is on its way—one that will revolutionise industry by creating network-centric production, using new manufacturing technologies and cyber-physical systems to increase participation in the value chain and decentralised production.
“Industry 4.0” is the driver of this technology, which will increase competitiveness and even re-industrialise Europe. Technology-based manufacturing will not only decrease the need for low-cost manual labour, but new technologies will provide solutions to our grand challenges. The shift to a resource-efficient, renewable bio-economy will require new industrial biotechnologies, and further developments in such areas as information and communication, photonics, electronics, and medical technologies are crucial for society as a whole. Today, the contribution of European industry to the gross domestic product (GDP) is about 15%, and an assessment of the European industrial base shows that Europe’s leadership in industrial manufacturing is declining (Figure 2). Manufacturing is considered a crucial component to economic growth and prosperity, so this shift in industrial leadership is of growing concern. It is clear that getting industry back to Europe is crucial and technology is key. New innovative manufacturing technologies will help to further robotisation, increase productivity in mass production, and enable the cost-efficient production of small quantities. In addition, technology will also create new innovative products and accompanying services, as well as providing solutions for our grand challenges.

The conclusion that new technologies are crucial to our society has a fundamental impact on innovation policy in many countries. A good example is the Department of Defence in the United States (US), which spends about USD 80 billion annually on research and development (R&D) to enhance defence and security. Countries like South Korea, Japan, and China have increased their public R&D expenditures to ensure their economic competitiveness and to deal with their societal challenges (Figure 3). It is clear that further investing in technology will be crucial to our economy and key to further societal development. But an efficient and effective strategy is needed to benefit from these investments.
Figure 2: Global expansion of research and development expenditures (USD trillion)

Source: National Science Foundation (2012).

Figure 3: Top 15 manufacturers by share of global gross value added of nominal manufacturing

2.2. Key enabling technologies as a concept

Increasing efficiency and effectiveness in innovation policy was the starting point for the KETs strategy. Although a strategic approach to research and innovation was seen in such areas as life science, energy, nanotechnology, and biotechnology, no real strategic approach was available for industrial innovation. This problem was addressed in the EC Communication SEC-1257 in 2009 (European Commission 2009), focusing on the following three issues:

- **Focus:** Overall, technology and innovation has grown to be highly complex and too extensive to be covered. Critical mass is needed and requires a focused support effort.

- **Deployment:** The valorisation of high-quality European research into societal benefits is suboptimal and this should be supported.

- **Re-industrialisation:** Manufacturing is essential to economic growth and prosperity, but is shifting towards Asia. A policy is needed to support the manufacturing industry to increase innovativeness and competitiveness and to re-industrialise Europe.

These issues were the basis for the definition of the KETs concept, which is seen by the European Commission as a non-sectoral and broad approach to industrial innovation (European Commission 2012c):

> KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts.

This EU communication led to the creation of the High Level Group on Key Enabling Technologies (HLG KETs) (HLG KETs 2010), where both industrial and research stakeholders were asked to assess the situation regarding KETs in the EU and to propose recommendations on further policy actions in order to create a more effective industrial deployment of KETs in the EU. Supported by a Sherpa group, 27 representatives from large enterprises, SMEs, industry associations, research and technology organisations (RTOs), and universities provided recommendations to make the KETs concept operational.

2.3. Core of KETs: Bridging the “Valley of Death”

One of the key aspects of the KETs strategy is addressing Europe’s major weakness: the translation of its knowledge base into goods and services. With their final report, the First HLG KETs introduced the concept of the “Valley of Death” as one of the central elements of the EU KETs strategy. It combines the two issues of deployment and re-industrialisation into an approach that differentiates between three fundamental stages in the innovation chain of KETs and KETs-based products:

- **Technological research**, transforming fundamental research into technologies.

- **Product development**, transforming technologies into product prototypes.

- **Competitive manufacturing**, creating production systems to commercially produce the products.

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2 In 2013, a new HLG KETs was launched, with a new mandate and slightly changed representation from industry and research.
This three-pillar approach (Figure 4) can be seen as a simplified representation of the innovation chain. Its main message is that new technologies will not easily cross the bridge to the market and that the barriers to transform product prototypes to low-rate mass production are mostly financial. A more nuanced view on this concept of the Valley of Death is provided by the Breakthrough Institute, which presents two valleys of death (Jenkins and Mansur 2011):

- **Technological Valley of Death**, in which further capital is needed to develop a commercial product and prove its basic market viability.
- **Commercialisation Valley of Death**, where entrepreneurs seek capital to fund first-of-a-kind commercial-scale projects or manufacturing facilities (Figure 5).

**Figure 4:** Valley of Death and the three-pillar approach

![Valley of Death and the three-pillar approach](image)

*Source: HLG KETS (2011).*

**Figure 5:** Two valleys of death

![Two valleys of death](image)

*Source: Jenkins and Mansur (2011).*

The fundamental difference between both valleys is their activities. Where, in the *technological* Valley of Death, it is about the research, development, and innovation of the *product*, the *commercialisation* Valley of Death is about the development of a commercial *production system*. This includes testing and validation of the manufacturing,
as well as demonstrating manufacturing to customers. This second valley integrates product technologies, manufacturing technologies, the establishment of the market network, and the restructuring of the organisation in order to establish a production system (Butter et al. 2013). The conclusion is that support to cross the Valley of Death is not only about technology (product/manufacturing), but it should also address organisational and market issues.

**Figure 6: Commercialisation: Integrating product, manufacturing, market and organisation**

![Commercialisation Diagram](image)

**Source:** De Heide et al. (2013).

In 2011, the HLG KETs suggested that the NASA concept of the TRL could be used as a tool to assess technological maturity (Figure 7) and make the Valley of Death more operational. A project could be analysed this way if it was about crossing the Valley of Death. Today, Horizon 2020 uses a TRL scale to enable the assessment of the eligibility of projects for certain kinds of funding (Horizon 2020 2014, Annex G). The European Association of Research and Technology Organisations (EARTO) recently analysed the TRL concept in more detail to determine if it can be used as a tool for assessing eligibility (EARTO 2014). Four observations were made. The TRL concept:

- does not address issues concerning setbacks in technological maturity;
- focuses on one single technology, and most innovations are multi-technology;
- is oriented to product technology and does not integrate developments in organisation, marketing, or even the maturity of manufacturing technologies;
- was originally a communication tool and needs to be adapted to its new purpose.
These observations address fundamental considerations, and perhaps a new concept should be developed. However, as the TRL concept is already accepted and being used in various communities, a new scale cannot easily be introduced. Although far from perfect, further adaptation of the TRL concept would seem to be better than developing and implementing a new one. The first change would involve the nine levels, which poorly address the stages of actual industrial levels of maturity, especially with regard to the different policies needed. A clustering of levels according to these policy needs would be in order. Second, as manufacturing is crucial to KETs, the levels need to address more than one technology, and the organisational and market aspects need to be incorporated. EARTO suggests rephrasing the TRL (Figure 8).

The stages in Figure 9 can be linked to different policy instruments, and even synchronised to the three types mentioned in the State Aid Rules (basic research, industrial research, experimental demonstration). In addition to using this revised scale, the first observation of setbacks in technological maturity needs to be addressed. Although at a high-TRL level (pre-production), funding for low-TRL activities (research) institutionally should be easily available if a setback occurs. This reduces possible capital destruction when fundamental

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3 The concept of the innovation readiness level developed at Cambridge University addresses some of these issues and could be seen as an alternative.
flaws in the product design emerge during the development of manufacturing. Last but not least, policy instruments should **address not only technology development**, but also such things as assessing intellectual property issues, creating industry networks of value chains, and facilitating training of personnel (incubator activities).

**Figure 9: The metamorphoses from KETs to a KET-based product**

Source: De Heide et al. (2013).

### 2.4. A closer look at key enabling technologies

But what is a key enabling technology? As stated in the EC definition, KETs are **knowledge and R&D intensive**, need a **highly-skilled workforce**, and require **high capital expenditures**. They initiate and enable innovative **products, goods, and services** and can assist the **valorisation** of research in other domains. Last, KETs are **systemic** to the industry base, the economy, and society and can be seen as industrial technologies.

However, a key enabling technology can be seen as a building block that is to be used by industry to increase its innovativeness and competitiveness. KETs are **key knowledge** on how to solve certain problems with tools, machines, or other techniques. Although crucial, they must be transformed into **technological components** of products (KETs-based components), which, in turn, must be transformed into **end-user** KETs-based products (Figure 9). It is this final product that creates most of the jobs, addresses societal challenges, and stimulates economic growth across a full range.

This KETs-based product is defined by the European Commission Communication (COM (2012) 341) as follows (European Commission 2012c):

- (a) an enabling product for the development of goods and services enhancing their overall commercial and social value;
- (b) induced by constituent parts that are based on nanotechnology, micro-/nanoelectronics, industrial biotechnology, advanced materials and/or photonics; and,
- (c) produced by advanced manufacturing technologies.

The question is whether KETs are a common concept in the global policy community. A recent assessment of 20 countries worldwide shows that although many countries focus on critical technologies, only a few use the term KETs (e.g., Belgium, Germany, Austria) (Butter et al. 2013). And when it is used, it refers to the EC KETs strategy, in order to align their research, development, and innovation (RDI) policy with funding from the European level. Many countries do use an approach that is comparable to the EU KETs approach (focus, deployment, re-industrialisation). The “Technologies Clés” from the French government, the American Critical Technologies, and the Italian National Research Program (using the Associazione Italiana Ricerca Industriale, AIRI, focus areas⁴) are just a few

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⁴ Tecnologie Prioritarie per l’Industria Italiana: Innovazioni per il prossimo futuro.
examples of technology-oriented approaches. Often a more thematic focus can be seen on societal/industrial needs: the “top sectors” policy of the Netherlands, the Chinese “strategic emerging industries” and the South Korean “key technology areas” are issue and industry driven. We can conclude that the KETs concept is only used by the European Commission and some EU countries. Focus is very common, but not only on technologies. Annex 1 presents an overview of KET policies in a number of EU countries and similar programmes on enabling technologies in a number of key countries worldwide.

The second issue—deployment—is also addressed by many countries, but less clearly. Some countries give priority to a linear, science-pushed approach (e.g., US, Japan, and France), where research is believed to provide a knowledge base that industry will translate into applications. Other countries show an interactive approach, with the establishment of institutional structures where industry is a partner in research, with more and more initiatives being developed in which the deployment of research findings and technologies is supported. The Catapult centres in the UK, the 863-Program in China, and the Korean techno parks are just a few examples.

This trend towards deployment shows the increasing attention to re-industrialisation. Many of the examples given here aim at supporting industry and, more importantly, manufacturing, in innovating and becoming more competitive. In the past, R&D often focused on the development of new products and services, but in the last decade, it became clear that industrial manufacturing is key in the valorisation of research outcomes. The Obama strategy for advanced manufacturing is one example; the German Industry 4.0, the Chinese Torch Program, and the Dutch Top Sectors Policy are examples of supporting manufacturing.

2.5. Definition and demarcation of six KETs and other EU concepts

The KETs concept originated during discussions within the information and communication technology (ICT) community and semiconductor industry. The initial observation was that, although the ICT industry was seen as one of the most important backbones of our modern economy, the European ICT industry was facing problems. A policy to strengthen the European ICT industry was needed in order to strengthen the industry base. But this proved to be relevant to other industries as well, and a non-sectoral approach using technologies as enablers crystallised. The following five KETs were regarded as strategically the most relevant:

- NT (nanotechnology);
- MNE (micro- and nanoelectronics, including semiconductors);
- PHOT (photonics);
- AM (advanced materials);
- IB (biotechnology).

A sixth, more overarching, KET was added to include the manufacturing side of the industry: AMT (advanced manufacturing technologies).

With regard to this selection of KETs, software is often also suggested as a KET. Many countries do focus on software as a pivotal technology for manufacturing and industrialisation (e.g., US, Korea, Japan, Germany), but software does not meet the criterion of capital intensity. A more practical reason is that, at this moment, opening up the discussion again on what technologies are KETs could jeopardise the KETs strategy.

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5 Further demarcated to Industrial Biotechnology in the accompanying Commission Staff Working document.
6 AMT was changed to AMS (advanced manufacturing systems) because of its multi-KET characteristics.
At the time of the EC Communication, a clear definition and demarcation of the six selected KETs was not made because this was seen as one of the tasks of the HLG on KETs. The KETs were further assessed within several working groups and reports were published, including a contextual description. However, this did not result in a well-defined description, as this proved to be complicated, not only because of political implications. A first definition and demarcation of the KETs was developed during a project to assess the feasibility of a monitoring mechanism for industrial deployment of KETs, continued by its successor, the KETs Observatory. It is clear that to assess deployment one needs demarcation and definition. The defining mechanism is based on the *Nomenclature Statistique des Activités Économiques dans la Communauté Européenne* (NACE), by attaching individual classes to a KET. In general, the following (broader) definitions, as presented in Table 1, can be used.

**Table 1: Overview of Definitions of the Individual KETs**

<table>
<thead>
<tr>
<th>KET</th>
<th>Definition and demarcation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NT</strong> (nanotechnology)</td>
<td>An umbrella term that covers the design, characterisation, production, and application of structures, devices, and systems by controlling the shape and size at an atomic, molecular, and supramolecular scale. Nanotechnology holds the promise of leading to the development of smart nano- and microdevices and systems and to radical breakthroughs in vital fields such as healthcare, energy, environment, and manufacturing.</td>
</tr>
<tr>
<td><strong>MNE</strong> (micro- and nanoelectronics)</td>
<td>Deals with semiconductor components and/or highly miniaturised electronic subsystems and their integration into larger products and systems. They include the fabrication, design, packaging and testing from nano-scale transistors to micro-scale systems integrating multiple functions on a chip.</td>
</tr>
<tr>
<td><strong>PHOT</strong> (photronics)</td>
<td>A multidisciplinary domain dealing with light, encompassing its generation, detection, and management. Among other things, it provides the technological basis for the economical conversion of sunlight to electricity (which is important for the production of renewable energy) and a variety of electronic components and equipment such as photodiodes, LEDs and lasers.</td>
</tr>
<tr>
<td><strong>AM</strong> (advanced materials)</td>
<td>Leads both to new reduced-cost substitutes to existing materials and to new higher-added-value products and services. Advanced materials offer major improvements in a wide variety of different fields, e.g., aerospace, transport, building, and healthcare. Advanced materials facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe.</td>
</tr>
<tr>
<td><strong>IB</strong> (industrial biotechnology)</td>
<td>Also known as “white biotechnology”, it is the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using microorganisms or components of microorganisms like enzymes to generate industrially useful products in a more efficient way (e.g., less energy use or fewer by-products) or to generate substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already on the market. The most mature applications are related to enzymes used in the food, feed, and detergent sectors. More recent applications include the production of biochemicals, biopolymers, and biofuels from agricultural or forest wastes.</td>
</tr>
<tr>
<td><strong>AMT</strong> (advanced manufacturing systems)</td>
<td>AMTs encompass the use of innovative technology to improve products or processes that drive innovation, including all production equipment that deploys a KET or any other innovative technology, but excluding the actual production as this is attributed to the individual KETs.</td>
</tr>
</tbody>
</table>

*Source:* De Heide et al. (2013).
Some important observations were made during the process of defining the KETs:

- **A KET today is not a KET tomorrow**, for example, the photonics technologies used in the CRT televisions. In the 1970s, the phosphoric materials used would surely have been NT and PHOT KETs; today they are out of date.

- Core to the KETs is its driver for innovation. A KET should significantly contribute to the **competitiveness** of a KET-based product. So, although blue-ray technology is considered photonics, new blue-ray technologies are not contributing to competitiveness and are not part of the KET PHOT.

- A KET-based product can be the result of the use of KETs in the product or the manufacturing system. Industrial biotechnology innovates manufacturing but its products do not include IB (e.g., bioethanol has the same chemical composition as petroleum-based ethanol). This complicates demarcation, because, for example, MNE is crucial to many manufacturing processes that produce products “without a KET”. So is an avocado a KET-based product (because high-tech sensors are used to assess its ripeness)? The conclusion must be that a KET project eligible for funding must show an innovative application of KETs and should make a **crucial contribution to competitiveness**, either in the product or the manufacturing.

### 2.6. Other related concepts: Cross-cutting, multi, integrated

In addition to the six individual KETs, the combination of KETs is also considered to be of importance. Within the H2020 programme, **cross-cutting KETs** are seen as pivotal to innovation. The following statement was made in the 2012 Communication on KETs (European Commission 2012c):

> While individual KETs are recognised as indispensable sources of innovation, the cross-fertilisation of different KETs is vital, in particular for the transition from R&D to pilot and industrial scale production. A considerable part of the KETs activities planned under Horizon 2020 will be dedicated to cross-cutting activities, which will bring together different KETs for developing innovative products and for contributing to solving societal challenges.

The following two concepts are often used:

- **Multi-KETs**, related to scale up activities towards low-volume mass production (the multi-KETs Pilot Lines).

- **Cross-cutting KETs**, related to the combination of technologies and finding new products and services that address grand challenges.

Several studies have addressed the definition and demarcation of these two concepts. The main conclusion is that there are differences between cross-cutting-KETs and multi-KETs, but they do not have any policy consequences.

