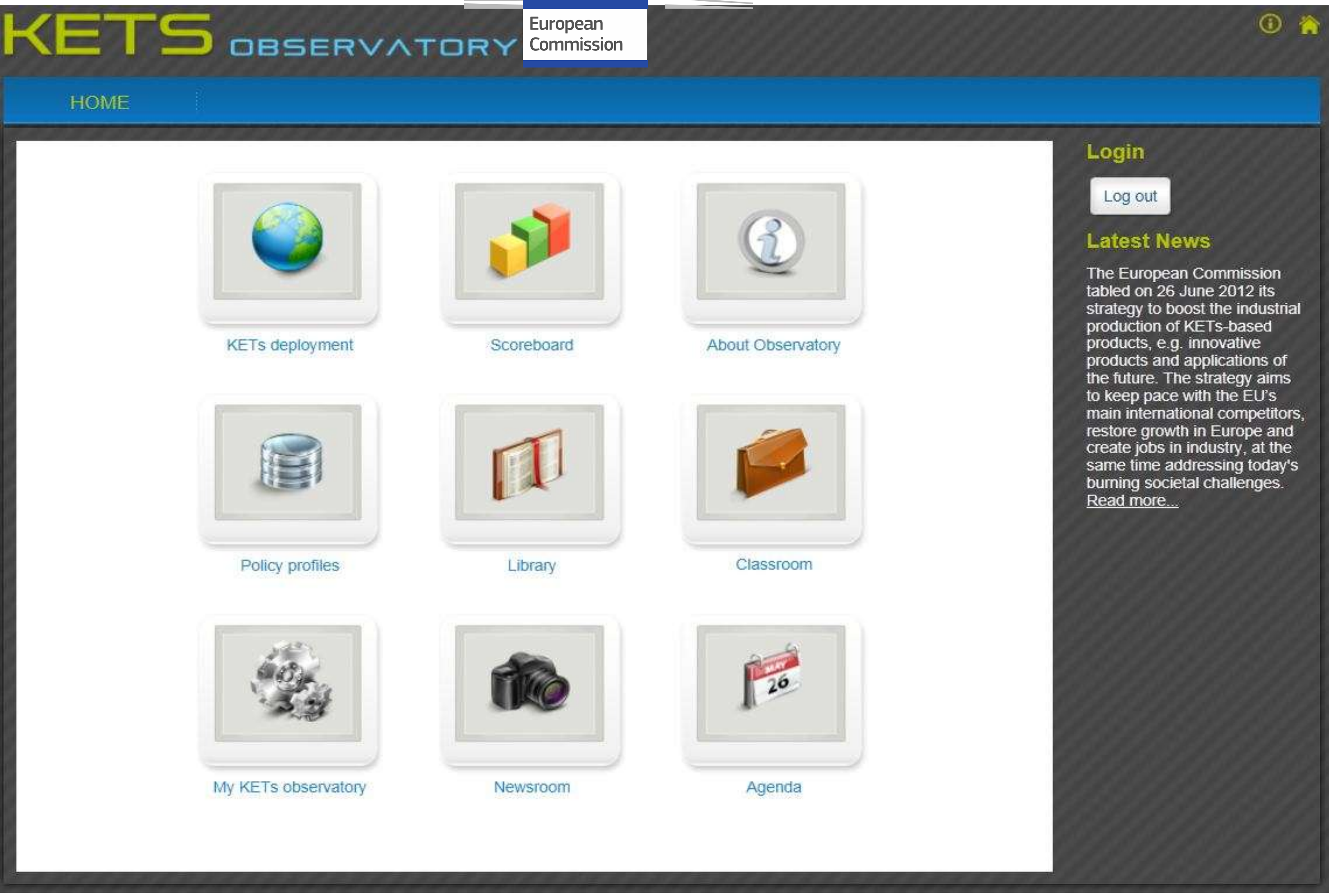

Feasibility study for an EU Monitoring Mechanism on

Key Enabling Technologies

Written by

Enterprise and industry

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Glossary of acronyms

AM	Advanced Materials
AMT	Advanced Manufacturing Technologies
BMBF	Federal Ministry of Education and Research (Germany)
CIS	Community Innovation Survey
CPA	Statistical Classification of Products by Activity in the European Economic Community
DG	Directorate General
DOE	Department of Energy (US)
EPO	European Patent Office
ES	Export Share
EU	European Union
HLEG	High Level Expert Group
HS	Harmonized System
IB	Industrial Biotechnology
IP	Information Provider
IPC	International Patent Classification
IS	Import Share
KET	Key Enabling Technology
MD	Medium-term Dynamics
MNE	Micro- and nanoelectronics
MS	Market Share
NACE	Statistical Classification of Economic Activities in the European Community
NANO	Nanotechnology
OECD	Organization for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
PHOT	Photonics
RCA	Revealed Comparative Advantage
SG	Significance
SITC	Standard International Trade Classification
SP	Specialisation
TB	Trade Balance
UN	United Nations

List of Country's Acronyms

AL	Albania	IT	Italy
AT	Austria	JP	Japan
BA	Bosnia	KR	South Korea
BE	Belgium	LT	Lithuania
BG	Bulgaria	LU	Luxembourg
BR	Brazil	LV	Latvia
CA	Canada	ME	Montenegro
CH	Switzerland	MK	Macedonia
CN	China	MT	Malta
CY	Cyprus	NL	Netherlands
CZ	Czech Republic	NO	Norway
DE	Germany	PL	Poland
DK	Denmark	PT	Portugal
EE	Estonia	RO	Romania
EL	Greece	RS	Serbia
ES	Spain	RU	Russia
FI	Finland	SE	Sweden
FR	France	SG	Singapore
HR	Croatia	SI	Slovenia
HU	Hungary	SK	Slovakia
IE	Ireland	TW	Taiwan
IL	Israel	UK	United Kingdom
IN	India	US	United States
IS	Iceland	ZA	South Africa

1 Executive summary

Underlying feasibility study has the aim to develop and test the methodological possibilities for monitoring the deployment of Key Enabling Technologies (KETs) and to provide the European Commission with a detailed proposal on how to set up a permanent "KETs monitoring mechanism”. To this end, a dedicated website containing a data repository and analysis component has been setup to provide EU, national and regional policy makers with data, indicators and information to better develop and implement industrial policies regarding the deployment of KETs (https://webgate.ec.europa.eu/ketsobservatory/[1]).

This feasibility study has the aim to monitor and measure the deployment of KETs. It has been a challenging study, as existing data and classification schemes can only be roughly linked to specific KETs and associated deployment data and indicators. Therefore, an innovative, conceptual approach has been developed to map and measure KETs deployment. The focus of the undertaken activities lied mainly on the conceptual and methodological level as the main objective of this study is to provide the European Commission with a detailed proposal on how to set up a KETs monitoring mechanism (a KETs Observatory). Next to an intensive conceptual phase, a pilot launch of the developed monitoring mechanism has been implemented. During the pilot phase, key KETs components have been identified and data and indicators on deployment were collected. It speaks to itself that the results stemming from the pilot run, i.e. the indicator values mentioned in this report and displayed on the KETs Observatory website, should be handled with caution as these values have not been validated yet at large, and hence will certainly be subject to change as soon as the permanent KETs Observatory becomes operational.

Concerning the methodological backbone of the KETs Observatory, measuring the deployment of KETs appeared not to be straightforward as existing classification systems do not contain specific references to one of the six KETs. Therefore, the consortium has developed three complementary approaches to identify KETs relevant data in existing databases: 1) the technology diffusion approach, 2) the component approach and 3) the value chain approach (Section 3).

The “technology diffusion approach” (Section 3.2) determines the economic sectors of organizations that are engaged in the development and exploitation of KETs. These organizations have been identified through the use of patent data. Based on a definition of KETs through IPC codes (i.e. technology classes to which a patent refers to), a list of KETs patent applicants has been composed. The outcome of the approach provides an indication of the relevance of a certain KET for the technological development in different economic sectors. At the same time, it also informs about the economic sectors that are most relevant for producing and commercializing a certain KET. The IPC classes are used to calculate technology indicators.

The “component approach” (Section 0) identifies components for each KET, as a basis to identify companies, relevant PRODCOM and HS codes. The outcome of this approach provides an initial list of companies active in different KETs, and an initial list of production and trade classification (PRODCOM

[1] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

and HS) codes for all KETs. These initial lists have been further refined using a variety of approaches for the different KETs. The refined lists of PRODCOM codes are used as a basis to identify HS codes as linking PRODCOM to HS is rather straightforward. As this study is a feasibility study, it was decided to pursue several options to refine the obtained list in order to create insight in the strengths and weaknesses of each option. The refined list of KETs relevant companies, PRODCOM and HS codes allowed the retrieval of data on production, demand, trade and business indicators from existing databases.

The "value chain approach" (Section 3.4) uses a right to left analysis on the value chain and consists in identifying the underlying components of final products relying heavily on KETs technology. The final product that was chosen is the electrical vehicle, whereby the focus lied on Li-ion batteries, a critical component in electric vehicles**.** As this approach has proved to be very time consuming, it has been used as a source of information for conducting so-called sanity checks for the other approaches (i.e. identified components and companies were compared to the results of the other approaches).

In addition, the possibility of collecting data bottom-up from industrial actors in the value chain has also been examined (Section 3.5). These actors do possess relevant information but are in general reluctant to share this information if confidentiality and anonymity are not guaranteed. It was decided not to pursue this approach further, but rather to use experts as a way to validate important steps in the process of data gathering and the obtained indicator values.