However, it should also be noted that there was another conclusion: there is a certain “natural” overlap between the individual KETs. For starters, AMS was considered a multi-/cross-cutting KET from the beginning, although not stated as such. A good second example is the overlap between NT, AM, and PHOT: an important discipline within photonics research is nanophotonics, which focuses on new photonic materials, using nanotechnology. Figure 10 shows that innovations often have a multi-/cross-cutting character, except for IB, which is distinguished by being a mostly a manufacturing technology. In conclusion, it can be said that, to safeguard the KETs concept, the purpose of cross-cutting/multi-KETs must be to bring together different communities to create new...
inspiring avenues of innovation, within an environment where the focus is on manufacturing.

**Figure 10: Natural connections between the six KETs**

![Diagram of natural connections between the six KETs](image)

**Source:** Based on Butter et al. (2013) and Chiappa et al. (2014).
3. CURRENT SITUATION REGARDING KETS: THE EU IN A GLOBAL CONTEXT

**KEY FINDINGS**

- Europe is a leader in knowledge creation for most of the KETs, as revealed by patenting and as reflected in, for example, patenting activity. But in exploiting this knowledge (i.e., the second and especially third pillar for crossing the Valley of Death), Europe falls behind its main competitors.

- In the mass manufacturing of KET-based products in particular, Asia, and especially China, is leading. China’s competitive advantage has primarily been based on low labour costs, but this is changing rapidly. Other Asian countries, such as Korea and Taiwan, have become leaders in specific KET domains.

- Within Europe, Germany dominates the market for KET-based products, followed by France, the UK, and Italy (with the last three ranked differently for different KETs).

- Specific clusters that build on KETs are present in Europe, in various Member States. These clusters are based on the proximity of leading actors, often multinational companies, but they do have a global scope in their activities, and rely on international counterparts for production.

This section examines the ways Europe and its main competitors perform in KETs and in KET-related sectors, describing the role that the six different KETs play with regard to their contribution to EU competitiveness and the competitiveness of EU actors in a global context. It offers a non-exhaustive overview of relevant clusters on KETs and the actors involved, and it describes the relationship (i.e., interaction) between the EU value chains deploying KETs and non-EU actors.

3.1. Photonics

For the photonics industry as a whole, production is dominated by Asia, especially Japan (32%) (European Commission, 2009). Europe, accounting for over 20% of the global production, can also be considered a world player in this industry (Butter et al. 2011; European Commission 2010). This share, however, differs greatly over the subsectors of the highly heterogeneous photonics market (Butter et al. 2011). While European photonics production in some markets is only marginal (in particular, flat-panel displays and IT products), Europe dominates the top actors of other sub-industries worldwide, such as optical systems and components, lighting, medical technology, life sciences, photovoltaics, and production technology (European Commission, 2010; Larsen et al. 2011). Nonetheless, competing regions, such as China, with huge financial support for these sectors from national and local governments, are catching up. One of the threats for further development of the European photonics industry is its reduced competitiveness in some of these subsectors in favour of Asian and Latin American countries (European Commission, 2010).

The European photonics industry can be considered a significant part of the global market. A leverage assessment by Butter et al. (2011) showed that the European photonics industry is highly relevant for the broader European economy, with 20% to 30% of all

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7 Because the KETs are of a very different nature, we present each individually, with overall conclusions provided only in the Key Findings.
European markets and industries depending on photonics for their competitiveness. In the coming decade, this dependency is expected to increase for photonic-enabled manufacturing industries and even more for final markets. This importance, however, varies over the different submarkets of this highly heterogeneous industry. The textile and clothing, automotive, telecom, oil and gas, lighting, medical equipment, and food and beverage industries, in particular, are dependent on photonic-based products and technologies.

Further globalisation in the already heavily globalised photonic industry is to be expected, (Butter et al. 2011). Globalisation might speed up the catch-up to European knowledge levels by Asian countries, and the corresponding changes in economic structures could create challenges for the European photonic industry. Given the high dependency of the photonic industry on highly skilled and innovative employees, increased competition for talent with Asia and the US may form a threat for Europe. Together with a reduction in government funding in Europe, this might put pressure on industrial linkages with research, which are crucial for certain parts of the European photonic industry.

In Europe, Germany is the European leader in photonics, in terms of production value (39 %), number of companies, and research activities (Larsen et al. 2011). An overview of the number of European companies active in this sector per country is shown in Figure 11, which shows that the photonic industry is represented in most European countries and that after Germany, the UK, France, Italy, and the Netherlands also have considerable shares in industrial activities.

**Figure 11: Number of industrial players in European photonics industry per country**

Although some large multinational organisations are headquartered in Europe, SMEs dominate the photonic industry⁸, with most specialised in specific niche markets (Butter et al. 2011). A large part of the high-level research organisations, universities, and companies (start-ups as well as SMEs and large enterprises) active in the photonic industry are concentrated in either regional cluster networks or national technology platforms (European Commission, 2010), a lot of which participate in the European Technology Platform Photonics21⁹ and include members who are active along the entire value chain.

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⁸ According to the Photonics21 database, more than 90 % of the approximately 2600 companies active in the EU photonics industry are SMEs.

⁹ Photonics21, the European Technology Platform, unites its 2000 members in the European field of photonics (both industry and research organisations) from the entire value chain and coordinates research initiatives and activities in this area.
3.2. Industrial biotechnology

The number of established companies active in the European industrial biotechnology market is more or less similar to that of the US. In Europe, however, these companies are mainly micro- or small enterprises (Critical I 2006), which account for a much smaller part of the worldwide revenue, R&D investments, employment, and capital raised in the industry, compared to their US competitors (Jonsson 2007). Obviously, the position of Europe differs within the different submarkets in the technology. Europe has an exceptionally strong, leading position in the development and production of enzymes, for example.

Europe is a global leader in the industrial biotechnology industry in terms of patents and scientific publications, with a global share in patent applications of over 40% in the period 2007–2011, and in scientific publications of almost 40% in the period 2002–2004 (Omiya and Noji 2014). However, in terms of revenue, market capitalisation, number of companies, and employment, Europe ranks second after its principal competitor, the US, which is the world leader. Despite the similarity in number of active companies in the industry, the US has twice as much R&D investment, venture capital, earned revenue, and employees in the industry. Aside from the US, intense global competition for Europe comes mainly from Japan and Canada; Brazil and Asia-Pacific countries\(^\text{10}\) are expected to become serious competitors in the coming years (Critical I 2006).

There is convergence with other technologies, such as nanotechnology, process engineering, and information and ICT (Sherpa Group 2011), but also creation of new markets and value chains. The strong industrial biotechnology-based sector in Europe is aiming to reduce its dependence on petroleum products; Europe could further exploit the potential of shifting from oil-based to bio-based or biodegradable materials and chemicals and enable re-industrialisation by the creation of new rural infrastructure and bio-refineries (Bio-based Industry Consortium 2014).

The high potential of the economic impact of the industrial biotechnology market can be illustrated by the research of Bloomberg New Energy Finance (2012), which indicated that the substitution of 10% of gasoline by cellulosic ethanol in 2030 in Europe has a potential revenue of almost EUR 80 billion and an increase in employment of 170 000.

In Europe, the top of the market, in terms of both number of companies and revenue, is dominated by Western and Northern European countries, namely Denmark, France, Germany, Sweden, Switzerland, and the UK (Steinbeis European Zentrum 2005). In recent years, a number of cluster initiatives have been launched in Europe, in which active companies in this industry typically concentrate. Among the most important clusters are Cambridge (UK), Berlin-Brandenburg and Heidelberg (Germany), Aarhus (Denmark), Marseille and Paris-Evry (France), and Milan (Italy). There are also a number of important transnational clusters like BioValley (Germany, France, and Switzerland) and Medicom Valley (Denmark-Sweden) (Larsen et al. 2011). Other initiatives aiming for further strengthening of collaboration between actors in the value chain, and thereby the competitiveness of Europe, are the European Technology Platform SusChem, the Knowledge Based Bio-Economy Network (KBBE-NET), CLIB2021, and the Industrial Biotech Council. Most clusters include companies and organisations active across the entire value chain, from agriculture and silviculture to feedstock industries (i.e., producers of renewable resources), bio-/chemical producers, and consumer industries.

As of 2006, the majority of companies active in the European industrial biotech market are involved in human healthcare (37%) and services (34%), including manufacturing and

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\(^{10}\) Such as China, India, Korea, Malaysia, Australia and New Zealand.
contract research (Steinbeis European Zentrum 2005). Mature bio-based products are food, feed, and detergents in which enzymes are processed (European Commission 2009). Other examples are corn-based ethanol, soy-based lubricants, biofuels, bioplastics, biopolymers, and biochemicals (Orr 2004; Sherpa Group 2011).

3.3. Micro- and nanoelectronics

The semiconductor industry value chain, which constitutes the basis for MNE, is dominated by actors from the US, followed by South Korea, China, Japan, and the EU28. Europe is an important player with respect to the manufacturing of semiconductors, but the sector is dominated by Asian countries. China, in particular, has the highest output and continuing growth of sales. The current figures reflect an ongoing development that will result in a further shift of the large-volume production of standard chips to emerging low-cost countries.

For Europe, there is nothing to gain in mass production, and it should focus on specialised and advanced systems with added value. A further consolidation of the market will subsequently take place among the European actors involved in the production of semiconductors. These will not play a dominant role in the production of integrated circuits. They will further specialise in their activities, focusing on specific areas (e.g. technologies/niches/applications), in line with developments in a market driven by More than Moore.

The semiconductor industry shows a geographical orientation with technology clusters in America, Europe, and Asia.

- European semiconductor manufacturers focus on innovative special solutions, driven by client requirements.
- A large part of the US production industry that makes use of semiconductors has been transferred to Asia. However, it is expected that Silicon Valley will continue to be a driver in technology innovation for the semiconductor industry.
- In the Asian market, different clusters are observed in Japan, Taiwan, South Korea, and China. It is expected that, in the future, the semiconductor market will continue

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11 Note that while some references in this report refer to reports that are not recent, in practice they represent the most relevant background for our analysis.

12 Bio-based products are defined as industrially valuable products or substances with specific characteristics, generated by the use of micro-organisms and enzymes.

13 Preliminary rankings for 2013 from Gartner (see www.gartner.com) indicate that INTEL (US) and Samsung (South Korea), two well-known integrated device manufacturers (IDMs) are at the top of semiconductor suppliers in terms of revenue. Qualcomm (US), a fabless company (i.e., a firm that designs and sells hardware devices and semiconductor chips while outsourcing the fabrication), follows in third position. Toshiba (Japan), Micron Technologies (US), Hynix (South Korea), Texas Instruments (US), Broadcom (US), STMicroelectronics (France/Italy), Renesas (Japan), and Sony (Japan) complete the top. The foundry segment (i.e., existing of firms that process and manufacture silicon wafers) is dominated by Taiwan Semiconductor Manufacturing Company (TSMC), followed by Global Foundries (US), United Microelectronics Corp (UMC) (Taiwan) and Semiconductor Manufacturing International Corp (SMIC) (Shanghai/China). The market for IP-cores is very diverse.

14 See https://www.wsts.org/. WSTS is a non-profit organisation of 62 semiconductor companies representing close to 80% of the world semiconductor market. Involved primarily in manufacturing of chips, they are at the core of the semiconductor industry value chain.

15 To illustrate this point: China is developing a semiconductor industry targeted at the standard chip processing available today. The size of the market in China might, in itself, warrant this development in the future.

16 In 1965, Gordon Moore, co-founder of Intel, was making the observation that “The complexity for minimum component cost has increased at a rate of roughly a factor of two per year.” Moore predicted that this trend would continue for the foreseeable future. This observation, known as Moore’s law, was later amended to “the number of components per integrated circuit (IC) doubles every 18 months”.

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to shift towards Asia, following the trend of the sales market and resulting from improvements of know-how in Asia, increased research efforts at Asian universities, financial support provided by Asian governments, and low wages. Most chips designed by US or European companies for computers and consumer electronics are manufactured in Asia. Processes such as testing and packaging had already been outsourced to Asia, and there is increasingly a trend to set up fabrication facilities in China.

In the EU27, Germany is the most prominent actor in MNE, contributing more than a third of the value-added generated in the sector, followed by Italy, France, the UK, and Austria. Large firms play an important role (nearly half of the value-added is located in firms with 250 or more employees).

The development of new products and processes requires large-scale research in internal R&D departments and by specialised technology and research centres, partly also focusing on process research. Knowledge production is largely done in global networks. SMEs are part of these networks, often supplying large integrated device manufacturers. R&D and innovation are guided by Moore’s law, leading to an average technology life cycle of three to seven years and an innovation-to-market cycle of between one and three years.

Minalogic is an important European cluster on MNE, located in Grenoble, France (see www.minalogic.org). Established in 2005 as an organised structure/entity (but in existence since the 1950s), it focuses on micro- and nanoelectronic hardware technologies and embedded systems-on-chips. It provides some 24 700 jobs in micro-/nanotechnologies and electronics (3000 jobs in research and 21 700 jobs in business) at 204 member organisations (154 companies, of which 82 % are categorised as SMEs; 16 research centres and universities17, 15 local government organisations, and four private investors).

3.4. Advanced materials

Because of the wide scope of the field captured by AM, and the overlap with other KETs (such as MNE and NT), it is very difficult to assess the relevance of advanced materials for the EU in a consistent and up-to-date way. The most recent and relevant figures indicate a global market size of about EUR 100 billion in 2008, expected to grow to EUR 150 billion in 2020 (EMRS & ESF/MatSEEC 2011; HLG KETs 2011; Oxford Research AS 2012.

An analysis of patents (Figure 12) indicates that the EU is an important player in AM. Only Japan is outperforming the combined EU Member States. Noteworthy, however, is the fact that Japan is increasing its share in patenting, while Europe shows a downward trend. Other competitors are considerably behind the two leaders18.

17 Four universities, renowned in higher education, especially in science; four international research centres (EMBL, ESRF, ILL, LCMI); and eight national research organisations (CEA, CENN, Cemagref, CNRS, CRSSA, Inra, Inria, Inserm).

18 In line with recent reports, we argue that it is practically impossible to further assess the specific strengths and weaknesses of the EU industry involved in AM. This, according to the Working Group on Advanced Materials Technologies (2011), is because of the wide scope of the field included in AM and the overlap with other KETs.
AM is a crucial input for other KETs such as photonics, NT, and MNE, all of which play a vital role in the competitive strength of the EU industry and form the basis for future growth. In practice, the industry involved in AM is subject to international competition, just as other KET-based industries are, but there is another issue that defines their competitiveness: a scarcity of raw materials. In total, 14 critical materials used for high-tech products are in danger of being in short supply. The literature suggests that a lack of these elements (which are mined in only a few countries, such as China, Russia, and Mongolia) will "influence the possibilities for large developments of materials' technologies". Recent problems with the availability of materials highlight the vulnerability of this industry sector.

According to the Working Group on Advanced Materials Technologies (2011), the answer to issues concerning the supply of essential raw materials could be recycling. Recycling technology is an important tool that will shape future industries, and Europe is recognised as world leader, thanks both to the closed-loop mindset and to its powerful industrial recycling trends.

In order to illustrate the relevance of AM for the EU, we compare market shares of different countries and economic zones in the total production of patents for AM. Although patenting refers primarily to knowledge creation, it also reflects deployment of KETs in products and manufacturing processes.

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19 The list includes cobalt, indium, and magnesium.

20 This indicator on market share is compiled within the framework of the KETs Observatory. It indicates the relevance of a country in the respective technology market and is compiled by dividing the number of patent...
Further analysis by HLG KETs (2011) confirms that the main European actors are located in Germany and France. The Working Group on Advanced Materials Technologies (2011) reveals that relevant value chains building on AM within a European context (i.e., concerning the critical mass of Europe-based industrial capacity and clustering around one or more world-class producers) involve photovoltaics, advanced batteries, solid-state lightning, gas turbines, and healthcare.

While our analysis of existing reports and studies revealed little detail on the structure of the industry sector involved in AM, it did provide insight into the changing role of actors, especially start-ups in the innovation process supporting developments in AM. According to Deloitte (2012, p.8), “A fundamental evolution has occurred in materials science and engineering innovation, previously achieved mainly by the large corporate R&D labs of the mid-20th century and then in the academic materials science and engineering departments of the late 20th century. Today, novel developments are increasingly the purview of interdisciplinary institutes emphasising systems-level engineering (many as public-private partnerships) and of start-ups efficiently bridging the gap between technology and markets.”

An interesting example of this is the cluster around the pilot line for battery production at the Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW) Baden-Württemberg. This research and development organisation in southwest Germany has expanded its activities in lithium-ion battery technologies and has established “eLaB”, the pilot production facility for batteries in automotive applications. The undertaking is supported by the industry-driven Competence Network Lithium-Ion Batteries (KLiB), which works across industries and sectors and covers the entire value chain of battery production.

### 3.5. Nanotechnology

With a relative share of over 30% worldwide, Europe constitutes the second largest nanotechnology market internationally, after the US (41%) (European Commission 2009). These shares are expected to be redistributed to the extent that both regions account for 35% in 2015. The US and Japan could be considered the main competitors for Europe, while China, Korea, and Russia are also heavily investing in nanotechnology.

Europe’s global share in publications is high (33%), but transferring these research efforts and knowledge into patents still seems to be challenging, with rather low shares in patent applications (17%). The potential for further development and commercialisation of European knowledge and expertise in the technology outside Europe has not yet been fully exploited (Larsen et al. 2011).

By enabling the use of innovative functions, higher resource efficiency, and cost reductions, the European nanotechnology industry contributes significantly to the competitiveness of such European economic sectors as ICT, automotive, materials, medical devices, and process and manufacturing. It has even been stated that these sectors would become non-competitive without this technology (HLG 2010). The introduction of technological innovations in established, economically prominent industries by nanotechnologies drives the improvement of products and processes and thereby enhances employment in Europe.

An overview of the number of European companies active in the nanotechnology industry per country is shown in Figure 13. It is evident from Figure 13 that Germany is leading in Europe, with nearly half of the European nanotechnology companies based there. This

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**Note:** This indicator is strongly influenced by the size of a country, as larger countries are more likely to produce more patents than small countries. See [www.ketsobservatory.eu](http://www.ketsobservatory.eu) for other indicators as well as a further explanation of the underlying methodology.
figure also suggests conclusions that are somewhat similar to those in the photonics industry, in that the nanotechnology market is represented in most of the European countries and that, after Germany, the UK, France, and Italy have substantial shares in industrial activities.

Many actors in both industry and research are concentrated in cluster initiatives, with the most important in Denmark, France, Germany, Ireland, the Netherlands, Spain, and the UK. A lot of the players in the nanotechnology industry also participate in the European technology integrating and innovation platform NANOfutures21. In Europe, research in nanomaterials, nanobiotechnology, and nanophotonics is particularly well established (HLG 2010).

3.7. Advanced Manufacturing Technology

It is also quite difficult to capture the relevance of AMT to the EU economy, given the variety of technologies involved. We adopt, in line with the European Commission (2014b), the idea that the size of the market is an indication of its significance. The global market for industrial automation solutions was estimated at USD 155 billion in 201122 (35 % in Europe) and forecast to reach USD 190 billion by 2015 (Credit Suisse 2012).

Figure 13: Number of companies in the European nanotechnology industry per country

![Bar chart showing the number of companies in the European nanotechnology industry per country.]


In terms of value added and employment, the largest EU27 manufacturing subsectors in 2010 were the manufacture of machinery and equipment, food, fabricated metal products, motor vehicles, and chemicals, indicating again the relevance of AMT (Eurostat Manufacturing Statistics, April 2013).

21 Stimulating a shared strategic vision on the future of the industry in Europe, NANOfutures is a cross-platform, integrated initiative that provides a collaborative environment for the European industry, as well as for research organizations, NGOs, and financial institutions in the field of nanotechnology.

22 Including industrial robots, sensors, valves, drives & motors, product lifecycle management systems, and industrial control systems.
An important cluster in AMT is concentrated in the Netherlands (notably ASML, but with global actors from the whole value chain), which is involved in the production of manufacturing equipment for the semiconductor industry. This network of companies of different sizes and actors from the research infrastructure dominates this market, building on different KETs (photonics, AM, and MNE).

Before the economic crisis in 2007, manufacturing industries contributed to 17.1% of GDP and accounted for some 22 million jobs in the EU. And if we measure the relevance of the sectors involved in AMT, the EU is leading its global competitors (Figure 14). An analysis by HLG KETs (2010) indicates that the strengths of the actors involved in AMT in the EU are based on a top-class engineering tradition, existing expertise and know-how, a broad technology base, and the availability of a sound structure with technological and manufacturing clusters. Specific weaknesses include the growing deficit of skilled staff, costly up-scaling of processes, access to finance in capital markets, fragmented European markets, and low labour mobility.

**Figure 14:** Patenting activities in AMT for a selection of countries

Source: KETs Observatory database (2014).
4. HORIZON 2020 STRATEGIC PROGRAMMING OF ACTIVITIES

**KEY FINDINGS**

- KETs have become a fundamental part of Horizon 2020, with an allocation of about EUR 30 billion.

- Horizon 2020 pays significant attention to pilot lines, where activities to translate prototypes into low-rate mass manufacturing will be supported.

- About 30% of the LEIT budget will be allocated to cross-cutting KETs, focusing on activities where more than one KET is integrated, and where the focus will be on activities on a scale of TRL 4 to 8.

- The State Aid rules can complicate the support of higher TRLs. Although Horizon 2020 itself does not fall under State Aid rules, the new combined funding mechanisms could lead to problems.

- Higher TRL activities ask for strong industry participation, but should also receive less support from government due to the effects of market distortion.

- Research and technology organisations have a relevant role during all stages of innovation.

- Multi-user shared facilities can provide technological infrastructure and expertise to stimulate pilot production in SMEs and large enterprises.

4.1. Introduction to Horizon 2020

The new framework programme Horizon 2020 succeeds the 7th Framework Programme (FP7), with funding that is almost 30% higher than for FP7 in real terms. With a total budget of EUR 77 billion (current prices at the end of 2013), this new programme is the financial instrument for the implementation of the Innovation Union.

One of the main differences between FP7 and H2020 is that more emphasis will be placed on societal challenges, the role and needs of SMEs, and supporting the market uptake of innovation by means of targeted procurements, standard setting, and loan and equity finance. H2020 also aims to improve coordination with regional policy objectives covered under the Structural and Cohesion policies. While the latter will support the build-up of the capacity for research and innovation at the regional level, H2020 will foster policy coordination and learning across regions through various networking and twinning schemes.

Corresponding to the priorities of Europe 2020 and its Innovation Union flagship programme, H2020 focuses its resources on three main distinct, reinforcing priorities:

- **Excellent Science**, including action lines on Future and Emerging Technologies, in the European Research Council, Marie Skłodowska-Curie actions, and the research infrastructure.

- **Industrial Leadership**, including LEIT, access to risk financing, and innovation in SMEs.

- **Societal Challenges**, focusing on addressing the grand challenges.
Some other programme sections are also included in H2020:

- Spreading Excellence and Widening Participation.
- Science with and for Society.
- The European Institute of Innovation and Technology (EIT).
- Euratom.

Except for the EIT, these other programme sections are not directly relevant for KETs.

In this section, special attention is given to joint public and private participation. These distinctive instruments were also present in the 7th Framework Programme and focus on implementing the participation of private entities and Member States: **Joint Technology Initiatives, Contractual Public-Private Partnerships** and **Public-Public Partnerships**. As these are also important for the implementation of the KETs strategy, they will be discussed briefly.

4.2. A rationale to support KETs in H2020

While Europe is a global leader in KET development (with a worldwide share in patent applications of 32% in the period 1991–2008), it is a global trailer in the commercialisation of KET-related goods and services (European Commission 2012a). Europe fails to translate its knowledge base into a production capability that can secure growth, employment, and sustainable living standards, which has provided the rationale for policy intervention, resulting in the establishment of the High level Group on Key Enabling Technologies (HLG KETs), which has translated it into a framework for RDI policy (see HLG KETs 2011). As mentioned in Section 2, the HLG KETs have named the gap between basic knowledge generation and its commercialisation into goods and services as the “Valley of Death”.

Discussions on translating this vision into policy resulted in the EU KETs strategy, of which the H2020 Programme is one of the main pillars. A criticism often heard about FP7 (even in the European Parliament) was that the actual societal benefit of the programme was limited because of its focus on research. The shift from a programme focused on research to one on research and innovation, oriented to a broader value chain, allows the support of valorisation of research into industrial applications. This is directly connected to the concept of KETs. In addition, specific attention is given to the six KETs, as they are considered technologies that are core to enhancing the competitiveness of the European industry and solving the grand challenges we are facing today. By including KETs as the core of the H2020 programme, the focus is not only on research development, but also the connection to industrial application in a non-sectoral approach.

4.3. H2020 Pillar 1: Excellent Science

The first element of the Excellent Science pillar is the **European Research Council**, which provides attractive and flexible funding to support talented and creative individual researchers and their teams in pursuing the most promising avenues at the frontier of science, on the basis of EU-wide competition. Through a bottom-up mechanism of peer-review panels, grants are given to individual researchers based on scientific excellence. The main research domains are the physical sciences and engineering; life sciences; and social sciences and humanities. The budget allocated for 2014–2020 is EUR 13 095 million.

The **Future and Emerging Technologies** (FET) programme addresses the grand science and technology challenges that require a research effort for a period of up to 10 years and, under H2020, has been allocated a provisional budget of EUR 2 696 million. The FET programme has three complementary lines of action to address different methodologies and scales, from new ideas to long-term challenges. **FET Open**, representing 40% of the overall FET budget, supports joint early-stage research in science and technology around new ideas for radically new future technologies.
The former Marie Curie Actions have been renamed *Marie Skłodowska-Curie Actions* (MSCA) and will award EUR 6 162 million over the period 2014–2020. The objective of the MSCA is to support the career development and training of researchers—with a focus on innovation skills—in all scientific disciplines worldwide through cross-sector mobility. Its mechanism is to encourage transnational, inter-sectoral, and interdisciplinary mobility by providing grants at all stages of a researcher’s career.

While this pillar can contribute to the KET strategy, because of the nature of KETs being close to market, its actual focus on KETs is limited, even though there is *no explicit focus* included today. Research in all KET-related activities can be addressed, depending on the bottom-up activities of researchers. The connection with the basic research conducted in Excellent Science is through valorisation in Pillar 2. At present, this is *not institutionalised*.

### 4.4. H2020 Pillar 2: Industrial Leadership

#### 4.4.1. Overview

In H2020, most dedicated support to KETs is provided by the *Industrial Leadership pillar*, which focuses on several underlying programmes (see Table 2). LEIT is specifically directed towards boosting the industrial deployment of KETs, meaning support for prototyping, product validation in pilot lines, and large-scale pilot and demonstration activities.

<table>
<thead>
<tr>
<th>Table 2: H2020 Funding under the Industrial Leadership Pillar (2014–2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agreed, in current prices (in billions)</strong></td>
</tr>
<tr>
<td>Horizon 2020—total</td>
</tr>
<tr>
<td>Industrial Leadership</td>
</tr>
<tr>
<td>Leadership in enabling and industrial technologies</td>
</tr>
<tr>
<td>ICT (including micro- and nanoelectronics and photonics)</td>
</tr>
<tr>
<td>nanotechnologies</td>
</tr>
<tr>
<td>advanced materials</td>
</tr>
<tr>
<td>biotechnology</td>
</tr>
<tr>
<td>advanced manufacturing and processing space</td>
</tr>
<tr>
<td>Access to risk finance</td>
</tr>
<tr>
<td>Leveraging private financing and venture capital for R&amp;I</td>
</tr>
<tr>
<td>Innovation in SMEs</td>
</tr>
<tr>
<td>Fostering all forms of innovation in all types of SMEs</td>
</tr>
</tbody>
</table>

#### 4.4.2. Leadership in enabling and industrial technologies

LEIT-KETs activities can range from R&D to close-to-market activities or projects addressing the validation of technology and products under industrial conditions. About 30 % of the allocated budget is earmarked for cross-cutting KETs (integrating KETs for more innovative products). Support for KET pilot lines is subject to specific selection criteria, including commitment to first exploitation/manufacturing, evidence of market potential, potential for creating jobs in Europe, and value-chain cooperation. KET support also combines financing for more ambitious industrial projects. In comparison to FP7, it remains to be seen whether substantially more funding will be allocated to KET support.
KET support can be provided in different stages of the development cycle of technology and products, measurable along a TRL scale. Boosting the deployment of KETs typically requires support to activities related to TRL 3 to 4 up to TRL 8. Compared to the 2007–2013 FP7 programme on Materials and New Production Technologies, the support foreseen under H2020 LEIT is markedly different. Whereas in FP7, KET-related activities were focused on TRL 1 to 4, and only more recently (during 2012–2013) on TRL 5 to 6 (first pilots and demonstrators), under LEIT, KET-related support will be provided for TRL 3/4 to 8, centring on TRL 5 to 6. Two funding rates are foreseen for LEIT: research and innovation actions, aiming at TRL 3 to 6, are eligible for 100 % funding; innovation actions, aiming at TRL 5 to 7 are eligible for 70 % funding, with non-profit participants able to claim 100 % funding.

4.4.3. Access to risk financing

Apart from LEIT, Industrial Leadership has two other sections covering access to risk financing and innovation in SMEs. For access to risk financing, the oncoming two years will continue and build on proven FP7 activities: the Risk-Sharing Finance Facility (RSFF) and the Risk-Sharing Instrument for SMEs (RSI), together with GIF-1, the early-stage part of the High-Growth & Innovative SMEs Facility in the Competitiveness and Innovation Framework Programme. The access to the risk-financing provision is approximately 3.69 % of the overall H2020 budget and will have a risk-sharing (loans and guarantees) and risk-financing (equity, mainly focusing on early-stage financing) component. Both measures are meant to stimulate private-sector investment in research and innovation and to create leverage on the EU budget contribution. More specifically, they are meant to facilitate access to financing for (1) RDI-driven/innovative SMEs and small mid-caps and (2) ambitious RDI projects carried out by a variety of recipients (companies, stand-alone projects, etc.).

At least one-third of the available EUR 2.725 billion23 under access to risk financing is meant for research-and-innovation-intensive SMEs and mid-caps through guarantees on loans, comprising the following (Janaszczyk, 2014):

- Loan Service for Research and Innovation ("RSFF II"): Loans and guarantees for investments in Research & Innovation above EUR 7.5 million, targeted particularly at innovative mid-caps, in addition to larger companies, research institutes, stand-alone projects, public-private partnerships, and other entities, managed by the EIB.
- SME & Small Mid-caps R&I Loans Service ("RSI II"): Loan guarantee facility for loans between EUR 25 000 and EUR 7.5 million meant for research-intensive and innovative SMEs and small mid-caps, managed by the European Investment Fund.
- SME Initiative (following the June 2013 European Council): Joint Guarantee Instrument/Securitisation for loans to innovative SMEs and small mid-caps; joint approach involving ESIF, H2020, and COSME, with crucial support from the EIB Group and Member States.

The H2020 early-stage equity facility is part of a common single EU equity financial instrument that supports EU enterprises investing in research & innovation and growth. In order to have the intended leveraging effect, guidelines on investment policies will only allow investments in funds with a minimum private capital share of 30 %. The facility is meant as early-stage financing for innovative enterprises (notably seed and start-up companies), with limited growth-stage financing as a possibility (successor to GIF-1). The equity financial instrument also covers a pilot facility for technology transfer (which is

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23 Answer to Parliamentary questions (29 January 2014) given by Ms Geoghegan-Quinn on behalf of the Commission: "The Access to Risk Finance part of Horizon 2020 is about EUR 1.2 billion less compared to the original Commission proposal for financial instruments under Horizon 2020 which amounted to EUR 4 billion (4.5 % of EUR 87.7 billion)."
under development) to bring R&D results from public research organisations and universities to the market (licensing and the creation of spin-off companies).

4.4.4. Innovation in SMEs

This is part of a dedicated SME Instrument to which at least EUR 3 billion will be allocated over the period 2014–2020, with funding from both the second and the third pillars of H2020 (i.e., Industrial Leadership and Societal Challenges, respectively). At least 20 % of the total budget of LEIT and Societal Challenges will be allocated to the SME Instrument, which will specifically offer the following:

- Business-innovation grants for feasibility assessment (feasibility assessment phase I): EUR 50 000 (lump sum) per project (70 % of total cost of the project).
- Business innovation grants for purposes of innovation development and demonstration (innovation phase II): an amount between EUR 500 000 and EUR 2.5 million (70 % of total cost of the project as a general rule and, in exceptional specific cases, up to 100 %).
- Free-of-charge business coaching (optional in phases I and II) to support and enhance a firm’s innovation capacity and help align a project to strategic business needs.
- Access to a wide range of innovation support services and facilitated access to risk financing (commercialisation phase III), to facilitate commercial exploitation. This includes support to protect intellectual property and support for further developing investment readiness, for linking with private investors and customers through brokerage activities, for applying for further EU risk financing, and a range of other innovation support activities and services offered via the Enterprise Europe Network.

As with the access to finance instruments, the SME Instrument is open to all eligible companies, including companies outside the KET domain. A typical KET topic for which the SME Instrument could provide funding is access for SMEs to KET technology platforms.

4.4.5. Fast Track to Innovation pilot action

The H2020 Fast Track to Innovation pilot action (FTI) is a separate instrument and is new to the Framework Programme. It aims to support innovation under LEIT and Societal Challenges, relating to any technology field. FTI will be implemented in the form of a pilot action in 2015 and will fund 100 proposals with an expected total budget of around EUR 200 million. Any legal entity may apply, with a minimum of three to a maximum of five in any action. No explicit KET focus is mentioned, but it can facilitate KET initiatives.

4.5. Pillar 3: Societal Challenges

As described above, one of the fundamental changes of the H2020 programme, compared to FP7, is the shift in focus to challenges, which is core to the third pillar: Societal Challenges. Large multi-disciplinary teams are working on the following challenges:

- health, demographic change, and wellbeing;
- food security, sustainable agriculture and forestry, marine and maritime and inland water, and the bio-economy;
- secure, clean, and efficient energy;
- smart, green, and integrated transport;
- climate action, environment, resource efficiency, and raw materials;
- Europe in a changing world: inclusive, innovative, and reflective societies;
- secure societies: protecting the freedom and security of Europe and its citizens.
Again, there is no explicit mentioning of KETs, and the KET strategy does not include an explicit focus on the third Pillar. However, the use of TRLs and the focus on higher TRLs is included in the working programmes. The project “Methodology, work plan and roadmap for cross-cutting KETs activities in Horizon 2020” (Ro-cKETs) shows that KETs are also key to many of the stated challenges. The concept of pilot lines is also not key to the working programmes, but the focus on the higher TRL scales leads to the use of pilots, pilot facilities, and piloting. The conclusion can be drawn that, implicitly, this third Pillar also supports the KET strategy.