The different approaches are used to identify KET-related economic activities in existing statistical information systems and to derive indicators on KETs deployment of countries over time from these statistics (Section 4). Technology indicators capture the performance/capability of countries in producing new technological knowledge in the field of KETs that is relevant for industrial application and commercialisation (Section 4.2). Production indicators offer information on the relevance of the sectors involved in KETs while demand indicators provide insight in the level of adoption and its dynamics (Section 4.3). International trade indicates whether the technology produced in a certain country can be commercialised in other countries as well (Section 4.4). Business indicators are a useful performance indicator as they cover the performance (i.e. 'quality') of the firm, with indicators on productivity (e.g. operating revenue) and employment (Section 4.5). A summary indicator, a KETs deployment indicator, is calculated for all five indicators (Section 4.6).

For all indicators, the data input and the calculation of the indicators is discussed, followed by a preview of the output (see sections 4.2.1, 4.2.2, 4.3.1, 4.3.2, 4.4.1, 4.4.2, 4.5.1, 4.5.2,4.6.1, and 4.6.2). The data input is currently based on refined lists of IPC codes, PRODCOM/HS codes and companies. There is a need to optimize these lists to final lists using the suggested routes. All output can be consulted on the KETs Observatory website but should be handled with great caution as the indicator values are not yet validated since the final lists of IPC codes, PRODCOM/HS codes and companies are not yet available and hence are subject to change. As this study is a feasibility study, the strengths and weaknesses of each indicator is discussed, followed by the next steps to refine and optimize it (see sections 4.2.3, 4.2.4, 4.3.3, 4.3.4, 4.4.3, 4.4.4, 4.5.3, and 4.5.4).

The KETs Observatory has taken the form of an online monitoring platform that aims to provide a single access point to information and analysis of KETs deployment and KETs related policies in Europe and competing economies (Section 6). Next to an interactive overview of all available indicator values plotted on a worldwide map, the KETs Observatory also contains policy profiles of EU27 countries and several non-EU27 countries (China, India, Israel, Japan, Korea, Switzerland, and United States). These policy profiles contain an overview of national policy measures, based on desk research of available databases and literature (Section 5).

The focus in this feasibility study lied on the conceptual and methodological level; hence there is a clear need for further optimization through validating the input to calculate the indicators. This optimization should be the single and first priority of the permanent KETs Observatory. Several routes are described that explain the best way to achieve this (Section 7.2.2). A first route is to set up a panel of technology experts to define KETs components and to refine the IPC codes. A second route is to set up a panel of classification experts to identify relevant KETs-related PRODCOM entries and to assign weights to these entries. A third panel consists of industry experts in order to compile list of KETs relevant companies and to assign appropriate weights to these companies according to their KETs activity. A fourth route is the development of a dedicated survey to gather information that is missing in the existing databases.

All routes should be run in parallel to enhance the input that is used to calculate the indicators. However, not all routes are relevant for all indicators as for example, only technology experts (route one) are required to optimize the technology indicators. The needed optimization effort for the technology indicators is limited, while it is minor for the trade indicators and major for the business indicators. With regard to the production and demand indicators, the needed optimization effort is huge.

In addition, an expertise and governance structure for the functioning of the permanent KETs Observatory has been developed (Section 7.4). This feasibility study has shown that it is possible to set up a KETs Observatory to monitor the deployment of KETs in Europe and the rest of the world. However, additional steps are necessary to validate and refine the input and output of the data.

2 Introduction

The European Commission has launched a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. The final report gives an overview of the activities conducted and results obtained throughout this study.

2.1 Background of the study

In September 2009 the Commission published its Communication "Preparing for our future: Developing a common strategy for key enabling technologies in the EU". This strategy clearly identifies the need for Europe to facilitate the industrial deployment of Key Enabling Technologies (KETs) in order to make its industries more innovative and globally competitive. The European Commission has identified the following technologies as Key Enabling Technologies (KETs): industrial biotechnology, nanotechnology, micro- and nanoelectronics, photonics, advanced materials, and advanced manufacturing technologies.

In the Communication, it announced its intention to review its policies on Key Enabling Technologies. For that purpose, a High Level Expert Group on Key Enabling Technologies has been set up to develop possible policy measures to promote the industrial take-up of KETs by EU industries. In its final report in June 2011, the High Level Expert Group recommended that "the European Commission establishes a European KETs Observatory Monitoring Mechanism tasked with the mission of performing analysis and a "KETs Consultative Body" comprised of stakeholders across the entire innovation chain to advise and monitor the progress in Europe of the HLG KET recommendations towards the development and deployment of KETs for a competitive Europe this should include all relevant data regarding policies and strategies evolution outside EU" (Recommendation nr. 11). The objective of the European KETs Observatory Monitoring Mechanism would be to provide European, national and regional policy makers with information to better develop and implement industrial policies regarding the deployment of KETs. It should analyze the situation with regard to KETs deployment by establishing a methodology to assess the situation in the EU and applying it to benchmark the EU with regard to the rest of the world.

Hence, the European Commission launched a call for tender to prepare a feasibility study on a monitoring mechanism (an Observatory) to follow-up, measure and appraise the deployment of KETs in the EU. Moreover, a pilot launch of the developed monitoring mechanism for a period of 6 months was foreseen.

In the Communication "A European strategy for Key Enabling Technologies – A bridge to growth and jobs" of June 2012, KETs are identified as "a key source of innovation as they provide indispensable technology bricks that enable a wide range of product applications, including those required for developing low carbon energy technologies, improving energy and resource efficiency, boosting the fight against climate change or allowing for healthy ageing". KETs are instrumental as a key accelerator for innovation and the competitiveness of EU industries. However, whilst Europe shows an excellent R&D performance in this area, its major weakness lies in translating this knowledge into commercially successful goods and services. Hence there is a need to stimulate the deployment of KETs.

This feasibility study has the aim to provide the Commission with a detailed proposal on how to set up a "KETs monitoring mechanism". The emphasis lies on measuring the deployment of KETs. In addition, a web based tool has been designed to provide EU, national and regional policy makers with information to better develop and implement industrial policies regarding the deployment of KETs.

2.2 Objectives of the study

The objective of this feasibility study is to develop a monitoring mechanism (an Observatory) to follow-up, measure and appraise the deployment of Key Enabling Technologies in the EU and to execute a pilot launch of the developed monitoring mechanism for a period of 6 months. The feasibility study comprehends the following tasks (work packages):

1. Conducting a feasibility study with detailed proposals regarding the governance, structure, measurement methods, definition of performance indicators and screening methods of the "KETs monitoring mechanism".
2. Developing a website designed for the purpose of disseminating the information gathered by the "KETs monitoring mechanism".
3. Launching a pilot run of the "KETs monitoring mechanism", with the aim of demonstrating the application of the methodology and indicators as presented in the work package 1 for a test period of six months.

In underlying study, the emphasis lies on measuring the deployment of KETs. In the first phase of this project, a needs analysis was conducted among multiple stakeholders. From this needs analysis, we could conclude that most existing Observatories and Platforms rely on classical data such as patents, scientific publications, and other economic data. Existing data can only be roughly linked to specific KETs and to deployment activities. We therefore identified the need to construct new indicators and setup new data collection mechanisms in collaboration with existing data collection platforms/initiatives and industry groups that study the deployment potential of KETs.

The consortium has developed three complementary approaches to identify KETs relevant data in existing databases: 1) the technology diffusion approach, 2) the component approach and 3) the value chain approach. In addition, the possibility of collecting data bottom-up from industrial actors in the value chain has been examined. The different approaches are used to identify KET-related economic activities in existing statistical information systems. From these statistics, indicators on KETs deployment are calculated such as technology, production, demand, trade, business and KETs deployment summary indicators. As the values of the indicators are calculated within the framework of this feasibility study, they are not yet validated and hence subject to change. All values of indicators mentioned in this report should therefore be handled with caution.

3 Conceptual approach towards mapping and measuring KETs deployment

3.1 Introduction

This feasibility study aims to develop and test the methodological possibilities for monitoring the deployment of Key Enabling Technologies (KETs) and to provide the European Commission with a detailed proposal on how to set up a permanent "KETs monitoring mechanism”. Measuring the deployment of KETs cannot be done in a straightforward way as existing classification systems (and several public data sources) do not contain specific references to one of the KETs. In this study, the consortium has examined various ways to extract data from existing databases. As KETs have a general purpose and an enabling character, data on a two-digit level is not sufficiently detailed in order to identify KETs relevant deployment data. The consortium therefore looked for databases that contain data on a six or eight-digit level as this is the required level of detail needed in order to trace back KETs related technologies, components, production and trade activities. EU-PRODCOM codes for example are identified on an 8-digit level. The first four digits are the classification of the producing enterprise given by the Statistical Classification of Economic Activities in the European Community (NACE) and the first six correspond to the Classification of Products by Activity (CPA). The remaining digits specify the product in more detail. For example, 20.13 is the NACE class "Manufacture of other inorganic basic chemicals", 20.13.24 is the CPA subcategory "Hydrogen chloride; oleum; diphosphorus pentaoxide; other inorganic acids; silicon and sulphur dioxide", while 20.13.24.75 is the PRODCOM "Silicon dioxide".