4.6. H2020 partnerships

The package also includes four so-called public-public partnerships between the European Commission and EU Member States, known as “Art. 185 initiatives” (successors to the Art. 185 initiatives under the sixth and seventh framework programmes). These include new treatments against poverty-related diseases, measurement technologies for industrial competitiveness, support for high-tech SMEs (Eurostar-2), and solutions for the elderly and disabled to live safely in their homes. The proposed budget for these four public-to-public partnerships adds up to a total of almost EUR 3.5 billion (combined funding from H2020 and participating Member States).

Joint technology initiatives (JTIs) were initiated in 2007 and represented a new instrument within FP7 to support large-scale multi-national research activities. Each JTI is implemented by means of a joint undertaking (JU), a legally established community body set up on the basis of Article 187 of the EC Treaty. Members of the JTIs/JUs are the Community (represented by the European Commission), EU Member States or other countries associated with FP7, industry (corporate companies, SMEs and not-for-profit industry-led associations), and R&D actors (research organisations and universities) (De Heide and Kappen 2013).

With the agreement of the Industrial Investment Package of 10 July 2013, the European Commission, the Member States, and European industry agreed to invest more than EUR 22 billion over the next seven years, to include a proposed EUR 8 billion investment from H2020, EUR 10 billion from industry, and close to EUR 4 billion from EU Member States (Table 3). Most of the investment goes to five JTIs, public-private partnerships, as listed below.
### Table 3: Innovation Investment Package 2013: Investments 2014-2020 (in million EUR)

#### Joint Technology Initiatives (JTIs)

<table>
<thead>
<tr>
<th>JTI</th>
<th>EU (H2020) + Member States (for electronics only)</th>
<th>Industry</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovative Medicines Initiative 2</td>
<td>EUR 1 725</td>
<td>EUR 1 725</td>
<td>EUR 3 450</td>
</tr>
<tr>
<td>Fuel Cells and Hydrogen 2</td>
<td>EUR 700</td>
<td>EUR 7 00</td>
<td>EUR 1 400</td>
</tr>
<tr>
<td>Clean Sky 2</td>
<td>EUR 1 800</td>
<td>EUR 2 250</td>
<td>EUR 4 050</td>
</tr>
<tr>
<td>Bio-based Industries</td>
<td>EUR 1 000</td>
<td>EUR 2 800</td>
<td>EUR 3 800</td>
</tr>
<tr>
<td>Electronic Components and Systems</td>
<td>EUR 1 215 (+ EUR 1 200 from EU Member States)</td>
<td>EUR 2 400</td>
<td>EUR 4 815</td>
</tr>
<tr>
<td><strong>Total JTIs</strong></td>
<td><strong>EUR 7 640 (= EUR 6 440 from H2020 + EUR 1 200 from EU Member States)</strong></td>
<td><strong>EUR 9 875</strong></td>
<td><strong>EUR 17 515</strong></td>
</tr>
</tbody>
</table>

#### Joint Programmes with Member States

<table>
<thead>
<tr>
<th>Public-Public Partnerships</th>
<th>EU (H2020)</th>
<th>Member States</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>European and Developing Countries Clinical Trials Partnership 2 EDCTP 2)</td>
<td>EUR 683</td>
<td>EUR 683</td>
<td>EUR 1 366</td>
</tr>
<tr>
<td>European Metrology Research Programme (EMPIR)</td>
<td>EUR 300</td>
<td>EUR 300</td>
<td>EUR 600</td>
</tr>
<tr>
<td>Eurostars 2 (for SMEs)</td>
<td>EUR 287</td>
<td>EUR 861</td>
<td>EUR 1 148</td>
</tr>
<tr>
<td>Active and Assisted Living (AAL) Research and Development Programme</td>
<td>EUR 175</td>
<td>EUR 175</td>
<td>EUR 350</td>
</tr>
<tr>
<td><strong>Total joint programmes</strong></td>
<td><strong>EUR 1 445</strong></td>
<td><strong>EUR 2 019</strong></td>
<td><strong>EUR 3 464</strong></td>
</tr>
</tbody>
</table>

#### SESAR Joint Undertaking

<table>
<thead>
<tr>
<th>Joint Undertaking</th>
<th>EU (H2020)</th>
<th>Eurocontrol and other members</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Air Traffic Management System (SESAR)</td>
<td>EUR 600</td>
<td>EUR 1 000</td>
<td>EUR 1 600</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>EUR 22 579</strong></td>
</tr>
</tbody>
</table>

**Source:** European Commission (2013a).

- Innovative Medicines 2 (IMI2): to develop next-generation vaccines, medicines, and treatments, such as new antibiotics;
- Fuel Cells and Hydrogen 2 (FCH2): to expand the use of clean and efficient technologies in transport, industry, and energy;
- Clean Sky 2 (CS2): to develop cleaner, quieter aircraft with significantly lower CO₂ emissions;
- Bio-Based Industries (BBI): to use renewable natural resources and innovative technologies for greener everyday products;
- Electronic Components and Systems (ECSEL): to boost Europe’s electronics manufacturing capabilities.
All calls for proposals organised by the JTI Joint Undertakings (which manage the JTIs) are open and competitive. The proposals to be funded are selected on the basis of scientific excellence.

Complementing the JTIs, the Commission in FP7 also engaged in structured partnerships with the private sector to seek direct input into the preparation of the work programmes in areas that were defined up front and which are of great industrial relevance. Unlike JTIs, these Contractual Public-Private Partnerships (cPPPs) (Table 4) do not require additional legislation because the funding is implemented by the Commission through normal procedures. JTIs and cPPPs are known as “Art. 187 initiatives”.

### Table 4: JTIs and Contractual Public-Private Partnerships under Horizon 2020

<table>
<thead>
<tr>
<th>Joint Technology Initiatives</th>
<th>Contractual Public-Private Partnerships</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Innovative Medicines (IMI)</td>
<td>• Factory of the Future (FoF)</td>
</tr>
<tr>
<td>• Clean Sky</td>
<td>• Energy-efficient buildings (EeG)</td>
</tr>
<tr>
<td>• Single European Sky ATM Research (SESAR)</td>
<td>• Green Vehicles (EGVI)</td>
</tr>
<tr>
<td>• Fuel Cells and Hydrogen (FCH)</td>
<td>• Future Internet (SG)</td>
</tr>
<tr>
<td>• Electronic Components and Systems (ECSEL) (old ARTEMIS + ENIAC)</td>
<td>New:</td>
</tr>
<tr>
<td>New:</td>
<td>• Sustainable Process Industry (SPIRE)</td>
</tr>
<tr>
<td>• Bio-Based Industries (BBI)</td>
<td>• Robotics</td>
</tr>
<tr>
<td></td>
<td>• Photonics</td>
</tr>
<tr>
<td></td>
<td>• High-Performance Computing</td>
</tr>
</tbody>
</table>


Two initiatives explicitly focus on KETs:

- **ECSEL.** The new JTI Electronic Components and Systems for European Leadership (ECSEL) is a merger of the ARTEMIS embedded systems JTI and the ENIAC nanoelectronics JTI set up in 2008. Electronic systems and components such as semiconductors and computer chips are essential to all digital products and services. They underpin innovation and competitiveness in all economic sectors. Cars, planes, trains, medical and health equipment, home appliances, energy networks, and security systems will all benefit from an advanced European capability and capacity to design and manufacture state-of-the-art electronic components and systems (European Commission 2013d). The new ECSEL JTI is expected to start in 2014 and to be fully operational up to 2020, followed by a reduction phase to 2024. It will bring together large companies and world-class European research and technology organisations linked with higher education research labs and SMEs providing technology and services. In particular, three private industrial associations representing the actors from the areas of micro-/nanoelectronics, smart integrated systems, and embedded/cyber-physical systems will be involved (European Commission 2013d). The estimated budget of the ECSEL JTI is expected to reach EUR 4 815 billion, with the EU contributing up to EUR 1 215 billion and the participating Member States EUR 1.2 billion. The industrial partners will contribute at least half of the total costs of around EUR 2.4 billion in kind. ECSEL will be managed by a dedicated JU whose governing board will be comprised of private members (ARTEMISIA, AENEAS and EPoSS), Member States, and the Commission, and which will take strategic decisions. A public authorities board consisting of representatives of the participating Member States and the European Commission will take funding decisions. Open calls for proposals will be used to implement the work plans of the
Joint Undertaking with co-funding by the EU and the participating Member States, based on an independent evaluation and synergies with national priorities (European Commission 2013d).

- **Factories of the Future.** Factories of the Future (FoF) is a contractual EU public-private partnership supported through the H2020 research programme. The overall aim of the partnership is to enable more sustainable and competitive European industry at the centre of Europe’s economy—generating growth and securing jobs. The partnership will achieve this by supporting European manufacturing enterprises in strengthening their technological base. FoF is industry-led with participation by small, medium, and large enterprises; universities; research organisations; and associations from across Europe who cooperate in pre-competitive, cross-border projects focusing on production technologies from multiple sectors. The research priorities of the partnership are identified in the “Factories of the Future 2020” roadmap that was developed by the European Factories of the Future Research Association (EFFRA) after Europe-wide consultations. The realisation of the research and innovation objectives of the FoF PPP will require public funding of EUR 500 million/year, which the private sector is committed to match with an equivalent contribution in kind (De Heide and Kappen 2013). EFFRA is a not-for-profit, industry-driven association, promoting the development of new and innovative production technologies. It was established in 2009 by MANUFUTURE (the European technology platform on future manufacturing technologies) to shape, promote, and support the implementation of the FoF PPP. The partnership brings together private and public resources to create an industry-led program in research and innovation with the aim of launching market-oriented cross-border projects throughout the European Union.

### 4.7. Other related H2020 actions

Through knowledge and innovation communities (KICs), EIT develops and tests new models of how innovation is approached, managed, financed, and delivered in Europe. KICs integrate the three sides of the “knowledge triangle”: higher education, research, and business. For the period 2014–2020, the EIT budget is predicted to be approximately EUR 2.7 billion. Five new KICs are foreseen in the oncoming programming period, two in 2014 (Innovation for healthy living and active aging and Raw materials—sustainable exploration, extraction, processing, recycling and substitution), two in 2016 (Food4Future—sustainable supply chain from resources to consumers and Added-value manufacturing), and one in 2018 (Urban mobility). An especially relevant development for KETs is the launching of the KIC on Added-value manufacturing, which will be a forum for the integration and promotion of trans-disciplinary skills and competence, particularly for the combination of multiple KETs.

The second EUREKA/Eurostars JTI (2014–2020) provides funding for research-performing SMEs in market-oriented collaborative transnational R&D projects leading to innovation, especially those SMEs without previous experience in transnational research. Eurostars-2 aims to increase the accessibility, efficiency, and efficacy of public funding for research-performing SMEs in Europe by aligning, harmonising, and synchronising national funding mechanisms, and to contribute to the completion of the European Research Area.

### 4.8. Pilot production in H2020

As described in Section 2, the very high costs involved in pilot production activities require combined funding from different resources: from public and private actors as well as different public funds (European, national, and regional). To give an illustration of the order of magnitude of the financing needs in KET-related investments for the oncoming years,
the special HLG KETs Working Group on Financial Instruments stated the following in its May 2011 report (HLG KETs WG7 2011, p.5):

> Over 7 years, it could be necessary to reallocate approximately EUR 20 billion for KETs, including 20 globally competitive sites (EUR 3 billion per site of which 16% would be funded by European institutions and focused on R&D aspects, if we use the reference of Joint Technological Initiatives, the industrial contribution would be 66% with the remaining percentage covered by both regional and national governments) and a hundred pilot lines (approximately EUR 600M per site equally with European public support of one sixth of the total project).

> However, the financing of KETs R&D should be made at European level: Member States do not have the means necessary to grow centres of excellence at world level for the entire spectrum of KETs: a European coordination and a specialisation per site (smart specialisation) is therefore indispensable.

The same HLG working group passed a strong judgement on the availability of capital to invest in KETs in Europe (HLG KETs WG7 2011, p.1): “Evidence shows that Europe’s financial markets do not provide sufficient investment for innovation as Europe is investing five times less in venture capital than the USA. This market failure is due to a higher risk aversion of investors to the asymmetry of information and high transaction costs due to much more fragmented markets, and justifies that public policies actively support the flow of venture capital to Europe’s innovative and high growth SMEs.”

Within H2020, the concept of multi-KET pilot lines is also used to focus funding. Some EUR 600 million has been allocated for projects in this category. The expected KET pilot lines, which address TRL 5 to 8, are of two types (HLG KETs WG4 2011):

- **A stand-alone KET pilot line** is constructed only for the purpose of maturing, qualifying, and producing pilot products in order to allow downstream users the rapid implementation of the pilot product in their system. After the achievement of this milestone, the pilot line may be closed or reconstructed for other missions.

- **An embedded pilot line** is the first part of subsequent mass production (the seed of a production line). It may even share some line equipment with existing lines in order to save money and time.

The pilot lines will be concentrated in four domains of high industrial interest: (1) Smart structures, (2) Embedded energy, (3) High-performance production, and (4) Innovative industrial bio-processes.

4.9. **Technology focus of H2020 on KETs (resources, priorities, and efforts)**

This concept of multi-KETs subsequently forms a new key element of H2020. As stipulated in the regulation establishing H2020 (European Union 2013, p.133):

> Innovation requires enhanced cross-technology research efforts. Therefore, multidisciplinary and multi-KET projects should be an integral part of the priority ‘Industrial Leadership’. The Horizon 2020 implementation structure supporting KETs cross-cutting KET activities (multi KETs) should ensure synergies and effective coordination, among others, with societal challenges. In addition, synergies will be sought, where appropriate, between KET activities and the activities under the cohesion policy for 2014–2020, as well as with the EIT.

A dedicated work programme on cross-cutting KETs (accounts for the fact that innovative products increasingly incorporate multiple KETs as single or integrated parts) will therefore be developed and implemented, as part of the LEIT section. The main goal of the cross-cutting KET work programme is to tap into the high cross-fertilisation potential of these technologies and to ensure that the result is the development of the most competitive products, goods, and services possible. In total, 30% of the LEIT will be
allocated to the cross-cutting KET work programme, addressing prototyping, product validation in pilot lines, large-scale pilot and demonstration activities, test beds, and living labs, which correspond to TRL 4 to 8. The objective is the development of cross-cutting KET-based products that will provide the technology building blocks for advanced product applications in order to address clear market needs and societal challenges. Cross-cutting KET activities will therefore present a bridge between technology development, on the one hand, and the need for advanced product applications, on the other.

4.10. Industrial involvement: Leading?
KETs are about the re-industrialisation of Europe, which, by definition, is about industry participation. In general, the H2020-LEIT pillar aims “to speed up development of the technologies and innovations that will underpin tomorrow's businesses and help innovative European SMEs to grow into world-leading companies” (European Commission 2014c). The research, technology, and innovation in this pillar is aimed to support business in using new technologies to address societal challenges. The second element to this is the provision of risk capital “to overcome deficits in the availability of debt and equity finance for R&D and innovation-driven companies and projects at all stages of development” (European Commission 2014c). The last element is the focus on SMEs, as important drivers for jobs and economic growth.

One of the key changes of H2020 with regard to KETs and industrial leadership is that a shift towards higher TRLs can be seen in the focus of the framework programme. The discussion involving the Valley of Death is also relevant. In some actions, the TRL concept described in Section 2 is used as a mechanism to select proposals in the range of TRL 5 to 8. With this shift, it is clear that industry participation is more important: higher TRLs are more about commercialisation and crossing the Valley of Death (Figure 15).

**Figure 15:** Technology readiness levels

![Technology readiness levels](image)

**Source:** Based on European Commission (2012a).

Within the HLG KETs, this aspect of industrial leadership was also discussed. In their 2013 interim report, it was stated that “the leading role of European industry in KETs pilot lines and other scale up activity” should be taken into consideration. Support should primarily be

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24 Societal challenges include food security; sustainable agriculture; the bio-economy; health; demographic change; well-being; secure, clean, and efficient energy; smart, green, and integrated transport; resource efficiency; and climate action as well as inclusive, innovative, and secure societies.
aimed at “Industrial companies with significant potential for manufacturing in the EU” (HLG KETs 2013, p. 37).

The main mechanism to enable this shift towards the industrial application of research and technology is the use of the TRL scale. The question is what the role of universities, RTOs, and the industry will be in the different stages of this innovation trajectory:

- **Universities**: Although the main focus of universities is on basic research (TRL 1 to 3), their presence can also be seen throughout the entire innovation trajectory. Even in the highest TRLs, academic research can fine-tune the product and manufacturing to achieve greater efficiency.

- **RTOs**: The main focus of these organisations is to initiate and support the translation of academic outcomes into applications. They should aim at TRL 2 to 7, while also participating in TRL 8 to 9, again to fine-tune the product and manufacturing.

- **Industry**: It is clear that the focus of industry is on TRL 6 to 9, but here too, participation in lower TRLs ensures application-oriented research as well as preparation of the company for future markets. Many (especially larger) companies have research laboratories that also address research at lower TRLs.

Figure 16 shows that this innovation chain can be seen as a relay race (TRL stages), handing over the baton (responsibility) to different partners. But the main difference is that after handing over, team members are not done with their task, and the distance to hand over the baton is not predetermined.

The main issue with industrial leadership in relation to KET-related policy is market distortion. According to the State Aid rules and common principles of innovation policy, governments should only support when there are market failures and system failures. If support would lead to unfair distortion of (international) competition, governments should be reluctant to intervene (HLG KETs 2011). With this in mind, discussions about industrial leadership prove to be more complicated. In a situation where individual companies would benefit from governmental support, without addressing a market failure, by definition this would lead to market distortion, and in the higher TRLs, the probability of this occurring is greater. In many other countries, it is common to support only the higher TRLs with government loans (which are available to all companies).

But even in TRL 6 to 7, industrial leadership is not clear, especially with SMEs, whose day-to-day business often limits opportunities for industry to take the lead. RTOs and specialised organisations focusing on creating intellectual property other companies can buy (as an initial public offering) often fill this gap, and larger companies buy the technologies.

**4.11. Involvement of research organisations**

Next to industry, within the KET discussion the role of research organisations also needs to be discussed. A distinction can be made here between universities and RTOs.
Due to the focus on higher TRLs, the involvement of universities will be limited, but in every stage of the innovation chain, universities can play a role in providing more fundamental insights, and they will often create an inspiring and new view on technological and even organisational issues. However, in principle, their role is limited to specific basic and fundamental research. As in pilot production, application is key—a leading role is not to be expected. However, the link to the lower TRLs is often to be made because experience in scaling up can lead to more fundamental questions for which academic research is required.

The role of RTOs is more important. Although often not optimally used, institutionally, RTOs play a crucial role in the valorisation of research into economic applications. EARTO recently published a paper on its view concerning the TRL concept, which also described its view on the participation of RTOs in the different TRLs.

Basically, EARTO’s view is that RTOs play a role at all TRLs, but it sees a major leading role up to TRL 7 (see Figure 16, above). In TRL 8 to 9, the contribution of RTOs is merely contract research, although in some cases, new insights in research can provide new applications to improve the existing product or manufacturing system. These can then evolve into new activities at lower TRLs.

Next to the more technological activities, RTOs can also play a role in advising on strategies and policy (e.g. technology foresight, market analysis, consortium building, incubator activities).
4.12. Multi-user technological infrastructures

In pilot production, costs and accompanying risks are often the result of investments in manufacturing equipment. It is clear that the semi-commercial production of even small quantities of a bio-based product needs a costly complex manufacturing system. In addition, the skills, experience, and knowhow needed to run experiments on these systems is often not available because of economies of scale, which prohibits many innovators from scaling up their prototypes. A solution is the creation of multi-user technological infrastructures, where many users can use the technical facilities and available local expertise. This is especially true for SMEs, but many large enterprises do not engage in pilot production because of the high costs of setting up a pilot line/plant for a limited time.

Within the framework of the HLG KETs, these facilities are called “technology platforms” and are particularly focused on supporting SMEs. The multi-KET pilot lines have assessed this concept and concluded that the feasibility of these infrastructures requires the involvement of large enterprises. A study is currently being conducted by the Directorate-General for Enterprise and Industry to identify technology centres of excellence in Europe.

Special attention is drawn to the role of RTOs in creating these facilities, and, being independent, they can play an important part in hosting them. This role would be enhanced by the highly skilled personnel available, and many RTOs already have the necessary infrastructure. It is just often more project based and focused on supporting prototyping.
5. OTHER EU POLICIES, PROGRAMMES, AND FINANCING MECHANISMS

**KEY FINDINGS**

- The EU policy framework on KETs comprises a number of instruments in addition to Horizon 2020, notably the cohesion funds and smart specialisation. Combined funding, using different instruments to promote the deployment of KETs at different TRLs will include a mix of instruments that will help to foster the adoption of KETs in both R&D and innovation at the EU, national, and regional level. Smart-specialisation strategies within EU cohesion policy have initiated an increasing uptake of KET-based priorities for regional innovation policy; all types of regions now aim for KETs, not only innovation leaders, but also followers. Questions remain in regard to state aid and financing of KETs, including rules of financing demonstration projects.

- In the absence of a distinct *EU budget for KETs activities and investment* at the EU level, it is difficult to calculate the exact level of public support for KETs up to 2020. Whereas some of the support is specifically open to KETs (and only KETs), other policy instruments can also be used for activities and investments in other domains of technological and industrial development (i.e., outside KETs), some of which directly compete with KETs for available funding.

- Public support for KETs comes from different levels (EU, national, regional). At the EU level alone, the variety of policy instruments that can potentially be deployed for supporting KETs activities and investment are so numerous that financial engineering and ditto skills are becoming an important asset in designing and implementing support programmes and projects involving KETs.

- Although available funding for KETs will increase significantly in the upcoming seven years to Horizon 2020 and the cohesion policy period, the extent to which these funding possibilities will actually be used and applied is not easy to predict. Some of the relevant EU legislation is still under revision (e.g., R&D&I State Aid rules). Moreover, the new funding period has just started. One important element is that in order to use Cohesion Policy funding, KETs activities/investments should be adequately included in the respective region’s smart specialisation strategy, with the Research and Innovation Strategies for Smart Specialisation (RIS3) being an ex ante (pre)condition for funding.

- The possibility of *combined funding* using both Horizon 2020 and ESIF funding opens up creative new ways of project financing for potential beneficiaries and for management authorities involved in the design and implementation of KETs projects. However, the complexity of designing and handling such combined funding projects has increased significantly. There is a risk that the new combined funding possibilities will have a counterproductive effect in terms of the number and size of projects eventually supported, as combined funding and the required financial engineering adds to the overall complexity of the programming exercise.

- *Combined funding* may add to the administrative burden of KETs investment projects and may lead to lengthy procedures, counter to the need for speed, decisiveness, and *light* administrative procedures, which are of prime importance for moving forward in KETs investment vis-à-vis competition from outside the EU.
This section provides a broad overview of policies, frameworks, and financing arrangements that support the development and deployment of KETs beyond and in addition to Horizon 2020 (which has already been described in Section 4). In particular, it highlights the way Cohesion policy can support KETs in its industrial uptake and roll-out and how Horizon 2020 and structural funds can be combined to level the overall impact of KETs investment. It further addresses state aid rules for RDI, which are currently under revision but are a vital element in making the EU KETs strategy work.

5.1. EU KET policies beyond Horizon 2020

On 26 June 2012, the European Commission tabled its strategy to boost the industrial production of KET-based products (e.g., innovative products and applications for the future). The strategy aims to keep pace with the EU’s main international competitors, restore growth in Europe, and create jobs in industry, while, at the same time, addressing today’s burning societal challenges. The EU KETs strategy consists of four pillars that together aim to support and thus boost the industrial deployment of KETs in Europe, as follows (see Figure 17):

- **adaptation and streamlining of EU policy instruments for KETs** (Horizon 2020 and related policy instruments discussed in Section 4 as well as other instruments discussed in this section);
- **coordination of EU and Member State policies and the commitment of private stakeholders** to contribute to growth and jobs (creation of synergies with national and regional policies on industrial innovation, and industry commitment to investment in KETs);
- **establishment of adequate and dedicated governance structures** within and outside the EC to ensure effective implementation;
- **mobilisation of existing trade instruments to ensure fair competition** and a level international playing field.

![Figure 17: Overview of EU KET strategy](image)

**Objective:** To boost industrial deployment of KETs in Europe

Source: Catinat (2013).

Although KETs play an important role in the EU’s agenda for sustainable competitiveness and growth, there is no distinct or separate EU budget support specifically for KETs activities and investments at the EU level. The new multi-annual financial framework 2014–2020 (MFF) foresees a balanced and efficient allocation of EU resources at all stages of KET RDI activities, including activities under Horizon 2020, the Structural Funds, and the EIB. In
its June 2012 Communication “A European strategy for Key Enabling Technologies—A bridge to growth and jobs”, the Commission underlined the need for an integrated framework for KETs and stronger coordination, with increased leveraging of public EU funding instruments being a key element. Combined financing of support for KETs is one of the ways to improve coordination, and the focus will be on projects that provide for integration of KETs and applications that address societal challenges. Apart from Horizon 2020, Structural Funds, and EIB activities, public funding could also include pre-commercial public procurement.

5.2. Cohesion policy, smart specialisation, and KETs

The European Commission’s Cohesion Policy aims to reduce differences between regions in Europe and to ensure growth across the continent. Structural Funds are among the main tools to implement the policy, and it is within this framework that smart specialisation was introduced. The Smart Specialisation Strategies (RIS3) are agendas for transformation that aims to focus regional innovation policies on regional priorities based on existing areas of strength, competitive advantage, and potential for excellence in each region. Smart specialisation is about identifying the unique characteristics and assets of each country and region, highlighting each region’s competitive advantages, and aligning regional stakeholders and resources around an excellence-driven vision of their future. It is an integrated agenda that:

- focuses policy support and investments on key national/regional priorities and challenges;
- builds on each country/region’s strengths, competitive advantages and potential for excellence in innovation, while exploiting potential synergies with other countries and regions;
- supports all forms of innovation, encourages innovation and experimentation, and aims to stimulate private-sector investment;
- involves all the stakeholders in the process;
- is evidence-based and includes a sound monitoring and evaluation system.

KETs have been identified as a priority area for investment and financing of regional innovation under the revised European Regional Development Fund (ERDF), creating increased funding possibilities for research and innovation under regional funding programmes. Funding will be subject to the existence of an approved regional RIS3, which is an ex ante condition for eligibility for ERDF funding in the programming period 2014–2020 (Foray et al. 2012). Thus a more strategic approach to regional programming and regional innovation financing is foreseen. More specifically, the ERDF investment priorities (Article 9(c), CPR) include the following: “supporting technological and applied research, pilot lines, early product validation actions, advanced manufacturing capabilities and first production in Key Enabling Technologies and diffusion of general purpose technologies”.

A more extensive description of ERDF investment priorities on the topic of strengthening research, technological development, and innovation is found in ERDF Article 5(1) (Regulation (EU) No 1301/2013):

(a) enhancing research and innovation (R&I) infrastructure and capacities to develop R&I excellence, and promoting centres of competence, in particular those of European interest;

(b) promoting business investment in R&I, developing links and synergies between enterprises, research and development centres and the higher education sector, in particular promoting investment in product and service development, technology transfer, social innovation, eco-innovation, public service applications, demand stimulation, networking, clusters and open innovation through smart specialisation, and supporting technological and applied research, pilot lines, early product validation actions, advanced manufacturing capabilities and first
production, in particular in key enabling technologies and diffusion of general purpose technologies.

Whereas a RIS3 is an ex ante condition for eligibility for ERDF funding, the funding itself is not restricted a priori, except for the requirement that, in the more developed EU regions, at least 80% of the total ERDF resources at the national level shall be allocated to two or more of the thematic objectives set out in points 1, 2, 3, and 4 of Article 9(1) CPR, notably (1) strengthening research, technological development, and innovation; (2) enhancing access to, and use and quality of, ICT; (3) enhancing the competitiveness of SMEs, of the agricultural sector (for the EAFRD) and of the fishery and aquaculture sector (for the EMFF); and (4) supporting the shift towards a low-carbon economy in all sectors. For transition regions, at least 60% of the total ERDF resources at the national level shall be allocated to two or more of these thematic objectives. For less-developed regions, this percentage is at least 50% of the total ERDF resources.

The available ERDF budget for the period 2014–2020 is EUR 185 374 billion (regional convergence) excluding co-financing. The Institute for Prospective Technological Studies (IPTS) has conducted research on priorities for KETs in the regions as part of its work in hosting the European Commission’s RIS3 platform. A database is being developed (Eye@RIS3) as an aid to strategy development in the regions, which also includes priorities for KETs (IPTS 2014), and as of April 2014, 87 regions had indicated an interest in KETs, with 160 priorities related to KETs across the following subcategories:

- advanced materials: 49;
- industrial biotechnology: 42;
- advanced manufacturing systems: 44;
- nanotechnology: 7;
- photonics: 9;
- micro-/nanoelectronics: 9.

The conclusions and possible next steps (Sörvik et al. 2013) arising from an initial analysis of this information include the following: first, regions indicate that the diffusion and/or application of KETs could be part of regional priorities; second, there are questions related to state aid and financing of KETs, including the financing of demonstration projects; third, all types of regions are interested in KETs—followers as well as leaders; and fourth, around two-thirds of the regions in the Eye@RIS3 database mention KETs as a priority.

5.2.1. Smart specialisation for innovation and industrial policy: The Vanguard Initiative

The “Vanguard Initiative for New Growth through Smart Specialisation” originated in the high-level conference “Regions as motors of new growth by smart specialisation” that was organised by the European Commission’s DG Regio and the Flemish government on 8 November 2013 in the European Parliament, with the support of the Committee of Regions and the President of the European Council, Herman Van Rompuy. The participating regions have made a commitment to smart specialisation as not only the ex ante condition for the European cohesion policy but as a guiding principle for their own innovation and industrial policies in order to spur competitiveness and new growth. The preparation of a European Council with a focus on European industrial policy provides a stimulus to send clear messages about the importance of the regions for new industrial growth and of the bottom-up partnerships for smart specialisation across regions. The Vanguard Initiative seeks to position and embed the smart-specialisation agenda within relevant EU policy frameworks in the following concrete activities (EWI 2014): matching strategic roadmaps
between national and European policy levels, aligning strategic investments coming out of these roadmaps, and upgrading regional partnerships and clusters with global potential.

The Declaration of the Vanguard Initiative was adopted on 8 November 2013 by political representatives from 10 European regions: the Basque Country, Flanders, Lombardia, Malopolska, North Rhine Westphalia, Scotland, the Skåne Region, Southeast Netherlands, the Tampere Region, and Wallonia. The partnership is open to all regions that share its ambition for actively (a) co-creating a more effective multi-level governance of industrial policy through cooperation with the European Commission and (b) leading by example in interregional cooperation. In the period between 8 November 2013 and early January 2014, additional regions made a commitment to giving political support to the Vanguard Initiative, namely, Rhône-Alpes, Upper-Austria, Norte (PT), Baden-Württemberg, and Asturias. Others are in the process (EWI 2014).

5.3. Possibilities for financial engineering between Horizon 2020 and other EU programmes

A central concept in the new programming period is combined sources of funding, which is the possibility to use different public funding sources, including different EU funding streams, within a programme, project, or group of projects. It seeks to exploit complementarities and synergies, while avoiding the risk of overlaps and excluding double funding of the same cost item(s). The legal basis for combined funding can be found in the Horizon 2020 Rules for Participation (Article 31) and the ESIF Common Provisions Regulation (CPR) (Articles 55(8), 60(2), and 87(2)(c)(v&vi)) which allows for the funding of the same action by two different instruments, subject to the absence of double funding. The following possibilities for combined sources of funding apply:

- A project supported by different funds—possible for different expenditure items. Legal basis: Art.55(8), CPR Art. 55(8) is derogation for enabling joint support by ESIF and H2020 for the same project.
- Support outside of the Cohesion Policy programme area—possible up to 10% (at priority level), enabling combined support from Cohesion Policy and H2020 to partners in different countries. Legal basis: Art.60(2), CPR.
- Support from different operational programmes—which enables the use of Cohesion Policy in interregional and transnational actions in mainstream operational programmes (Art. 87(2)(c)(v&vi)), on the basis of the opportunities offered by the provisions of the Art. 55(8) and Art. 60(2), mentioned above.

The combined funding provision adheres to the basic EU budgetary principles, which entail the following:

- Adherence to the "non-cumulative principle", stating that each action may give rise to the award of only one grant from the budget to any one beneficiary (Art 129 Financial Regulation); even under derogations, double funding to the same cost item is prohibited.
- Application of State Aid rules (see next section).

Combined funding allows for creative, not “one-size fits all” solutions for different situations, often with more than one funding arrangement for the same situation, but ensuring sound financial architecture for an investment or RDI project in terms of seeking

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25 Art. 87(2)(c)(v) concerns interregional and transnational actions. Art.87(2)(c)(vi) concerns macro-regional and sea-basin strategies.
and combining different funding sources will be more important than in previous programming periods.

For the same industrial project, one could choose two fundamentally different ways of using combined funding. The first would be the *simultaneous and parallel use* of different sources of public funding in the same industrial project (for example, the use of H2020 and ESIF financing together to fund different cost items within a single industrial project). When simultaneous and parallel use of different funding sources is applied, it is important for the accounting to be organised from the very beginning in such a way that double funding for the same cost item is excluded. The second way of applying combined funding would be the *sequential use* of different sources of public funding by slicing the project into separate, sequential subprojects (for example, using ESIF financing for RDI infrastructure and H2020 funding for subsequent innovation activities). Combinations of both approaches are also possible, as shown in Figure 18.