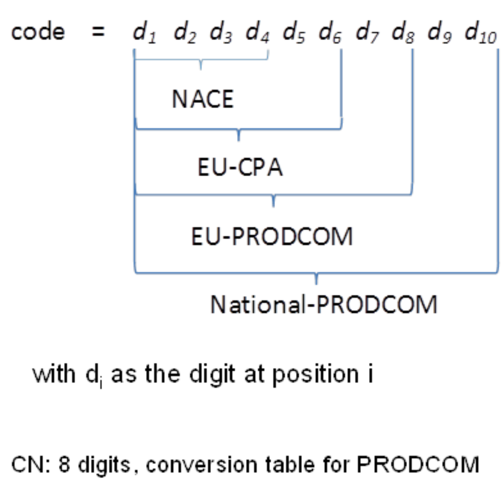

Figure 1: Classifications and their linkages

Only a few statistics offer such disaggregated industry data which restricts the opportunities for indicator construction:

- Data on innovation activities is collected through dedicated surveys, such as the Community Innovation Survey (CIS) of Eurostat and similar surveys in other countries. CIS results are available on 2-digit level of NACE only, which prevents using these data for deriving KETs indicators. In order to capture innovation activities in KETs areas, patent data is used, taking into account the limitations of these data to measure innovation.[2] Patent data relate to new technology (inventions) that have a potential for commercial application and are therefore a key indicator for monitoring developments in the generation of new technologies[3]. PATSTAT covers the patent data.

- International comparative industry-level data on investment, production and employment is provided by the STAN database of OECD and the EU-KLEMS database. Both databases only provide a sector breakdown by 2-digit level meaning that these data cannot be used for deriving indicators on KET-related activities. Production data on a detailed industry level (6-digit CPA) is available from Eurostat's PRODCOM database. Since this database also includes trade data on exports and imports, it allows to constructing indicators on domestic demand of KETs products. Since PRODCOM only includes European countries, no indicators for non-European countries can be calculated from this database. Coverage of other countries depends on availability of comparable data from national statistics[4].

- International data on trade is provided by the COMTRADE database of the United Nations. Trade data are provided on a highly detailed level of HS codes which enables to identify KETs products using the concordance tables developed in the components approach.

- Industry plays an essential role in the deployment of KETs. It is therefore also crucial to look at the industrial actors that are involved in deploying KETs. Several company databases exist such as Amadeus or Orbis. Company registers such as the BvD databases Amadeus or Orbis provide detail information on large and medium-sized companies from all over the world, including information on sales, employment, investment and R&D. Main KETs actors can be identified in these databases through name searches which allows for the construction of specific business indicators.

[2] See Griliches, Z. (1998), Patent Statistics as Economic Indicators: A Survey, in Z. Griliches (ed.), R&D and Productivity: The Econometric Evidence, Washington: National Bureau of Economic Research, 287-343; Pavitt, K. (1985), Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems, Scientometrics 7, 77-99.

[3] One should keep in mind that patent applications are only disclosed 18 months after the date of application, hence the emerging issue of a 'time lag' in produced statistics and indicators.

[4] In practice, OECD members, and also some other countries do collect production data, but the PRODCOM classification is only used by EU countries. The non-EU countries use different classifications (the US for example has adopted a classification based on sectors but not on products). More information can be found in section 4.3.4.

Table 1 gives an overview of relevant databases to measure the deployment of KETs. As KETs deployment is taking place throughout the world, there is a focus on databases that have a wide coverage. Hence, national databases are not selected. As several databases contain a limited level of detail, a solution is proposed by the consortium to obtain the necessary level of detail (see column 7 to 10 in the table). This implies that for example for employment, data has been collected using the Amadeus database instead of the STAN, LFS or EU-KLEMS database.

Data	**Database**	**Source**	**Coverage**	**Data collection**	**Level of detail**	***Solution***	***Database***	***Level of detail***	***Coverage***
R&D	ANBERD	OECD	32 OECD countries and 6 non-member countries	Yearly	2-digit ISIC (plus a few 3-digit industries)	*Companies*	*Amadeus/ Orbis R&D Scoreboard*	*5-digit NACE*	*All countries*
Innovation	Community Innovation Survey	EUROSTAT	EU Member States, EU Candidate Countries, Iceland and Norway	On a 4-year basis	2-digit NACE	*Patents*	*PATSTAT*	*8-digit IPC*	*All countries*
Investment	STAN/ EU-KLEMS	OECD/ EC	32 OECD countries/ 25 EU countries, Japan and US	Yearly till 2009/ One point in time	2-digit NACE/2-digit NACE	*Companies*	*Amadeus/ Orbis*	*5-digit NACE*	*All countries*
Production	STAN/ EU-KLEMS	OECD/ EC	32 OECD countries/ 25 EU countries, Japan and US	Yearly till 2009/ One point in time	2-digit NACE/2-digit NACE	*Production data*	*PRODCOM*	*8-digit PRODCOM*	*European countries*
Employment	STAN & LFS/ EU-KLEMS	OECD/ EC	32 OECD countries/ 25 EU countries, Japan and US	Yearly till 2009/ One point in time	2-digit NACE/2-digit NACE	*Companies*	*Amadeus/Orbis*	*5-digit NACE*	*All countries*
Labour	STAN & LFS/ EU-KLEMS	OECD/ EC	32 OECD countries/ 25 EU countries, Japan and US	Yearly till 2009/ One point in time	2-digit NACE/2-digit NACE	*Companies*	*Amadeus/Orbis*	*5-digit NACE*	*All countries*
Trade	COMTRADE	UN	All countries	Yearly	6-digit HS code	*Trade data*	*PRODCOM/ COMTRADE*	*6-digit HS*	*All countries (except Taiwan)*

Table 1: Overview of available databases relevant to measure the deployment of KETs

Restricted by data availability, we have been able to identify relevant KETs-related activities with regard to patents, production, trade, demand and business. Figure 2 gives an overview of the selected databases that are available at a desired level of detail to measure the deployment of KETs.

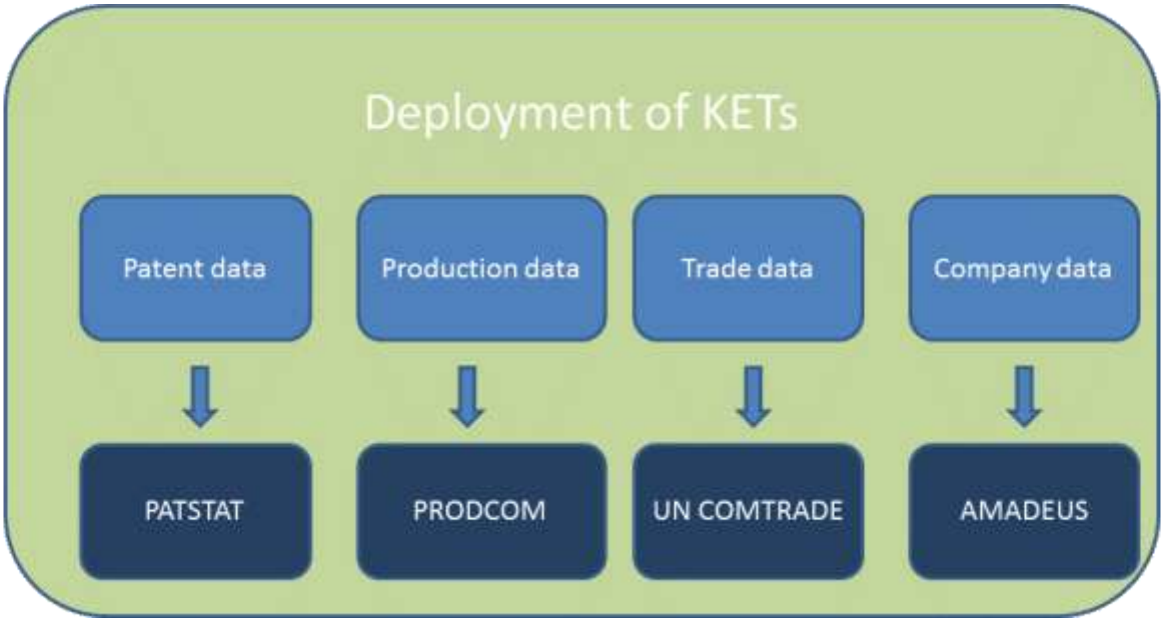

Figure 2: Overview of databases available at a desired level of detail to measure the deployment of KETs

Four approaches have been explored to link existing statistical nomenclatures to the deployment of KETs. The first approach, **the technology diffusion approach**, departs from KETs patents. The objective of this approach, starting from the technology base (patents), has been to identify the impact and significance of KETs technology in the industrial as well as technological base by linking KETs patents to KETs applicants, and KET applicants to company data in order to identify classification codes (e.g. NACE) of KETs applicants. The aim of this approach is to determine the economic sectors of organizations that are engaged in the development and exploitation of new technologies in the field of KETs.

The second approach, **the component approach**, aims to identify KETs components and companies active in the development and production of these components. The premise underlying the component approach is that products are made out of components, and whereas products may evolve rapidly over time, components in comparison develop and change at a slower pace. This is indeed a slight simplification/generalisation, as this may differ per technology and sector. The goal of the approach, however, is to construct a list of key components for each KET and to identify a representative list of companies that are active in the development and production of these components.

The third approach, **the value chain approach**, 'reconstructs' one particular value chain of a well-chosen and societally relevant KETs-based product. The advantage of this approach is that one can identify all components and companies involved in the particular value chain in depth. This approach is hence the most comprehensive one, but also the most resource intensive one. The approach has been illustrated through the analysis of the battery pack (in an electrical vehicle). This approach is used as a sanity check for the first two approaches.