**Figure 18:** Example of a project using combined ESIF and H2020 funding

The financial design and architecture of larger industrial projects, in particular, will require smart financial engineering. The possibility of combined ESIF and H2020 funding has increased funding opportunities, but it is not as clear-cut and straightforward as it looks at first glance. One of the challenges is that both ESIF and H2020 have their own specific programme logic, goals, and implementation rules. Whereas H2020 is, in essence, a multi-country approach, Cohesion Policy is “place-based”, with dedicated regional operational programmes. Competition for H2020 funds is along annual work programmes, whereas in Cohesion Policy, projects are based on geographical pre-allocation of funding under seven-year operational programmes. H2020 has centralised (EU) management, whereas projects under the operational programmes are implemented by the regions. H2020 has research excellence as its prime goal, while operational programmes aim for socioeconomic development.

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A “cost item” refers to a specific expenditure incurred and eligible in a project (e.g., proven by an invoice).
For the managing authorities in Member States, combined funding requires a more carefully structured and planned project and programme design. Figure 19 represents the various phases in the process of making of an H2020 and ESIF project proposal.

**Figure 19: Financial architecture of an industrial project using combined funding**

![Financial architecture of an industrial project using combined funding](image)

**Source:** Moens (2013)

### 5.4. State Aid rules

Funding in support of KETs should be in accordance with State Aid rules in order to ensure a competitive level playing field in Europe and to prevent distortion of competition. Among other things, State Aid rules prevent the creation of ineffective market structures and the preservation of inefficient firms, as well as the crowding-out of private funding.

The least distortive way for Member States to support KETs is through measures that do not constitute State Aid in the sense of Art. 107(1) of the Treaty on the Functioning of the European Union\(^\text{27}\) (TFEU). These can be general fiscal measures, general training measures, the support of knowledge partnerships, etc.

Where State Aid is allowed, it should be compatible with the EU’s internal market. State Aid rules provide Member States with compatibility criteria and define the range of possibilities that Member States have at their disposal. Within the State Aid rules, Member States are allowed to support undertakings that are active in the area of KETs by granting State Aid for RDI, as well as other types of aid, such as for risk-capital investments.

The Community framework for State Aid for RDI and the General Block Exemption Regulation\(^\text{28}\) (GBER) form the legal basis for the assessment of State Aid related to RDI. The R&D&I State Aid framework provides compatibility criteria laid down in Art. 107(3)(c) TFEU. Art. 107(3)(c) is the legal basis used in all State Aid cases with a KET objective. State Aid is conditional on the following: (a) it should address a clearly identified market failure, (b) it should be limited to the minimum necessary, and (c) it should have a clear incentive effect. Given these three conditions, the RDI framework allows support for a range of activities,


including industrial research and experimental development, technical feasibility studies, industrial property rights support for SMEs, and assistance to young innovative enterprises and to innovation clusters.

Member States may grant RDI aid without a priori notification to the European Commission, but such aid should remain within the limits set out in the GBER. Moreover, the RDI framework provides for specific criteria to assess RDI aid for “Projects of Common European Interest” as intended by Art. 107(3)(b) TFEU. Such projects are subject to a case-by-case assessment and may be authorised up to the level necessary to overcome the pronounced market failures and risks that hinder the deployment of large-scale, cross-border projects. Applied to KETs, Projects of Common European Interest could facilitate capital-intensive cross-border KET projects with a positive effect on competitiveness and the Europe 2020 strategy.

State Aid does not concern EU funding that is centrally managed by the Commission, either directly or indirectly. Funding provided by the Commission, by its executive agencies, by joint undertakings (Art 185, Art 187), or by any other implementing bodies where EU funding is not directly or indirectly under the control of Member States is not considered as State Aid. If and where EU funding is combined with other public funding (from Member States, regions, etc.), only the other funding is considered for determining whether individual notification thresholds and maximum aid intensities are respected. H2020 is thus not considered as State Aid. Where ESIF co-financing is concerned, EU national/regional funding is subject to State Aid rules.

The RDI State Aid framework applied until 31 December 2013 and is currently under review in line with the objectives of modernising the State Aid rules, notably:

- fostering sustainable, smart, and inclusive growth in a competitive internal market;
- focusing ex ante scrutiny on cases with the greatest impact on the internal market while strengthening cooperation with Member States in State Aid enforcement;
- streamlining the rules and providing for faster decisions.

The Commission envisages having the new R&D&I State Aid Framework enter into force on 1 July 2014 and has prolonged the validity of the existing framework until 30 June 2014. Particular provisions of the proposed Framework include the following:

- an increase to the threshold amounts above which RDI aid needs to be notified to the Commission;
- a doubling of notification thresholds if the project is a EUREKA project or a project implemented by an EU Joint Undertaking (one of a series of recognised joint structures specifically established under Art. 187 TFEU for research, technological development, or demonstration programmes);
- higher levels of RDI aid to be permitted under the future GBER—up to 70 % of eligible costs for large companies and 90 % for small companies in cases of applied research, even including the costs of prototyping and demonstration;
- RDI projects that are also co-financed by the EU (e.g., under H2020) will benefit from legal presumptions regarding the necessity and appropriateness of State Aid;
- greater legal certainty in public-private RDI interactions;

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29 See, for example, www.lexology.com/library/detail.aspx?g=e6b30e4a-e0f5-4821-810b-1192d7fdfe4a.
guidance on the concepts of “economic activities” where funding is subject to State Aid rules and of “market price” in situations of public-private research contracts and knowledge transfer;

- an explanation of when pre-commercial and commercial procurement are presumed not to involve State Aid to contractors.

The GBER is also under revision, alongside the R&D&I Framework. In January 2014, the Commission launched a public consultation on a draft communication on how Member States can support the execution of important projects of common European interest (IPCEIs), including ways to assess their compatibility. IPCEIs constitute transnational projects that are strategic for the EU and for the realisation of the objectives of Europe 2020, the EU’s growth strategy. They range from cross-border transport projects to energy infrastructure, to research infrastructure or pan-European investments linked to the development of KETs. The draft communication introduces more flexibility regarding the form of public support by Member States (repayable advances, loans, guarantees, grants) and the possibility to cover up to 100% of the funding gap. In order to reduce red tape and to facilitate the assessment of the financing of IPCEIs by the Member States, the draft communication introduces the possibility for the participating Member States to submit a joint notification to the Commission.
6. **KET EMPLOYMENT, JOBS, SKILLS, AND GROWTH**

### KEY FINDINGS

- KETs have considerable scope to contribute to economic growth. KETs-based industries will not only generate direct employment, but more importantly, they will be the basis of new value chains and clusters of high-quality economic activity. Advanced industries based on KETs will generate significant amounts of employment in design, R&D, and a range of other industry-based services.

- Over the last decade, KETs patenting activity worldwide has seen a rapid growth in East Asia, a modest decline in Europe, and a stronger decline in the US. In Europe, for all KETs Germany is the clear leader in patenting, accounting for 40% to 50% in all KETs over the last decade.

- Overall, European competitiveness in KETs-related products (based on trade data) shows a mixed picture, with European industry competing effectively in advanced manufacturing technologies, advanced materials, photonics, and industrial biotechnology. In micro- and nanoelectronics and in nanotechnology, Europe appears to be less competitive.

- While KETs generate new employment, they may also contribute to technological unemployment as advanced manufacturing plants are highly automated and robotised.

- Effective deployment of KETs requires a mix of skills, which includes not only skills in science, technology, engineering, and mathematics (STEM), but also a range of business and soft skills.

- While it is unlikely that there will be major shortages in the number of staff for KETs development, skill mismatches and shortages of specific skills in specific countries will occur and require urgent policy attention.

**6.1. KETs, economic growth, and trade**

6.1.1. **KETs, economic growth, and grand challenges**

The deployment of KETs and the development of KET-based products are expected to make an important contribution to economic growth. KETs play a key role in the renewal of the European industrial base and will make a decisive contribution to the shift towards a highly advanced manufacturing sector (European Commission 2012a). A strong and highly productive manufacturing sector, in turn, forms the basis for a range of upstream and downstream activities that will be integrated into new types of value chains—referred to by the McKinsey Global Institute (2012) as the outsized contributions that advanced manufacturing makes to trade, to R&D and productivity, and to competitiveness. These new economic activities in both manufacturing and services will be the source of new high-quality jobs.

While KETs will also provide an essential contribution to addressing the grand challenges that Europe is facing, technologies alone are unlikely to solve societal problems—institutional, regulatory, and social change will need to go hand in hand with technological change. Looking, for example, at technologies in **health and demographics**, such as advanced prosthetics, exoskeletons and robotics will have their use in cures as well as care. Nanomedicine and the integration of imaging and heat-sensitive chemotherapy are just a few of the options. Technologies that help an aging population to remain independent are a priority as well. The challenge of sustainable **food security** requires industrial biotechnology to help...
make high-quality food products from flexible sources and to reduce waste. Other KET applications are being developed in relation to renewable energy, climate change, transport and mobility and to support a secure, innovative, and inclusive society.

6.1.2. KETs and value chains
The concept of the value chain was introduced by Michael Porter (1985) to describe how value is created and distributed in chains that link producers of raw materials, suppliers, manufacturers, distributors, and consumers. Value chains have evolved from local and simple to global and complex—especially in the case of high-tech KET-based value chains, which are evolving into global production and innovation networks (Ernst 2014). As a result, how and where value is created in the chain is changing. As manufacturing is outsourced to low-wage countries, and products become more knowledge intensive at the same time, the share of assembly in the total value-added is declining and the value-added in pre-production R&D and design and in post-production distribution and services is growing, as shown in Figure 20 (Baldwin 2013)\(^3\). The deployment of KETs in value chains will lead to a further “deepening of the smile”: they are R&D intensive and produce complex products that often require high levels of service and support. And as robots replace humans in the assembly phase of the production process, the value-added on wage levels and the skills required in production will remain stable or will decrease, depending on the nature of the production process.

**Figure 20:** Changing value chains over time

![Image of the微笑曲线图](source: Baldwin (2013)).

6.1.3. KETs, manufacturing, and the industrial base
If the European economies are predominantly service economies and if manufacturing is increasingly done by robots, why is manufacturing still important? And how can KETs contribute to the renewal of the European manufacturing sector? Manufacturing as a share of the economy has declined in the EU and the USA to around 25 % in 2012. And because of growing productivity through automation and robotisation, factories employ fewer and fewer people. Yet the manufacturing sector remains of crucial importance to European economies

\(^3\) This figure, known as the "smile curve", was first presented by Stan Shih, CEO of Acer computers who "used it to argue for a need to diversify away from fabrication" (Baldwin 2013, p.39).
because of the major contributions it makes to productivity, trade, R&D, and innovation. The role of manufacturing changes with economic development: in low-wage countries, it generates employment; in more mature economies, its contributions are to innovation, productivity growth, and trade, far beyond the limited direct employment generated in factories. The manufacturing sector also makes these outsized contributions to the economy as it requires or facilitates the generation of a range of other products and services, and as such, it forms the basis of an ecosystem of production of goods and services. Over time, the “distinction between manufacturing and services has blurred” (McKinsey Global Institute 2012). Manufacturing and high-tech products require a range of specialised knowledge-intensive services, not only to support the manufacturers and their suppliers, but also the customers. An example is how the availability of 3D printers gives rise to a (for the time being) cottage industry of print shops that allow businesses and consumers to produce parts and products.

6.1.4. KETs, competitiveness, and the trade environment
KETs contribute to upgrading value chains, a process that increases competitiveness in a number of different ways:

- through the application of new technologies;
- through new products (intermediate and final);
- through more efficient and effective processes that add value and reduce waste;
- through complementary services to KETs, either upstream in R&D and design or downstream in marketing and new product-service combinations.

Not much information is available yet on how and how much KETs contribute to EU competitiveness. Van de Velde et al. (2013) look at European competitiveness in KET technologies and in KET-based products. They also provide case studies of two specific value chains. How Europe competes in KET technologies is measured through patents. In the period 2002 to 2010, patenting activity for KETs has grown rapidly if unevenly. Worldwide, KET patent applications increased by 7% (slower than growth in all patenting activity, which amounted to 23%). Over that period, East Asia reports a growth of 85% in KET patenting, while the US and Europe showed a decline of 32% and 10%, respectively (Van de Velde et al. 2013, p. 52). In Figure 21, we present the overall trend in market shares for patenting of all KETs in the period 2002 to 2010. It shows continuous growth for East Asia (25% to 45%), a modest decline for Europe (33% to 28%), and a stronger decline for the US (39% to 24%). A review of the six individual KETs (let alone the key products for each KET) is beyond the scope of this paper. But as an example, Figure 22 shows the results for micro-/nanoelectronics (one of the most important KETs), which is also rather typical for the other KETs. The figure shows that East Asia’s share has grown continuously over the last decade and amounted to 56% in 2012. The US and Europe are both showing a declining market share, and the rest of the world does not play any significant role. Looking at Europe, we see the typical pattern for all KETs: strong domination by Germany, which holds 40% to 50% of all patent applications, and France as the second most important country, followed by the UK, the Netherlands, Switzerland, and Italy.
In addition to an analysis based on patents, Van de Velde et al. (2013) present an assessment of the European export performance of “KETs related products” looking at the technology content of these products, whether European producers compete on quality or on price with the US and East Asia, and how competitiveness changes over time. The analysis is based on trade data in the UN PRODCOMM database, which allows a detailed look at individual products in each of the six KETs. The results of this analysis are presented in summary form in Table 5.

The analysis has some limitations as it takes into account on KETs ‘final’ products, and does include those KETs products that are used as inputs in other KETS products. Also, a specific PRODCOMM code is assumed to be entirely KETs related, while in practice the KETs content of products will vary.
Table 5: The Position of EU 28 in the Production and Trade of KET-Related Products

<table>
<thead>
<tr>
<th></th>
<th>Industrial Bio-technology</th>
<th>Nano-technology</th>
<th>MNE</th>
<th>Photonics</th>
<th>Advanced Materials</th>
<th>AMT for other KETs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology content of exports</td>
<td>High and increasing</td>
<td>Low, mostly decreasing</td>
<td>Low and decreasing</td>
<td>High and increasing</td>
<td>High and increasing</td>
<td>High and increasing</td>
</tr>
<tr>
<td>Type of competition</td>
<td>Mostly price competition, price advantage</td>
<td>Price competition, mostly with price advantage</td>
<td>Price competition, no price advantage</td>
<td>Price competition, no price advantage</td>
<td>Price competition, mostly with price advantage</td>
<td>Mostly quality competition, quality advantage</td>
</tr>
</tbody>
</table>

Source: Van de Velde et al. (2013, p.150).

Table 5 indicates that, for industrial biotechnology and advanced materials, exports show a high and increasing technology content with international competition on price. For nanotechnology, European products show a low and decreasing technology content with international competition on price. In MNE, Europe shows a weak position with low and decreasing technology content, strong international price competition, and no price advantage for European products\(^{32}\). In photonics, Europe shows a stronger performance with high and growing technology content of products exported; international competition is mainly on price with no price advantages for European products. Finally, in AMT for other KETs, Europe holds a strong position in exports: technology content is high and increasing and European products compete mainly on quality. Improving market access for KETs should be based on an analysis of these strengths and weaknesses vis-à-vis other global competitors. Linking up the different stages in the value chain (R&D, piloting, and industrial production) will be of crucial importance in enhancing competitiveness and improving market access).

International and global competitiveness in KETs is of key importance for Europe’s long-term industrial development, but Europe also has a very important internal market that might act as a driver for KETs development. The European market is the largest global market and is home to leading KET-based industries in automotive, aerospace, energy, chemicals, etc., but to realise its potential as a driver of KET development, a number of obstacles such as market fragmentation and differences in regulation need to be addressed. Two approaches might help to overcome these problems: first, a focus on the entire KETs value chain, integrating upstream and downstream activities, with special attention to overcoming the "valleys of death", and second, a complementary approach would be to focus on the development of KET clusters, based on geographic proximity using strategies of smart specialisation to bring together universities, research institutes, and companies in one or more countries, based on a common technology, product, or problem. An example is the three-country Eindhoven-Leuven-Aachen triangle (ELAT) a high-tech region that brings together leading companies (large as well as SMEs), technical universities, business parks (e.g., High Tech Campus Eindhoven), and research institutes such as Interuniversity MicroElectronics Centre (IMEC) in Leuven and TNO Eindhoven.

\(^{32}\) The results of this analysis may be biased by the fact that only basic integrated circuits are considered and MNE content of more complex products had to be ignored (see previous footnote).
6.2. KET employment and new jobs

A discussion of the employment aspects of KETs needs to be placed in the context of overall employment trends in Europe, especially since the beginning of the financial crisis in 2008 and in the context of expected shortages of skilled labour, especially in the high-tech sector.

Trends in employment in Europe differ significantly among sectors and countries. For the EU 28, unemployment stood at 12% in December 2013 (Eurostat 2014). While countries like Germany and Austria have seen little growth in unemployment since 2008 and maintain low levels of unemployment (5.1% and 4.9% respectively) (Eurostat 2014), in December 2013, a number of southern EU Member States saw rapid growth in unemployment to unacceptably high levels (e.g., Spain and Greece, with 25.8% and 27.8% of the labour population) (Eurostat 2014). At the same time, significant shortages in the labour market are expected for the future, a phenomenon known as the “skill gap”. We will discuss this in section 7.3.

KETs, like other advanced technologies, and often in combination with new business models, have a two-sided relationship to employment. On the one hand, KETs are expected to provide large numbers of new, high-quality and well-paying jobs (European Commission 2012a). On the other hand, there are increasingly widespread fears of jobless growth and technological unemployment to which KETs may also contribute. We examine both arguments in turn.