The fourth approach, **the expert approach**, explores the possibility to use experts to collect detailed information on the relevance of KETs for their economic activities, including research, innovation, investment, production and international competitiveness. Industrial actors are however rather reluctant to share information which could provide/reveal insight in their market position or strategy if confidentiality and anonymity are not guaranteed. It is also difficult for them to provide relevant information as they do not structure their technologies according to KETs. Therefore, this approach has not been pursued as it proves more promising to use experts in a validation role rather than as a primary source of data collection. The role and importance of experts to validate the input to measure the deployment of KETs will be further discussed in the following chapters.

Restricted by data availability, we have been able to identify relevant KETs-related activities in existing classification systems and databases with regard to patents, production, trade, demand and business. Figure 3 gives an overview of the selected databases that are available at a desired level of detail to measure the deployment of KETs.

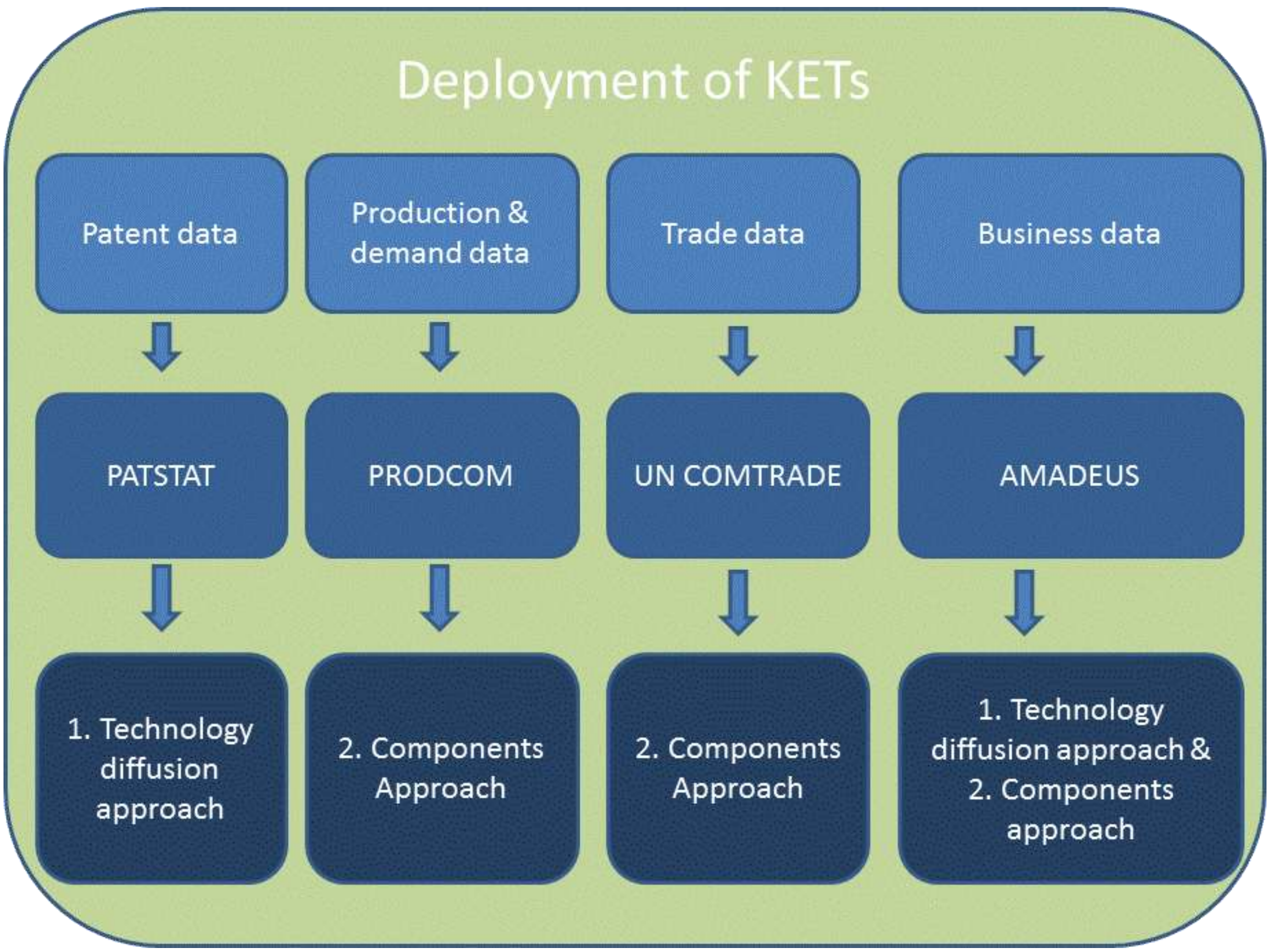

Figure 3: Overview of databases and associated approaches to measure the deployment of KETs

3.2 Technology diffusion approach

3.2.1 Introduction

The main goal of this approach is to identify the economic sectors in which KET developing and exploiting organisations are active. We do this by determining the economic sectors of applicants of KETs patents. The main outcome of this approach is a matrix that links KETs on the one hand with economic sectors on the other. Since patent activity is related to the production of new technology while the economic sector of applicants represent the field of commercialisation, this approach is called technology diffusion approach. Its outcome provides some indication about the relevance of a certain KET for the technological development in different economic sectors. At the same time, it also informs about the economic sectors that are most relevant for producing and commercialising a certain KET, though these sectors are not necessarily the sectors of end application nor do they represent all application sectors. The technology diffusion approach provides input for the calculation of the technology indicators and the business indicators.

We use the term 'KETs developing and exploiting organisations' for organisations that are engaged in the production of new knowledge related to KETs with a view to commercialise this knowledge. We decided to use patent data as these provide the best and most comprehensive available data on such organisations in the field of KETs (see Box 1 on the suitability of patent data). Patent data represent a first step of technology deployment activity as they relate to inventive activities that have a potential for commercial application. Patents can be to fields of technology, and they include the name of the applicant which allows to merging sector affiliation.

Patent data are a useful starting point for analysing the deployment of KETs:

- Patents refer to technical inventions that contain new knowledge and that have a potential for commercial application. Patent information goes beyond R&D data as patents can only be applied if a certain proof of technical feasibility has been achieved. Patents can be seen as a first step in the deployment of new technological knowledge. However, patent data are imperfect - as any other available data - as not all new technologies are patented, and not all patents are commercialised.
- Patent data contain information on the technological area(s) a patent is related to, based on an internationally standardised classification system (International Patent Classification - IPC). Since IPC classes are highly disaggregated, most KETs can be directly identified through a number of IPC codes (or their combination). Patent data also contain text information of the technical content of a patent (patent abstracts) which allows to identify KETs patents through text search.
- Patent data contain information on the name of the applicant which can be linked to other data in order to identify the applicants' sector affiliation.

- Patent data allow to calculating performance indicators such as market shares, technological specialisation and technological dynamics. In addition, information on the place of resident of inventors allow for regional analysis for patent activity.

Box 1: Suitability of Patent Data for KETs Analyses

3.2.2 Analytical steps

The technology diffusion approach consists of five analytical steps:

1) Identifying KETs patents based on IPC codes (see conversion table in box 2)

2) Assigning sector codes to the applicants of KETs patents based on NACE codes

3) Calculating a KETs-to-sector matrix for all patent applications in the field of KETs in order to link each KET to the industry sector of applicants

4) Producing a list of main actors per field of KETs based on patent applicants with the largest number of applications

5) Conducting robustness checks in order to validate whether the identification of KETs through IPC codes works:

a) Analysing to what extent patent applications of organisations that are known to have a strong KETs focus are identified as KETs patents - a low share of KETs patents for these organisations may imply that the IPC code based approach misses important parts of KET-related patent activity;

b) Analysing sector codes of organisations that predominantly patent in the field of KETs (i.e. they have a high share of KETs patents in total patents) - a significant deviation of the sector pattern for KET-focused applicants from the sector pattern for all applicants of KET patents may indicate that the list of main applicants identified through the IPC code based approach may be biased;

c) Identifying KETs patents through a text search in patent abstracts (for the field of photonics) – a strong deviation between the text search results and the results of the IPC code based approach may imply that the latter is not fully capturing the relevant patent activity in that KET.

Figure 4 provides an overview of the different analytical steps taken in the technology diffusion approach.

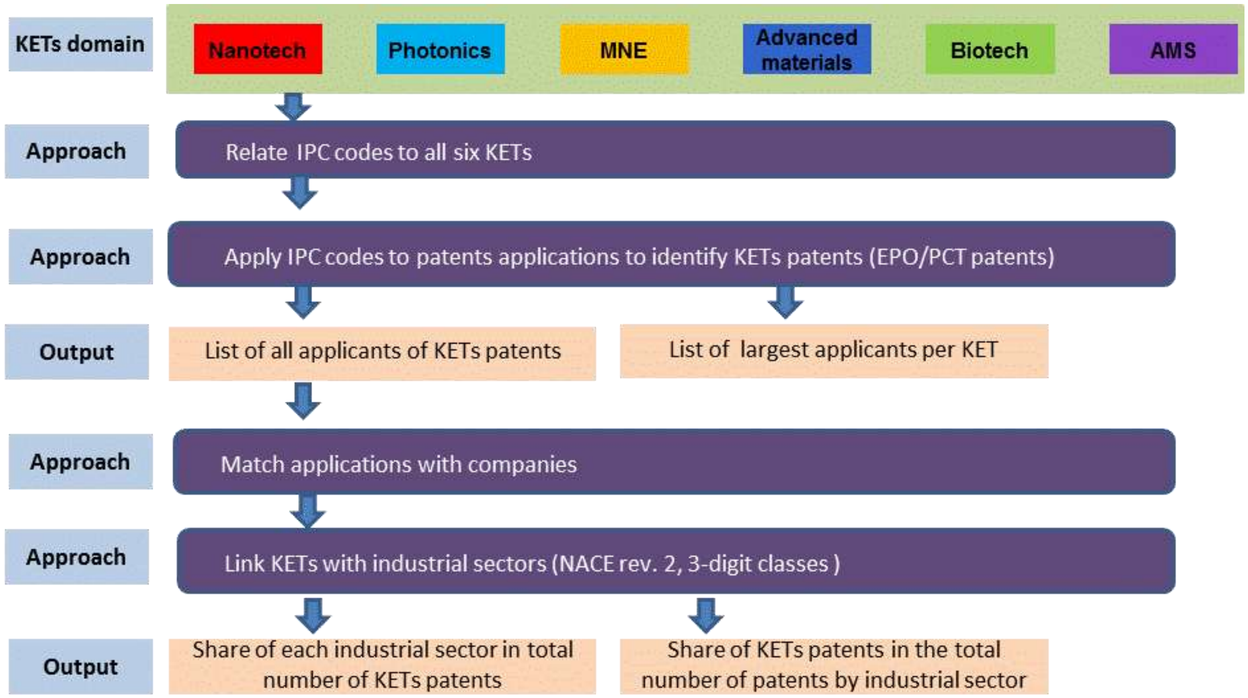

Figure 4: Overview of the different steps of the technology diffusion approach

Step 1 is conducted by using a list of IPC codes to assign patents to KETs. The initial list was taken from a predecessor study on KETs[5] and has been refined and further developed for this project based on expert reviews and the results of the robustness checks listed above. The final list of IPC codes used for each KET is shown in Box 2 which already incorporates changes made as a result of the robustness checks. The robustness checks were based on an earlier version of this list. The results of the robustness checks are not affected by the changes made to the list after the findings of the robustness checks.

For one KET -advanced manufacturing technologies- a major deviation from the approach used in the predecessor study was made. In this earlier study, advanced manufacturing technologies focused on automation, robotics and the use of advanced information technology in mechanical engineering. These advanced manufacturing technologies can be employed in any manufacturing sector, though an implicit focus was on sectors that process materials (such as metal working, plastics, wood and paper processing, manufacture of non-metallic mineral products) or assemble materials and components to complex products (such as manufacture of vehicles, electronics, optical or electrical equipment, machinery and the like). For the present study, a different definition of advanced manufacturing technologies was applied that focuses on process technology which is needed to manufacture products in any of the other five KETs areas. Since most of the other KETs areas are concerned with the development of new materials (which is true for advanced materials as well as industrial biotechnology and nanotechnology and also applies to major parts of technological development in micro- and nanoelectronics and

[5] Centre for European Economic Research and TNO (2010), European Competitiveness in Key Enabling Technologies, Background Report, May 2010, Mannheim and Delft.

photonics), manufacturing technology for these KETs areas is often linked to apparatus for performing chemical processes and treating basic materials.

For some KETs areas, such type of advanced manufacturing technologies can be easily identified through IPC by using codes that directly relate to the technology for the manufacture of certain materials or devices. This mainly applies to advanced manufacturing technologies for industrial biotechnology, nanotechnology, micro- and nanoelectronics, and advanced materials. One should note that IPC codes on specific manufacturing technologies related to one of these four KETs areas often co-occur with IPC codes that define new materials or components. For this reason, many applicants in one of the four KETs areas also appear as applicants of advanced manufacturing technologies. This is particularly true for chemical companies. They often both co-develop new materials and the technological principles needed to manufacture these new materials, though they rarely engage in the production of manufacturing equipment as such.

For photonics, the situation is more complicated since photonics is rather about using certain properties of light in various applications. Typical photonics products are different types of instruments, devices, apparatus or components often used in more complex products. To manufacture photonics products, very different manufacturing technologies may be applied, and the same manufacturing technology may be used to produce photonics instruments or devices as well as other instruments or devices. Since IPC codes do not allow identifying manufacturing technologies that are purely or mainly used to produce photonics products, such manufacturing technologies are poorly captured by the technology diffusion approach.

Nanotechnology deals with methods to analysing, controlling and manufacturing structures on a molecular or atomic scale, i.e. of a size of 100 nanometers or less. There is a separate IPC tag class used by EPO to mark nanotechnology patents (B82Y, previously Y01N). In addition, B81C and B82B are further codes directly related to nanotechnology.

Photonics relates to optical technology applications in the areas of lasers, lithography, optical measurement systems, microscopes, lenses, optical communication, digital photography, LEDs and OLEDs, displays and solar cells. All these areas can be identified through IPC classes: F21K, F21V, F21Y, G01D 5/26, G01D 5/58, G01D 15/14, G01G 23/32, G01J, G01L 1/24, G01L 3/08, G01L 11/02, G01L 23/06, G01M 11, G01P 3/36, G01P 3/38, G01P 3/68, G01P 5/26, G01Q 20/02, G01Q 30/02, G01Q 60/06, G01Q 60/18, G01R 15/22, G01R 15/24, G01R 23/17, G01R 31/308, G01R 33/032, G01R 33/26, G01S 7/481, G01V 8, G02B 5, G02B 6 (excl. subclasses 1, 3, 6/36, 6/38, 6/40, 6/44, 6/46), G02B 13/14, G03B 42, G03G 21/08, G06E, G06F 3/042, G06K 9/58, G06K 9/74, G06N 3/067, G08B 13/186, G08C 19/36, G08C 23/04, G08C 23/06, G08G 1/04, G11B 7/12, G11B 7/125, , G11B 7/13, , G11B 7/135, G11B 11/03, G11B 11/12, G11B 11/18, G11C 11/42, G11C 13/04, G11C 19/30, H01J 3, H01J 5/16, H01J 29/46, H01J 29/82, H01J 29/89, H01J 31/50, H01J 37/04, H01J 37/05, H01J 49/04, H01J 49/06, H01L 31/052, H01L 31/055, H01L 31/10, H01L 33/06, , H01L 33/08, H01L 33/10, H01L 33/18, H01L 51/50, H01L 51/52, H01S 3, H01S 5, H02N 6, H05B 33.

Industrial biotechnology is more difficult to identify through IPC classes since many classes covering inventions related to industrial biotechnology may also cover new technologies linked to red or green biotechnology. We apply a rather narrow definition which focuses on enzymes, micro-organisms, amino acids and fermentation processes and only consider patents that are not related to the fields of medicine or agriculture: C02F 3/34, C07C 29, C07D 475, C07K 2, C08B 3, C08B 7, C08H 1, C08L 89, C09D 11, C09D 189, C09J 189, C12M, C12P, C12Q, C12S, G01N 27/327 except for co-occurrence with A01, A61, C07K 14/435, C07K 14/47, C07K 14/705, C07K 16/18, C07K 16/28, C12N 15/09, C12N 15/11, C12N 15/12, C12N 5/10, C12P 21/08, C12Q 1/68, G01N 33/15, G01N 33/50, G01N 33/53, G01N 33/68, G01N 33/566, C12N 1/19, C12N 1/21, C12N 1/15, C12N 15/00, C12N 15/10, C12P 21/02. Some subfields of industrial biotechnology such as biopolymers and biotechnologically produced vitamins are poorly covered because they are difficult to distinguish from chemical polymers and chemically produced vitamins.

Advanced materials can cover a broad area of innovation in materials, including polymers, macromolecular compounds, rubber, metals, glass, ceramics, other non-metallic materials and fibres as well as the whole field of nanomaterials and speciality materials for electric or magnetic applications. We focus on material innovations in the areas of layered products, compounds, allays and nanomaterials: B32B 9, B32B 15, B32B 17, B32B 18, B32B 19, B32B 25, B32B 27, B82Y 30, C01B 31, C01D 15, C01D 17, C01F 13, C01F 15, C01F 17, C03C, C04B 35, C08F, C08J 5, C08L, C22C, C23C, D21H 17, G02B 1, H01B 3, H01F 1/0, H01F 1/12, H01F 1/34, H01F 1/42, H01F 1/44, H01L 51/30, H01L 51/46, H01L 51/54.

Micro- and nanoelectronics covers new technologies related to semiconductors, piezo-electrics and nanoelectronics which all are easily to identify through IPC classes: G01R 31/26, G01R 31/27 , G01R 31/28 , G01R 31/303 , G01R 31/304, G01R 31/317, G01R 31/327, G09G 3/14, G09G 3/32, H01F 1/40, H01F 10/193, H01G 9/028, H01G 9/032, H01H 47/32, H01H 57, H01S 5, H01L, H03B 5/32, H03C 3/22, H03F 3/04, H03F 3/06, H03F 3/08, H03F 3/10, H03F 3/12, H03F 3/14, H03F 3/16, H03F 3/183, H03F 3/21, H03F 3/343, H03F 3/387, H03F 3/55, H03K 17/72, H05K 1. We also include the nanotechnology trap class B82Y 25 (nanoelectronics) which results in a certain overlap to nanotechnology.