6.2.1. KETs as a source of new jobs

KETs are expected to be a major source of new employment in the European Union. The HLG report (HLG KETs 2011) discusses different technologies, industries, and related employment. KETs are the basis of very sizable and rapidly growing industries in Europe. For example, nanotech-based industries are expected to grow from EUR 254 billion in 2009 to EUR 2.5 trillion in 2015. The report estimates that “300 000-400 000 jobs will be needed in Europe by 2015 (HLG on KETs 2011, p.13). In the photonics sector, there are 5 000 companies in Europe with 300 000 jobs, with 2 million jobs generated indirectly. According to the HLG report, the MNE industry in Europe counts 500 companies with 200 000 jobs and indirect employment of 1 million33.

The Commission Communication “A European strategy for Key Enabling Technologies – A bridge to growth and jobs” reiterates these numbers and states that “More specifically, in the KETs-area of nanotechnology, estimates indicate that 400 000 jobs will be needed in Europe by 2015. For photonics, estimates suggest that 80 000 additional qualified experts will be needed in order to cope with the anticipated rapid industry growth and the retirement” (European Commission 2012a, p.6).

The expected shortages of KET-related skills require a European strategy, without which, future European competitiveness will be jeopardised, high-quality employment opportunities will not materialise, and economic growth will be reduced. We will return to the issue of the skills gap below.

6.2.2 KETs and technological unemployment

As stated in many reports (e.g., HLG KETs 2013) KETs and other advanced technologies, such as ICT, contribute significantly to productivity growth. In combination, they cause a

33 The importance of indirect jobs generated by industry (suppliers, services) and the contributions to trade, R&D and productivity is also discussed in McKinsey Global Institute (2012) and in section 7.1.3 above.
process of technological acceleration in industry, which is leading to major debates about jobless growth and technological unemployment. There have always been fears about technological unemployment, a term first used by Keynes (1930, p.3) and defined as “unemployment due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour. But this is only a temporary phase of maladjustment.” Thus, the argument has been that new technology destroys jobs, but also generates new (and often higher quality) jobs in new sectors. This has been the picture since the first Industrial Revolution and forms the basis of the prescription that labour-market and employment policies should protect workers, not jobs. Recently, however, a fierce debate has emerged on both sides of the Atlantic as to whether the old wisdom still holds, or whether things are truly different this time.

The controversy has been sparked by Brynjolfsson and McAfee’s book “Race Against the Machine” (2012), among others, which argues that the deep penetration of ICT and other new technologies is such that many more jobs than previously are now at risk of being replaced by machines and that the balance between the potential for creating jobs and destroying them is now shifting towards the latter. This affects the balance between highly skilled and low-skilled workers, between the top 1% and the rest of the workforce (winner takes all) and between capital and labour (Brynjolfsson and McAfee 2011). The authors quote the venture capitalist Marc Andreesen as saying that “the spread of computers and the internet will put jobs in two categories: people who tell computers what to do, and people who are told by computers what to do” (Brynjolfsson and McAfee 2011, p.73). This phenomenon, more commonly known as “skill-biased technological change” will be discussed in more detail in section 7.3.

The hypothesis of the race against the machine is not uncontroversial. Miller and Atkinson (2013) provide an historic overview of the continuous fears of new technology from the days of the Luddites to the present-day fear of robots, arguing that fears of new technology stealing our jobs have always become more prominent at times of high unemployment. Rather than slowing down the rate of technological change and innovation, they argue that what we need is much more productivity through innovation to ensure future economic growth and well-being. Policy measures to redistribute labour and to slow down the pace of technological change will prove to be counterproductive.

6.3. KET skills and competencies

The final report of the first HLG on KETs pays explicit attention to KET skills, highlighted in a dedicated part of its main recommendations (HLG KETs 2011, p.38):

In order to exploit KETs technological fields and their industrial dimension, new skills and competencies will be necessary. Exploitation of KETs synergies and crossing the boundaries towards KETs trans-disciplinarity requires competencies that current linear training and education cannot supply... Academia and training institutions should devise mechanisms to offer KETs training and education since the supply of skilled workforce at all levels is already lacking today.

Regarding KETs human resources two gaps have to be filled. One is related with the need to know what interdisciplinary competences are required for KETs in terms of future industrial needs. The second is quantitative and consists in assessing the numbers of engineers and scientists required at European Level in order to supply future European industrial needs.

In this section, we look at these two main questions: what types of skills are needed for KETs, and is there a “skill gap” in relation to the supply of engineers and other qualified personnel for KETs?
6.3.1. Skills and competencies needed for KETs

KETs include a wide variety of different technologies in a highly dynamic series of fields. It is therefore not possible to identify specific KET-related skills. Different types of skills will be needed for KET development and deployment at different stages in the value chain. The R&D phase, the prototyping and the pilot phase, the production phase, and the post-production phase require different skills. Also, rather than taking single skills into consideration, it is important to look at the combinations of skills required (skill sets). The skills required in the different types of KET-related activities include the following:

- **Hard skills, especially the so-called STEM skills:** knowledge and capabilities in science, technology, engineering and mathematics. STEM knowledge and skills form a generic basis for the development of specialised knowledge and skills for individual KETs. There is concern about the expected shortage Europe will be facing in STEM skills over the longer term, although since 2007, the demand for STEM skills has decreased (Cedefop 2012).

- **Domain-specific cutting-edge knowledge and skills related to the six individual KETs:** these are highly specific disciplinary and subject-matter skills, and a discussion of these skills is beyond the scope of this paper. For nanotechnology, for example, Zukersteinova (2007) identifies 18 different qualification profiles (e.g., specialist in nanobiotechnology research and specialist for nanosurface treatment). For each qualification profile, a range of skills is identified (e.g., surface physics, surface coatings with modern machines, thin-film technology, quality assurance, and reproducible working).

- **Soft skills:** including teamwork, problem solving, “cross functional and cross geography skills” (McKinsey Global Institute 2012), critical thinking, project management, networking, and communication that will allow the scientific skills to be optimally deployed in the workplace.

- **Business skills:** many entrepreneurs with a background in the natural sciences (physics, engineering, chemistry, biology) tend to lack the critical business and entrepreneurial skills required to turn science into a successful enterprise (e.g., data analysis, supply-chain management, financial and personnel management, and skills related to intellectual property rights).

The 2012 Communication on KETs (European Commission 2012a) stresses the need for more professionals at all technical levels and in different disciplines. It also addresses the wider implications of technological change for formal education systems and access to lifelong learning opportunities for adults.

6.3.2. Is there a KET skill gap?

Given the new skills needed for the development and deployment of KETs (and other advanced technologies), is there likely to be a skill gap in Europe? The skill gap has to dimensions: a **quantitative** dimension, which indicates an overall shortfall in labour supply in comparison with demand (for the labour market as a whole or, more specifically, for skills in engineering or KET-related skills). The other dimension is **qualitative**, which is a mismatch between the specific types of skills and competencies needed in jobs: there may be a sufficient number of engineers, but they might lack the qualifications needed for a rapidly developing KET-based sector.

The discussion of KET skills, jobs, and employment also needs to be placed in the broader debate on high-tech skills that is taking place in both the US and Europe. This debate
focuses on the question of whether the skill shortage is “real” or not. Some economists (e.g., Paul Krugman in his New York Times columns) argue that there are no shortages of tech skills because there is no evidence that industrial wages have increased relative to other sectors. Those who hold that skill shortages are “real” find that many companies are struggling to find skilled employees and argue that the other view is based on a narrow, macro-assessment of supply and demand and that many companies are indeed facing problems in finding qualified people.

While there are definitely shortages in specific companies and sectors, the picture also differs between countries. Some German companies (because of strong industrial growth and rapid aging of the population) are indeed facing staffing problems, but elsewhere in Europe, the problem seems to be more manageable. A recent report for the UK Commission for Employment and Skills (UKCES) on the demand for and supply of STEM skills concludes that “Supply and demand calculations for 2020 under both the ‘2007’ (pre-recession) and ‘2011’ (recession) scenarios do not suggest an overall shortage of STEM graduates (in terms of numbers) in most regions or nations of the UK” (Bosworth et al. 2013).

There are a number of reasons why the overall and major quantitative shortages predicted earlier are unlikely to materialise:

- **Continued slow growth of European economies:** while there are indications that the worst of the financial crisis may be over, Europe may continue to suffer from a post-crisis period of reduced growth (crisis hangover).

- **Retirement ages:** many European countries are raising the retirement age, which will dampen the effect of aging; however, this might not be a solution for shortages in the latest high-tech skills that are most likely to be found in recent graduates.

- **Growing numbers of students following STEM studies:** at least in some countries (such as the Netherlands), a reversal of trends can be seen, with financial and business studies becoming less popular and larger numbers of students enrolling in engineering studies.

- **An emerging European labour market for high-skilled jobs:** young, highly skilled workers are increasingly internationally mobile. Germany, for example, has been actively recruiting engineers from Spain and other South European countries.

- **Advances in outsourcing:** This is no longer limited to labour-intensive manufacturing tasks. In principle, everything that can be digitised can be outsourced, and this allows European companies to tap more effectively into the huge potential of STEM and KET skills in China, India, and Russia.

Estimations of labour-market shortages are often linear projections over time, with given, fixed assumptions. In reality however, supply and demand for skills converge over time into a dynamic equilibrium. This implies that the structure of the economy will evolve in such a way that supply and demand are in balance, meaning that, in practice, such a long-term shortage will subsequently not occur.

From a qualitative perspective, an important question is to what extent workers have the necessary skills that companies need. Here, a continuous effort will be needed to match the qualifications of, for example, trained engineers with what companies need. The HLG KETs (2013) stresses the importance of the right qualifications for Europe to maintain its competitive edge. The HLG KETs (2013) calls for a “European wide education and training plan” and for an early launch of a knowledge and innovation community (KIC) on advanced KET-enabled manufacturing.
It is important to remember that KETs are cutting-edge technologies that might not yet be part of the curriculum of universities, so there will always be shortages of the highly advanced skills that KET-based industries require. This reinforces the importance of both lifelong learning and linkages between KET-based industries and universities to ensure that the gap between what is taught and what is needed is reduced as much as possible. Knowledge development and sharing are key elements in successful KET initiatives. An example of how the development and sharing of knowledge and skills can be taken up successfully is provided by the Bavaria Nano Cluster (Box 1).

**Box 1: Knowledge sharing in the Bavaria Nano Cluster**

The Nano Cluster Bayern is one of the clusters supported under the Bayern Cluster Initiative. Managed by Nanoinitiative Bayern GmbH it operates through Nanonetz Bayern e.V. as a network association. It was founded in 2007 with 20 partners and presently counts 400 members in Bavaria, other states in Germany, and internationally. The Nano Cluster Bayern supports a range of different activities:

- promotion of cooperation between R&D institutions and users;
- initiation, support, and coordination of projects and project management;
- support of project proposals;
- support of application-oriented research;
- international research marketing;
- organisation of seminars and workshops and participation in exhibitions;
- knowledge procurement and assessment;
- promotion of nanotech teaching contents in schools universities;
- open discussion of opportunities and risks.

The cluster addresses a number of priority areas: nano-materials, nano-process technologies, nano-analytics (particle measurement), nano-optics, nanobiotechnology, nano-mechanics, nano-finance, and nano-regulation and risk assessment.

Finally, it is important to remember that specific KET-related knowledge and skills are not just a problem at the level of PhDs and engineers; this is a problem that also occurs at the level of technicians. One reason is that many vocational training schools produce people with old-fashioned engineering skills (traditional factory skills instead of high-tech skills). Upgrading and training of trainers is an important issue.
7. CONCLUSIONS AND POLICY RECOMMENDATIONS

This section presents the main conclusions and policy recommendations from the research study as follows:

- The current concept of KETs, as developed and promoted by the EU, focuses on six specific enabling technologies. Because technology develops very rapidly, in the future some flexibility will be needed with regard to the selection of specific technologies under the KETs concept. An example is "software", which is seen by some as a “missing KET” because of its crucial importance in advanced manufacturing (e.g., Internet of Things, Industry 4.0).

- At present, the development of KETs is strongly based on technology push and the development of advanced processes and products. Although some attention has been paid to the role and potential contribution of KETs to solving the grand challenges, there is both a need and an opportunity to link KETs and the grand challenges in a more direct manner.

- It is usually difficult for SMEs to participate effectively in the development and deployment of advanced technologies, so the new dedicated SME instrument will be crucial to facilitating SME participation. The same applies to the proposed Fast Track to Innovation pilot action. The implementation of the Fast Track SME instrument should be closely monitored to assess its impact on SME participation. Multi-user technology infrastructures can play a key role in facilitating SME participation in KET-related activities.

- The possibility of combined funding from different sources in a specific KET project is a promising development. In practice, however, different programme logic, different project design needs, and different timing horizons under Horizon 2020 and Cohesion Policy will lead to operational hurdles that will complicate funding through combined Horizon 2020 and European Structural and Investment Funds for a KET innovation project, and will make it a less predictable procedure in terms of its potential success. Companies are also worried that combined funding will entail multiple requirements for financial accounting, further adding to complexity.

- The combination between the Structural Funds and Horizon 2020 is crucial to creating critical mass for the high investments needed for pilot production. However, the Structural Funds focus on developing underdeveloped regions and Horizon 2020 is about excellence, so there is a risk that some excellent regions will not be supported in further exploiting their capacity. A funding mechanism should be developed that allows excellent regions to further grow with combined funding.

- At present, the KET concept is strongly focused on providing technological support to companies. But the effective deployment of KETs also requires attention to organisational change, to new business models, to related services, and to the changing role of labour in advanced KET-based industries throughout the different stages of the innovation cycle.

- The KET concept is not yet widely applied beyond the level of the European Union, even though many Member States address some or all of the six technologies and some countries (e.g., Austria and Belgium) align their own agenda to EU priorities. There is considerable scope for countries to align their priorities and their policy timing more closely to the European KET agenda in order to benefit from potential synergies and policy complementarities and to develop combined funding strategies.
• There is considerable discussion about support to industry at different levels of technological maturity. Support to industry at technology readiness levels (TRLs) of seven and higher could lead to market distortions, both intra- and extra-EU, and should be considered very carefully. Policy interventions should not support innovation activities that are the responsibility of industry.

• There is also discussion about industry leadership in KET development. As industry has higher TRLs as its core business, it is unlikely that it will play a lead role in the lower TRLs. There is a role for publicly supported research and technology organisations to bridge the lower and higher TRLs in KET development.

• A focus on pilot production in policies and programmes is effective, but linkages to other (lower) TRLs are needed to ensure systematic support throughout the entire innovation chain. Fragmented policy support leads to ineffective governmental investments and capital destruction.

• EU global competitors such as the US and China are stepping up their research and development and industrial investment in high-tech sectors, including KETs. This requires a continuous and highly dedicated effort by all relevant European actors to ensure that Europe maintains and improves its global position.

• Effective deployment of KETs may be supported by (1) a focus on the entire KET value chain, integrating upstream and downstream activities, with special attention to overcoming the “valleys of death” and (2) a focus on the development of KET clusters, based on geographic proximity using strategies of smart specialisation to bring together universities, research institutes, and companies in one or more countries, based on a common technology, product, or problem.

• The global war for talent in KET-related knowledge and skills will grow more intense as a European and global labour market for highly skilled labour emerges. The development of cutting-edge knowledge and skills for KETs should be a top priority and requires joint action by European actors, including traditional education and training institutions and relevant organisations such as clusters and associations.

• While KETs will provide new and high-quality jobs, the direct employment impact in manufacturing will be increasingly limited, as advanced manufacturing, particularly robotisation, will further reduce labour demand, especially in large enterprises. KETs will generate more jobs in related services (such as design, marketing, and other upstream and downstream activities), which should be an integral part of any policy to promote KETs.

• At the same time, there is a risk of new “technological unemployment” resulting from rapid automation and robotisation across the economy. This is no longer affecting only low-skilled jobs, but increasingly the middle and highly skilled work force. This requires policy measures at the level of the EU and Member States in restructuring, training, and creating alternative forms of employment.
REFERENCES

- Brynjolfsson E, McAfee A (2011) Race against the machine: How the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy. Digital Frontier Press.


• European Commission (2013a) EU and industry join forces to invest EUR 22 billion in research and innovation. Press Release, Brussels, 10 July 2013. Brussels: European Commission.


Forge S, Blackman C (2013) ICT key enabling technologies: Preliminary study on potential of EU ICT KETs. Seville: European Commission, Joint Research Centre, Institute for Prospective Technological Studies.


ANNEX 1: KET DEPLOYMENT IN A NUMBER OF COUNTRIES

This annex provides an overview of policies and frameworks that support the development and deployment of KETs in a number of EU Member States and key countries outside the EU.

Selected Member States and KETs

Germany

Germany is clearly a big player in the world of highly innovative technologies, and KETs in particular. Innovation has been a main policy priority of the Federal Government for several decades, and all KETs play a significant role in the German innovation system and receive policy attention. The main national innovation policymaking bodies in Germany are the Ministry of Education & Research (BMBF), which includes research organisations, technology programmes, and the Ministry of Economics & Technology (BMWi), covering innovation-oriented initiatives, R&D funding in SMEs. As Germany is a strong player within high technology and has strong innovation performance and a solid base in science and technology, the policy focus is on establishing better conditions for innovation and technological progress and facilitating commercialisation (KETs Observatory 2013a).