Advanced Manufacturing Technologies for other KETs covers process technology that is used to produce any of the other five KETs. In case of advanced materials, industrial biotechnology, nanotechnology and micro- and nanoelectronics, such process technology typically relates to production apparatus, equipment and procedures for the manufacture of specific materials and components. In case of photonics, process technology covers apparatus and equipment that is used to manufacture photonics items. Though using the following detailed list of IPC classes, not all relevant process technology can be covered through IPC codes: B01D 15, B01D 67, B01J 10, B01J 12, B01J 13, B01J 14, B01J 15, B01J 16, B01J 19/02, B01J 19/08, B01J 19/18, B01J 19/20, B01J 19/22, B01J 19/24, B01J 19/26, B01J 19/28, B01J 20/30, B01J 21/20, B01J 23/90, B01J 23/92, B01J 23/94, B01J 23/96, B01J 25/04, B01J 27/28, B01J 27/30, B01J 27/32, B01J 29/90, B01J 31/40, B01J 38, B01J 39/26, B01J 41/20, B01J 47, B01J 49, B01J 8/06, B01J 8/14, B01J 8/24, B01J 10, B01L , B04B , B04C , B32B 37, B32B 38, B32B 39, B32B 41, B81C 3, B82B 3, B82Y 35, B82Y 40, C01B 17/20, C01B 17/62, C01B 17/80, C01B 17/96, C01B 21/28, C01B 21/32, C01B 21/48, C01B 25/232, C01B 31/24, C01B 9, C01C 1/28, C01D 1/28, C01D 3/14, C01D 5/16, C01D 7/22, C01D 9/16, C01F 1, C01G 1, C02F 11/02, C02F 11/04, C02F 3, C03B 20, C03B 5/24, C03B 5/173, C03B 5/237, C03B 5/02, C03C 21, , C03C 29, C04B 11/028, C04B 35/622, C04B 35/624, C04B 35/626, C04B 35/653, C04B 35/657,

C04B 37, C04B 38/02, C04B 38/10, C04B 40, C04B 7/60, C04B 9/20, C07C 17/38, C07C 2/08, C07C 2/46, C07C 2/52, C07C 2/58, C07C 2/80, C07C 201/16, C07C 209/82, C07C 213/10, C07C 227/38, C07C 231/22, C07C 249/14, C07C 253/32, C07C 263/18, C07C 269/08, C07C 273/14, C07C 277/06, C07C 29/74, C07C 303/42, C07C 315/06, C07C 319/26, C07C 37/68, C07C 4/04, C07C 4/06, C07C 4/16, C07C 4/18, C07C 41/34, C07C 41/58, C07C 45/78, C07C 45/90, C07C 46/10, C07C 47/058, C07C 47/09, C07C 5/333, C07C 5/41, C07C 51/42, C07C 51/573, C07C 51/64, C07C 57/07, C07C 67/48, C07C 68/08, C07C 7, C07D 201/16, C07D 209/84, C07D 213/803, C07D 251/62, C07D 301/32, C07D 311/40, C07D 499/18, C07D 501/12, C07F 7/20, C07H 1/06, C07K 1, C08B 1/10, C08B 17, C08B 30/16, C08C , C08F 2/01, , C09B 41, C09B 67/54, C09D 7/14, C09J 5, C12M , C12S , C21C 5/52, C21C 5/54, C21C 5/56, C21C 7, C21D , C22B 11, C22B 21, C22B 26, C22B 4, C22B 59, C22B 9, C22C 1, C22C 3, C22C 33, C22C 35, C22C 47, C22F , C23C 14/56, C23C 16/54, C25B 9, C25B 15/02, C25C , C25D 1, C30B 15/20, C30B 35, C40B 60, D01D 10, D01D 11, D01D 13, D01F 9/133, D01F 9/32, D06B 23/20, D21H 23/20, D21H 23/70, D21H 23/74, D21H 23/78, D21H 27/22, F24J 1, F25J 3, F25J 5, F27B 17, F27B 19, F27D 19, F27D 7/06, G01C 19/5628, G01C 19/5663, G01C 19/5769, G01C 25, G01R 3, G11B 7/22, H01L 21, H01L 31/18, H01L 35/34, H01L 39/24, H01L 41/22, H01L 43/12, H01L 51/40, H01L 51/48, H01L 51/56, H01S 3/08, H01S 3/09, H01S 5/04, H01S 5/06, H01S 5/10, H05B 33/10, H05K 13, H05K 3

*Box 2 **:** Conversion table, identifying KETs patents by IPC codes*[6]

KETs patents are identified by applying the list of IPC codes to patents applications at the EPO or through the PCT procedure (EPO/PCT patents). We restrict the analysis to EPO/PCT patents since these patents are likely to represent higher economic values as application costs are higher compared to an application at a single national patent office. In addition, a home office bias tends to be less pronounced compared to applications at the US or Japanese patent office though European applicants will be somewhat overrepresented when using EPO/PCT applications. The PATSTAT database of EPO (March 2012 edition) was used to perform the analytical steps of the technology diffusion approach.

The technology diffusion approach uses **patent application data** instead of data on **granted patents**. The choice for applications over grants is first of all motivated by the higher timeliness of application data, which are disclosed 18 months after a patent application has been filed. Applicants often receive patent grants only a considerable time later, and some grant procedures can take many years. As a result, the number of granted patents with a certain priority year (that is the year from which on a patent seeks to protect the underlying IP and which is generally linked to the year in which the technology to be protected has been invented) will change back for many years. Somewhat complete data on granted patents for a certain priority year will be available only several years later. Since the KETs Observatory aims, among others, at presenting and analysing recent trends in KET-related activity, using granted patents would imply a considerable time lag.

In practice, results on technology indicator results used for the KET Observatory are likely to be very similar for both patent applications and granted patents. This is first of all due to the fact that most

[6] Based on the 2012 edition of IPC.

applied patents are granted by patent authorities. The main reason is that patent applications, particularly those at EPO and through the PCT procedure, are costly, and applicants carefully examine the likelihood of getting a patent grant in advance. Inventions that are less likely to receive a patent grant are typically not filed for a patent.

The results of step 1 are used to produce a list of all applicants of KETs patents (step 2). KETs applicants are organisations (enterprises, universities, research institutes) or individuals that own at least one (EPO/PCT) patent with an IPC code that is assigned to at least one KET. Owners of a patent are typically the organisations or individuals that applied for that patent. In case patents have been purchased to other organisations, these organisations are recorded as KETs applicants as long as their name is recorded in the field "applicant" by the patent authority (which is not always the case as new owners can opt for not having shown their names).

This list of applicants was matched with company directories to assign 3-digit[7] industry codes[8] based on NACE rev. 2 to applicants, including a manual checking of assigned industry codes. Since KETs applicants come a variety of countries and include many small firms, not all applicants could be matched automatically. In order to keep the amount of manual research and checking to a volume that was in line with the resources for this sub-task, only applicants with a certain minimum number of patent applications by KETs have been checked manually. For each KET, a minimum coverage of 50 percent (in terms of KETs patents with applicants assigned to industry codes in all KETs patents) was aimed for. In fact, the actual coverage goes clearly beyond, with 55 percent for industrial biotechnology, 60 percent for advanced manufacturing technologies, 65 percent for photonics, 70 percent of advanced materials, 82 percent for micro- and nanoelectronics and 96 percent for nanotechnology. Note that patent applications by private individuals were not assigned to any sector and have been ignored for further analysis because they represent an inhomogeneous group of applicants. Some private individuals are researchers at universities or public research organisations while others may be owners of enterprises who provide their patents to their enterprise but retain private ownership for liability, tax or other reasons. In many of these cases, private individuals appear as patent applicants jointly with enterprises which mostly mean that they are employees of the patent applying enterprise.

In step 3, a matrix was produced that links KETs on the one hand and industrial sectors on the other. The matrix is depicted in Table 2 and Table 3. Table 2 shows the share of each industrial sector in the total number of KETs patents by KET. Table 3 shows the share of KETs patents in the total number of patents by industrial sector. While the first result informs about the relative significance of a sector in the production of patents for a certain KET, the second result indicates the relevance of KETs for the technological development within a certain sector.

[7] We refrained from using a more detailed (4- or 5-digit) level since the largest share of patents are applied by large, diversified companies for which the most important activity on a 4- or 5-digit level often represents only a tiny fraction of their total business.

[8] Industry codes are also assigned to non-profit organisations such as public research organisations, hospitals or government agencies as well as to private individuals. In the field of research and development activities, we used 4-digit coding to separate biotechnology R&D (7211) from other science and engineering R&D activities (7219). In addition, organisations with nanotechnology R&D were given a separate code (7212) though this code does not exist in the official NACE rev. 2 classifications.

Step 4 aims at identifying key actors in each KET area. For this purpose, the list of KETs patent applicants produced in step 2 is consolidated at a company group level and the ten largest applicants per KET are determined.

The fifth and final step of the technology diffusion approach was to conduct some robustness checks on the results achieved in step 3. These robustness checks test the validity of the identification of KETs patents and the validity of the KETs-to-industries matrix produced in step 3.

In a first robustness check, we established two lists of companies that may be regarded as particularly linked to the deployment of KETs. One list includes nine companies which have been known as significantly active in producing and commercialising different types of KETs. Another contains ten companies that are leading in the field of separators and electrolytes for advanced batteries to be used for electric cars. Both lists were produced by CEA based on expert interviews. The lists are matched with applicant names in PATSTAT using special software developed at ZEW. For each company, all patent applications since 2000 (regardless of the patent office at which a patent has been applied) were recorded using PATSTAT database. These patents were assigned to KETs using the same procedure as in step 1.

As a second robustness check, we investigated the companies with a patent activity predominantly in the field of KETs. For this purpose, all applicants that applied patents at EPO/PCT during 2000 and 2010 have been analysed. For each applicant - based on the so-called docstd information[9] provided by EPO - patent applications were assigned to KETs-based on IPC codes, and patents not assigned to any of the six KETs considered in the robustness check were classified as non-KETs patents and the share of KETs patents in all patents was calculated. Applicants were then grouped according to the total number of patents applied during 2000 and 2010 in three groups: large applicants (500 or more applications), medium applicants (100 to 499 applications) and small applicants (50 to 99 applications). For each group, organisations with highest share of KETs patents were selected, using a threshold of 50 percent for large applicants, 80 percent for medium applicants and 90 percent for small applicants. These organisations were then assigned to NACE rev. 2 4-digit codes based on manual search. Organisations with main activities in several industries received multiple codes.

A third robustness check is concerned with the validity of KETs identification through IPC codes by comparing these results with the results of a text search. Text search technology identification is based on searching for keywords in the abstracts of patent applications. Such text search requires a substantial effort for, first, developing a keyword list (including links between keywords), secondly, double-checking the results on plausibility and likely false positives, and thirdly, redefine the keyword search. This procedure has to be reiterated until false positives are reduced to an acceptably small number. Since such a robustness check could not be performed for all KETs with the available resources for this sub-task, we choose photonics as a case study. The text search was developed by CEA based on expert interviews and prior experience in similar activities and implemented through special software

[9] docstd is a variable contained in Patstat that identifies unique applicants based on the name and the legal form of the organisation. In case organisations change names or legal forms, docstd will change. Subsidiaries of organisations have their own docstd.

developed at ZEW. Box 3 presents the initial version of the search routine which was adapted later to exclude false positives, e.g. in the field of laser systems used for medical treatment or in the application of lasers for control and automation purposes. Further adjustment of the search algorithm was needed to avoid mis-assignment of short words such as nano, led or pic.

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seeker photon "photonic", "optical network", "optical signal", "optic fibre", "laser
design", "photovoltaic", "photo-voltaic", "OPVC", "organic pv", " LED ", " LED,", "
LED.", " LEDS ", " LEDS,", " LEDS.", " OLED ", " OLED,", " OLED.", " OLEDS ", "
OLEDS,", " OLEDS.", "light emitting diod", "solid state light", "electrolumin", "thin
film"

seeker laser "optical", "laser"

seeker system "device", "system"

seeker light "light", "optical", "luminescence", "laser"

seeker emiss "emission", "transmission", "modulation", "signal processing", "switch",
"amplicication", "detect", "sensing", "sensor", "emitter"

seeker nano "nano"

seeker opto "photonic", " pic ", " pic,", " pic.", "quantum dot", " qdot",
"optoelectronic", "optronic", "plasmonic"

texan Photon analyses photon

texan Laser analyses laser max 5 words near system

texan Light analyses light max 5 words near emiss

texan Nano analyses nano max 3 words near opto
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Box 3: Text search for photonics patents (initial version)

The patents identified as photonics patents through the text search were merged with the photonics patents identified through the IPC code classification, producing three groups of patents: (a) patents that were identified as photonics patents by both approaches, (b) patents only found through the text search and (c) patents only found through the IPC code classification. For patents (b), a detailed analysis of the IPC codes of these patents was performed in order to identify IPC codes that often appear. These codes were then further analysed on how well they represent photonics technologies and to what extent other technologies are covered by them. As a result, some changes in the list of IPC codes used to identify photonics patents were made. For patents (c), we performed a similar analysis and investigated IPC codes that often appear in this group whether they accurately represent photonics technologies.

3.2.3 Sector composition of KETs applicants

A main output of this approach is a sector breakdown of applicants of KETs patents. Table 2 presents a list of sectors that show a share of at least 1.0 percent in total KETs patent production for at least one KET area, based on the final definition of KETs (Box 2) and the most recent version of PATSTAT (March 2012). A total of 29 different 3-digit sectors (out of 272 individual 3-digit codes present in NACE rev. 2) represent about 96 percent of all KETs patents. Almost all sectors belong to manufacturing except for four service sectors (wired telecommunication, research and experimental development, higher education, hospital services). Three sectors appear to be important producers of KETs patents in all six KETs areas: manufacture of basic chemicals (201), science and engineering R&D (721) and higher education (854). The latter two primarily represent public research. Manufacture of electronic components (261) is another main player at the level of sectors which shows a high share in total KETs patents for all KETs areas except industrial biotechnology.

Table 2: KETs patents by sector of applicant (based on final KETs definition)

NACE rev. 2		Share in total patents by KET (percent)						
		Industrial bio-tech-nology	Micro- and nano-electro-nics	Advan-ced mate-rials	Photo-nics	Nano-techno-logy	AMT for other KETs	All KETs 1)
108	Manufacture of other food products	2.0	0.0	0.1	0.0	0.0	0.2	0.2
192	Manufacture of refined petroleum products	1.3	0.8	2.7	1.1	0.4	1.8	1.7
201	Manufacture of basic chemicals, fertilisers, plastics/synthetic rubber in primary forms	21.9	9.5	35.7	8.7	10.5	14.5	19.2
202	Manufacture of pesticides, agrochemical products	0.7	0.0	0.0	0.0	0.0	0.1	0.1
204	Manufacture of soap, detergents, cleaning/polishing preparations, perfumes, toilet preparations	0.6	0.1	1.6	0.1	1.1	0.5	0.8
205	Manufacture of other chemical products	0.6	1.9	2.6	3.4	1.4	1.3	2.0
211	Manufacture of basic pharmaceutical products	1.4	0.0	0.0	0.0	0.1	0.2	0.2
212	Manufacture of pharmaceutical preparations	12.1	0.1	0.7	0.3	1.9	1.4	1.8
221	Manufacture of rubber products	0.1	0.2	2.6	0.7	0.3	0.5	1.1
222	Manufacture of plastics products	0.3	0.4	2.9	0.3	0.3	0.5	1.1
231	Manufacture of glass and glass products	0.4	1.3	5.2	2.9	1.1	1.5	2.6
241	Manufacture of basic iron, steel and of ferro-alloys	0.0	0.4	2.9	0.2	0.1	2.1	1.2
244	Manufacture of basic precious/non-ferrous metals	0.1	0.6	2.9	0.2	0.5	2.1	1.3
261	Manufacture of electronic components and boards	1.1	22.4	4.8	11.7	9.5	15.7	11.4
262	Manufacture of computers/peripheral equipment	0.7	6.6	1.2	4.3	5.0	4.8	3.6
263	Manufacture of communication equipment	0.1	2.7	0.3	2.9	1.9	1.6	1.7
264	Manufacture of consumer electronics	0.6	8.1	1.1	13.8	3.9	4.6	6.0
265	Manufacture of instruments for measuring, testing and navigation; watches and clocks	2.3	2.3	0.9	2.6	2.5	2.8	2.1
267	Manufacture of optical instruments and photographic equipment	1.3	7.0	2.7	14.7	4.5	4.2	6.0
271	Manufacture of electric motors, generators, transformers, electricity distribution apparatus	1.9	7.5	4.8	6.3	4.1	6.3	5.8
274	Manufacture of electric lighting equipment	0.0	0.6	0.1	2.6	0.3	0.2	0.9
289	Manufacture of other special-purpose machinery	0.5	9.0	5.4	2.8	1.9	10.0	5.0
291	Manufacture of motor vehicles	0.2	1.4	1.7	1.4	0.9	1.2	1.4
293	Manufacture of parts/accessories for motor vehicles	0.1	2.4	1.2	2.2	1.3	1.5	1.9
303	Manufacture of air and spacecraft machinery	0.0	0.7	0.7	1.6	0.6	0.6	0.9

611	Wired telecommunications activities	0.0	0.0	0.0	0.2	0.0	0.0	0.1
854	Higher education	22.0	5.3	4.1	5.3	20.7	6.9	7.0
861	Hospital activities	1.4	0.0	0.0	0.1	0.3	0.1	0.2
7211	R&D on biotechnology	11.7	0.4	0.5	0.4	2.9	2.4	1.8
7212	R&D on nanotechnology	0.7	0.8	1.0	0.7	6.8	1.0	1.1
7219	Other R&D on natural sciences and engineering	11.6	4.7	4.3	4.4	11.8	6.0	5.6
	All other sectors	2.4	2.7	5.1	4.0	3.1	3.5	4.1
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	HHI*	1,406	967	1,483	790	926	780	769
	Share of 5 largest sectors (percent)	79.3	56.5	55.9	55.3	59.3	53.3	49.7

1) Patents that are assigned to at least one KET area, no double-counting of patents assigned to more than one KET area. The total number of KET patents (EPO/PCT applications during 2000 to 2010, all countries) used for this table is 240,830[10].
* Hirschman-Herfindahl-Index, calculated based on all NACE 3-digit codes.
Source: PATSTAT, ZEW calculations

Other sectors that are engaged in producing patents across several KETs areas to a significant extent include manufacture of computers and peripheral instruments (262), manufacture of consumer electronics (264), manufacture of instruments for measuring (265), manufacture of optical instruments (267), manufacture of electric equipment (271) and manufacture of other special-purpose machinery (289). Most other sectors show shares of more than 1 percent in total patent applications only for one or two KETs areas.

Summing up across all six KETs, the chemical industry (201 to 205) and the electronics industries (261 to 264) appear as the two single most important industries for producing KETs, each holding a share in the total number of KETs patents of 21 to 22 percent. Public research (854 and 721) is another important player in KETs, accounting for roughly 18 percent of all KETs patents.