Information on the latest scientific outcomes, labour, infrastructure, and R&D services are the main factors supporting the economy in regard to publicly funded research. Instruments are established to bring academia and industry together, as there are top cluster competitions and research campuses on the federal level or regional networking platforms, like Bayern Innovative or Steinbeis Foundation on the Länder level (Braun and Thielmann 2013).

In the early 2000s, the Federal Ministry of Education and Research fostered these networking activities with a broad, publicly supported Competence Network Initiative. Since then, many independent regional clusters have been founded all over Germany, especially those that are technology oriented. The current trend goes to more-specific platform initiatives such as the National Platform on Electric Mobility. In addition to networking, these platforms are designed to adjust national activities on a specific issue. Politics meets the economy and academia in order to develop a joint strategy for the whole country (KETs Observatory 2013a).

In 2006, the Federal Government launched the High-Tech Strategy. This was the first approach to align the activities of all the ministries responsible for R&D funding, particularly the Ministry of Education and Research and the Ministry of Economics and Technology. The main purpose of the strategy was to prioritise funding activities to foster the national knowledge and competence base in research and innovation. In addition, the overall budget for research and development has since been increased perceptibly (KETs Observatory 2013a; Braun and Thielmann 2013).

In its first version, the High-Tech Strategy was based on 17 technologies. The re-launch in 2010 has focused more on strategic areas related to global challenges. In addition, the so-called High-Tech Strategy 2020 still determines eight key technologies, which are largely identical with the KETs defined by the European Commission. But the general trend is toward calls for more visible, application-oriented programmes than technology-centred ones (Forge and Blackman 2014; Braun and Thielmann 2013).
France

In 1999, the French public authorities were already showing an interest in KETs, with a call targeting KETs. But the programme has not been continued and the French policy mix took another direction, with more-thematic calls, closer to the classical sectoral calls for projects, being launched on many occasions since then. In 2011, France adopted a report on KETs (“Etude Technologies clés 2010”) that identified 80 key technologies as being of main importance for the country (KETs Observatory 2013b).

Traditionally, the Ministry of Economy, Finance and Industry (MINEFI) is in charge of the post-research part of the innovation value chain. It develops the policy for industrial innovation, while the Ministry of Higher Education and Research (MESR) focuses on fundamental research as well as technology transfer. Over the years, the scope of activities for the MESR has moved towards more diversified activities, and implementation has been taken over by agencies. The National Agency for Research (ANR), under the MESR, handles the main calls for projects (including calls for funding basic research). The Innovation Financing Organisation Oséo (under the MINEFI) is in charge of innovation policy and SMEs. The ANR develops thematic calls while Oséo develops generic tools for companies and investors. The Caisse des Dépôts is a public group in charge of investing and supporting national policies with a long-term perspective. It makes long-term investments aimed at developing the French economy and is in charge of pensions and the “Fonds national pour la société numérique” (National Fund for Numeric Society, FSN) (KETs Observatory 2013b).

Netherlands

In the Netherlands, key enabling technologies are considered to be important knowledge areas that can make a significant contribution to resolving major societal questions, such as keeping an aging society healthy and keeping our environment liveable in a changing climate. The basis for being able to provide this contribution lies in the creation of an open, dynamic and sustainable ecosystem for research and innovation in which the Netherlands can continue to play its leading role in the world, and can extend this role further. This system is created by initiating and guiding research projects within specific themes. Support programmes that aim at supporting the development and deployment of KETs are mostly project-based. The formats for such support range from measures oriented to small businesses (such as Small Business Innovation Research [SBIR] and the Valorisation Grant) to financing large research projects that involve the cooperation of private and public research entities (such as Advanced Chemical Technologies for Sustainability and Horizon Initiatives) (KETs Observatory 2013c).

A special feature of the Dutch innovation-support programmes is their extensive “agencification”. The implementation of these programmes is often delegated to the specialised authorities responsible for administering support in a particular knowledge field, such as having the SBIR programme administered by the Netherlands Organisation for Scientific Research (NWO) to stimulate academic spin-offs, and by the Technology Foundation STW for SMEs that already exist.

The current Dutch government initiated a process of redesigning the policy mix, which is aimed at strengthening the innovation system, moving away from subsidy-led innovation support to predominantly tax-based support. This redesign includes a more sector-thematic approach, with the identification of nine so-called “Top Sectors”, which also co-address KETs, although not in name and through the top sector rather than the technology axis. This also includes the implementation of new generic policy instruments that address these specific targets, and the strengthening of current ones.
Belgium

The KETS Platform Flanders was established in November 2012 and aims to develop roadmaps for KETs in Flanders, in alignment with the European roadmaps, PPPs, platforms, and programmes targeting KETs. For each KET, a roadmap is being developed through a platform of industry, research organisations, and policymakers. Each roadmap starts with the identification and assessment of key actors, European roadmaps, existing initiatives, programmes, facilities, and infrastructures in Belgium and internationally (Europe). Although the roadmaps are developed for each KET individually, a multi-KETs approach will be enabled in a matrix where the individual KETs initiatives are on the horizontal axis and the value chains and application areas are on the vertical axis. An example is the newly developed Nano for Health Programme, which aims to combine nanoelectronics with biopharmaceuticals (Kappen and van der Giessen 2013).

KETs are also addressed in the support and stimulation of specific cluster initiatives and strategic research centres. Flanders’ Mechatronics Technology Centre (FMTC) is established by Agoria, the Belgian association for technology industry and mechatronic companies. The FMTC conducts industry-driven joint projects and contract research assignments in smart sensors, self-optimisation of mechatronic systems, energy-efficient electro-mechanical drive-lines, and model-based design of mechatronic systems. The most recently established cluster initiative is the Flanders Innovation Hub for Sustainable Chemistry (FISCH). FISCH was established by Essenscia Flanders, the industry association for the chemical and life-science industries, and the Flemish Institute for Technological Research (VITO), in cooperation with various companies in the sector and all Flemish university associations. FISCH aims to support open innovation by organising cross-company collaboration for research and innovation and by clustering existing knowledge and innovation platforms at companies, knowledge centres, and universities (Kappen and van der Giessen 2013; van Helleputte et al. 2013).

The Flemish Government has established several strategic research centres, for developing and conducting strategic research and technology transfers in specific domains, bringing together knowledge centres and industry. The Flemish Institute for Biotechnology (VIB) focuses on strategic basic research in the life sciences; the Interuniversity Micro-Electronics Centre (IMEC) focuses on nanotechnology and nanoelectronics. IMEC and VIB, together with KU Leuven, established Neuro Electronics Research Flanders (NERF), a research lab for collaborative, interdisciplinary research combining nanoelectronics with neurobiology. Strategic Initiative Materials (SIM) concentrates on strategic research for advanced materials (Kappen and van der Giessen 2013; van Helleputte et al. 2013).

Austria

KETs are not mentioned explicitly in Austrian innovation policy documents or programmes, but they are included in the general target of improving the innovation system through funding and supporting cooperation between research and industry. Relevant policy actors include the Federal Ministry of Science and Research (BMWF), the Federal Ministry for Transport, Innovation and Technology (BMVIT) and the Federal Ministry of Economy, Family and Youth (BMWFJ), which assign the Austrian Research Promotion Agency (FFG) and the Austria Wirtschaftsservice Gesellschaft (aws) to manage the funding for applied R&D and innovation in Austria.

Different kinds of policy measures are used to foster industry-science cooperation and interaction between different KETs in Austria. Most of these policy measures are thematically open and none of them explicitly addresses KETs. Some of them are structural programmes managed by the FFG. These comprise the programmes Competence Centres for Excellent Technologies (COMET), Cooperation & Innovation (COIN), and Research
Horizon 2020: Key Enabling Technologies (KETs), Booster for European Leadership in the Manufacturing Sector

Studios Austria and are characterised by functional priorities. All these programmes support cooperation between science and industry to make the transfer from research to industrially usable applications easier and are open to all technological fields. COMET supports the development of competence centres, where science and industry cooperate in top-level research (FFG 2013a). COIN aims to stimulate and increase activities in research and technology development, especially for SMEs (FFG 2013b).

Further policy measures regarding KETs are thematic programmes managed by the FFG. These are characterised by thematic priorities and define key research areas in order to encourage and promote Austrian participation in internationally recognised research fields of future importance. KET-related programmes are Intelligent Production (FTI Initiative), ICT of the future, the Austrian Genome Research Programme (GEN-AU), Environment, Health and Safety (NANO EHS), the Austrian NANO Initiative, Advanced Research and Technology for Embedded Intelligence and Systems (ARTEMIS), and the European Nanoelectronics Initiative (ENIAC).

The Christian Doppler Research Association (CDG) supports temporary laboratories at universities, which work on application-oriented fundamental research. Thematic coverage includes chemistry, life sciences, electronics, and materials. Similar work is done at the Josef Ressel Centres. In contrast to CDG work, these centres support public-private cooperation between industry and universities of applied research (Erawatch 2013).

**KET-relevant policies in other countries**

**USA**

All six KETs are subject to federal policy attention in the United States. Some of these have their own specific initiative, such as the National Nanotechnology Initiative, while others are incorporated across different national programmes and agency research programmes, such as the SBIR/STTR at the National Science Foundation (NSF) or Advanced Research Projects Agency–Energy at the US Department of Energy (KETs Observatory 2013d).

The US Government has just launched a new innovation strategy—A Strategy for American Innovation—which focuses on supporting R&D and promotes market-based innovation. In terms of technologies, the strategy has pointed out the following national priorities (KETs Observatory 2013d):

- unleash a clean-energy revolution;
- accelerate biotechnology, nanotechnology, and advanced manufacturing;
- develop breakthroughs in space applications;
- drive breakthroughs on healthcare technology;
- create a quantum leap in educational technologies.

The US government has earmarked additional support for science and basic research through the provision of double funding for three basic research agencies: the NSF, the Department of Energy's Office for Science, and the laboratories of the National Institute of Standards and Technology. However, the US is facing growing challenges from competitors in R&D and innovation, especially from Asia, which could become more intense in the face of potential budget cuts, with a negative impact on R&D spending (budget sequestration) within the coming years. But despite its overall slowdown, the US still has highly sophisticated industries and educational and research institutions, and there is good collaboration between business and research. KETs are supported through increased investments in existing initiatives, such as the National Nanotechnology Initiative (NNI), as well as new initiatives. The innovation strategy also highlights specific areas of national
importance within each of the technology areas, which provides a focus for investment for both industry and academia (KETs Observatory 2013d).

In 2011, the HLG on KETs noted the new US focus on manufacturing, highlighting the point that public investment on KETs related RDI projects and strategic manufacturing capacity had exceeded USD 7 billion, and that the new innovation strategy would bolster this further. For instance, a key feature of the recommendation from the President’s Council of Advisors on Science and Technology (PCAST) on 19 May 2011 was the creation of a USD 500 million Advanced Manufacturing Initiative run by the Commerce Department and involving other federal agencies. The programme would fund "generic" projects on the commercialisation of industrial technology that would have widespread economic impact and create jobs. The effort was planned to grow to USD 1 billion a year over four years (Forge and Blackman 2014).

At the regional level, aggressive state-level actions to attract KET-based foreign firms have been noticeable in some states such as Ohio and Florida in recent years as cases of SAFT and BASF for lithium ion batteries show (Crean 2012).

**South Korea**

KETs are defined through the governmental plan, which is driven by scientific and technological research. There are several initiatives to support the development of specific KETs in Korea. The public sector plays an important role in the promotion of emerging technologies, and currently the government prioritises the following key areas (Kim et al. 2013):

- **key industrial technologies**: automotive, machinery and manufacturing, semiconductors, liquid crystal displays, etc.;
- **emerging Industrial technologies**: cancer (diagnosis and treatment), brain science, drug discovery and development technology, etc.;
- **knowledge-based service technologies**: software, culture technology and design.
- **state-led technologies**: construction, transportation, space and ocean, nuclear power.
- **national issues-related technologies**: programmes on auto-immune diseases and infectious disease response, food-safety evaluation, and IT nano-device technology.
- **global issues-related technologies**: technologies related to energy, climate change, environment, and food, etc.;
- **basic and convergent technologies**: platform technology development bio-chip and biosensor, intelligent robotics, nanotechnology, convergent/composite materials, technologies.

From 1999 on and as a part of South Korea’s scientific development strategy (“Long-term Vision for Science and Technology Development Toward 2025”), the government has established the “21C Frontier R&D Programme”, which supports 23 projects over a 10-year period, developing core technologies with commercial potential, including nanotechnology, space technology, and bioscience. Each of these projects benefits from funds of at least USD 1 million. In 2003, a second research plan, which identified the “Growth Engine Industries for the Future” from biotechnology to semiconductors, was introduced by the government. These projects are receiving up to 50 % funding from public R&D.
investments. Basic research receives a quarter of the total public spending on R&D (Kim et al. 2013).

The Future Industry Pioneering Technology Development Programme is the main R&D programme managed by the Office of Strategic R&D Planning (OSP), the R&D management body of the Ministry of Trade, Industry and Energy (MOTIE). It aims to create new growth engines that will have a significant impact on Korea’s future industry. The programme is divided into two sub-programmes that focus, respectively, on short- and mid-term economic results and on the creation of new markets. The topics of the first include new natural pharmaceuticals, system semiconductors for IT-convergent devices, green transportation systems based on next-generation electro-vehicles, high-efficiency large-area thin-film photovoltaic products, and the Korea-Micro Energy Grid (K-MEG). The latter includes topics like transparent flexible displays, offshore plants for producing deep-sea resources, high-precision roll-to-roll production systems for printed electronics, multifunctional graphene materials and components, and wellness human-care platforms (Kim et al. 2013).

Japan

The concept of KETs is not directly included in the Japanese innovation policy; however, it is implicitly contained in the public programmes through the overall technologies identified most important, which partially resemble KETs and multi-KET ideas (Meister et al. 2013).

The Ministry of Economy, Trade and Industry (METI) refers to a strategic technology roadmap (STR) to allocate public R&D funding within the New Energy and Industrial Technology Development Organisation (NEDO) and METI. The roadmap is used to identify technological fields of importance (METI 2005), and some of the main fields are strongly KET related: e.g. nanotechnology and materials or new manufacturing technologies. The STR is subdivided into 31 more precise fields, of which several have relevance to KETs (METI 2010). The idea of the roadmap is explicitly stated to promote cross-field and cross-industrial alliances, technology fusion, and coordinated implementation of relevant policies, but it also serves to join the comprehensive strength of industry, academia, and public institutions. The roadmap is developed and updated by a task force with representatives from universities, private companies, METI, NEDO, and the National Institute of Advanced Industrial Science and Technology (AIST), reflecting the expertise of industry, academia, and public institutions. It is further evaluated by several industrial and political councils and committees as well as users and manufacturers. By understanding technological and market trends, prioritising critical technologies, and developing policy infrastructure for planning R&D projects, the roadmap is used to allocate R&D resources. The STR, as the basis for the R&D strategy, takes into account market pulls and technology pushes (METI 2005).

Several initiatives deal with KETs and multi-KETs, for example the recently founded Tsukuba Innovation Arena Nano, which is supported by METI (AIST) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), with research focuses on nano-electronics, micro- and nano-electromechanics, nanotubes, etc. (Rehn 2013). Furthermore, there exist several initiatives to create networks, such as the Knowledge Cluster Initiative by MEXT (ASTF 2013b).

The intermediaries (e.g., NEDO) address the identified key technologies in their programmes. KETs can be found within these topics, and the idea of multi-KETs is also incorporated somewhat through crossover fields. The supported programmes of METI closely resemble the KET and multi-KET spirit, for instance multi-KETs are promoted in the programme “Realization of Technology for the Future” (METI 2011).
The fourth basic plan is devoted to the New Growth Strategy and states several interdisciplinary issues related to multi-KETs being strongly related to the needs for the future of the nation, even if they not mentioned explicitly. While the technologies involved are not explicitly mentioned, the challenges are: e.g., green innovation and life innovation. Some initiatives related to multi-KETs and to better integration of industrial and basic research include the enhancement of knowledge networks among the industrial sector, academic sector, and government, the creation of new places to promote collaboration among the industrial sector, academic sector and government (involving the formation of centres of open innovation, etc.), the improvement of circumstances for strengthening the supports of commercialisation, the utilisation of regulations and institutions to promote innovation, building regional innovation systems, promoting strategies for intellectual property and international standardisation, strengthening national security and key technologies, building S&T bases for pioneering new frontiers, strengthening interdisciplinary S&T, and the advancement and networking of common and basic S&T infrastructures (Meister et al. 2013).
ANNEX 2: INTERVIEWEES

- Paul Mijlemans (Member of the KET-HLG Sherpa Group).
- Željko Pazin (Executive Director EFFRA).
- Jochen Donauer (Policymaker Saxon Region).
- Johann Massoner (CEO Infineon).
- John Lincoln (Consultant to the UK South East Physics Network).
- Andreas Wild (Executive Director ENIAC).
- Andrea Gentili (Deputy HoU AM and Biotech RTD).
- M. Catinat (Head of Unit ICT for Competitiveness and Industrial Innovation, DG ENTR).
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