The most important patent producing sectors for the six KETs areas are as follows (only sectors with a share of at least 5 percent are listed):

- Industrial biotechnology: m/o basic chemicals, m/o pharmaceutical preparations, higher education, biotechnology R&D and other R&D account for 79 percent of all patent applications.
- Nanotechnology: higher education, other R&D, m/o basic chemicals, m/o electronic components, nanotechnology R&D and m/o computers account for 64 of all patent applications.
- Micro- and nanoelectronics: m/o electronic components, m/o basic chemicals, m/o special purpose machinery, m/o consumer electronics, m/o electric equipment, m/o optical instruments, m/o computers and higher education account for 75 of all patent applications.
- Photonics: m/o optical instruments, m/o consumer electronics, m/o electronic components, m/o basic chemicals, m/o electric equipment and higher education account for 61 of all patent applications.

[10] The total number of KETs patents is 317.737 over the period 2000-2009.

- Advanced materials: m/o basic chemicals, m/o special purpose machinery and m/o glass and glass products account for 46 of all patent applications.
- Advanced manufacturing technologies: m/o electronic components, m/o basic chemicals, m/o special purpose machinery, higher education, m/o electric equipment and other R&D account for 59 of all patent applications.

While photonics and advanced manufacturing technologies show the lowest concentration of applicant sectors as revealed by the Hirshman-Herfindahl Index and the share of the five largest sectors in total number of patents, patenting in industrial biotechnology and advanced materials is very much concentrated on a few sectors, particularly chemicals.

Correlation analysis of sector composition of patent applicants further reveals that micro- and nanoelectronics and advanced manufacturing technologies show the most similar sector pattern (correlation coefficient of 0.93). In addition, patent applicants in industrial biotechnology and nanotechnology also tend to come from similar sectors (correlation coefficient: 0.79), which is also true for micro- and nanoelectronics and photonics (0.83). Interestingly, nanotechnology and advanced materials show a rather low correlation coefficient for sector shares (0.50). Rather low correlations of sector patterns are also found for micro- and nanoelectronics and advanced materials (0.49) and photonics and advanced materials (0.46). The most unsimilar sector patters appear for industrial biotechnology and micro- and nanoelectronics (0.33) and industrial biotechnology and photonics (0.34).

3.2.4 Sectorial patent activities by KETs

A second main output of the technology approach is the share of patents that organisations from a certain sector apply in the field of KETs. Table 3 shows this share, as well as the distribution of KETs patents by the six KETs areas. Only sectors for which a minimum threshold of 250 EPO/PCT patent applications in the period 2000 to 2010 has been met are reported in order to assure robust results. The results are based on the final definition of KETs through IPC codes as shown in Box 2 and the most recent version of the PATSTAT database.

The share of KETs patents in total patent activity of a sector rarely exceeds 50 percent. Highest shares of KETs patents (above 50 percent) are reported for three sectors with a rather small share in total output of KETs patents: manufacture of glass (NACE 231) and manufacture of basic iron and steel (241). Technological development in these sectors is very much focussed on new materials and more efficient process technology to manufacture these new materials. KETs shares in total patenting between 40 and 50 percent are reported for manufacture of electric lighting equipment (274), nanotechnology R&D (7212), manufacture of plastics (222), manufacture of non-ferrous metals (244), manufacture of optical instruments and photographic equipment (267), manufacture of basic chemicals (201) and manufacture of ceramic products (234). Most of these sectors focus on advanced materials except for the optical industry and the electric lighting industry, which both have the highest share of KETs patents in photonics.

Among the sectors with a high KETs patent activity (measured by the total number of patents applied, see last column of Table 2), only manufacture of basic chemicals (201) and manufacture of optical instruments and photographic equipment (267) also show a high share of KETs patents in total patent activity. Most other sectors report medium shares of KETs patents in their total patenting activity of about 20 to 30 percent, including manufacture of electronic components and boards (261), manufacture of consumer electronics (264), manufacture of electric equipment (271), manufacture of other special-purpose machinery (289), higher education (854) and other R&D (7219).

Table 3: Share of KETs patents by industrial sectors [a)] (based on initial KETs definition)

NACE rev. 2		Share of KETs patents	Patents by KET (percent of all KETs patents[b])					
			Industrial biotechnology	Micro- and nano-electronics	Advanced materials	Photonics	Nanotechnology	AMT for other KETs
108	Manufacture of other food products	14	66	0	12	0	1	20
110	Manufacture of beverages	31	28	19	19	0	3	31
120	Manufacture of tobacco products	5	23	0	32	2	13	30
131	Preparation and spinning of textile fibres	28	5	3	71	9	1	12
171	Manufacture of paper and paper products	13	1	8	56	15	2	18
172	Manufacture of articles of paper and paperboard	13	8	2	67	1	2	20
192	Manufacture of refined petroleum products	28	6	13	40	13	2	27
201	Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms	42	8	13	46	9	3	19
202	Manufacture of pesticides/agrochemical products	5	71	1	6	1	2	20
203	Manufacture of paints, varnishes, coatings, printing ink	39	1	2	77	3	6	11
204	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	10	6	4	59	4	10	17
205	Manufacture of other chemical products	32	2	22	28	30	4	15
206	Manufacture of man-made fibres	33	0	21	22	40	5	12
211	Manufacture of basic pharmaceutical products	28	60	0	3	4	3	31
212	Manufacture of pharmaceutical preparations	9	54	2	11	3	7	23
221	Manufacture of rubber products	28	1	7	65	14	2	13
222	Manufacture of plastics products	48	2	11	66	7	2	12
231	Manufacture of glass and glass products	61	1	13	48	22	2	14
234	Manufacture of other porcelain and ceramic products	40	0	21	43	3	5	27
239	Manufacture of abrasive/non-metallic mineral products	43	0	28	14	30	4	24
241	Manufacture of basic iron and steel and of ferro-alloys	54	0	8	50	3	0	38
244	Manufacture of basic precious/non-ferrous metals	46	0	11	49	3	2	36
256	Treatment and coating of metals; machining	4	0	12	48	8	12	20
261	Manufacture of electronic components and boards	31	1	42	8	17	4	28
262	Manufacture of computers and peripheral equipment	19	1	39	6	20	7	27
263	Manufacture of communication equipment	6	0	37	4	32	6	21
264	Manufacture of consumer electronics	25	1	32	4	42	3	18
265	Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks	23	7	25	9	22	6	30
266	Manufacture of irradiation, electromedical equipment	5	18	13	21	13	8	27
267	Manufacture of optical instruments/photographic equipm.	44	1	27	9	43	4	15
271	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus	21	2	31	18	20	4	25
272	Manufacture of batteries and accumulators	13	0	8	24	56	5	7
273	Manufacture of wiring and wiring devices	17	0	22	18	45	1	13
274	Manufacture of electric lighting equipment	50	0	22	3	69	2	5

275	Manufacture of domestic appliances	2	0	14	33	45	3	5
279	Manufacture of other electrical equipment	36	1	29	12	42	8	8
281	Manufacture of general-purpose machinery	15	2	21	47	1	4	25
282	Manufacture of other general-purpose machinery	13	2	25	13	7	5	48
284	Manufacture of metal forming machinery/machine tools	11	0	10	24	51	1	13
289	Manufacture of other special-purpose machinery	33	1	34	19	8	2	36
291	Manufacture of motor vehicles	7	1	25	29	19	4	22
293	Manufacture of parts and accessories for motor vehicles	11	0	34	16	25	4	21
303	Manufacture of parts and accessories for motor vehicles	11	0	21	20	38	4	16
304	Manufacture of military fighting vehicles	32	1	28	11	35	4	21
309	Manufacture of other transport equipment	5	6	19	12	7	12	44
325	Manufacture of medical/dental instruments and supplies	15	7	4	51	18	4	16
332	Installation of industrial machinery and equipment	17	1	26	21	20	5	27
351	Electric power generation, transmission and distribution	21	1	34	26	2	2	36
611	Wired telecommunications activities	2	1	10	6	73	6	5
620	Computer programming, consultancy and related activities	2	15	10	1	36	14	23
711	Architectural/engineering activities, technical consultancy	18	0	24	20	13	11	32
712	Technical testing and analysis	15	15	21	6	19	10	29
854	Higher education	28	20	17	13	13	15	22
861	Hospital activities	15	59	1	4	8	10	18
7211	R&D on biotechnology	25	43	5	6	5	9	32
7212	R&D on nanotechnology	49	4	17	19	11	31	19
7219	Other R&D on natural sciences and engineering	29	13	20	17	14	11	24
	Total (incl. sectors not shown above)	24	7	24	22	19	5	23

a) only NACE rev. 2 3-digit classes are listed for which more than 150 EPO/PCT patent applications in the period 2000 to 2010 have been recorded. - b) Sum adds to 100 percent. Patents that were assigned to more than one KET are counted several times.
Source: PATSTAT, ZEW calculations

This output of the technology diffusion approach –the sector composition of KETs patents for each KETs area as well as for the share of KETs patents in total patent activity per sector- can be valuable information when it comes to using weights for the significance of KETs activities for certain economic activities. Though the KETs shares derived from patent activity are subject to certain biases such as imperfect assignment of applicants to sectors, multi-sector activities of large applicants and patenting strategies of applicants that are deliberately outside the core technology areas of their sector, the information presented in Table 2 and Table 3 still reflect priority fields of technology of R&D and innovation activities in different sectors.

3.2.5 Main actors by field of KET

Table 4 lists - for each KET- the organisations that appear among the 15 largest applicants of KETs patents based on EPO/PCT patent applications in the period 2000 to 2010. Organisations appear with their current name. Patents of subsidiaries as well as patents of former subsidiaries and predecessor organisations that ceased operation meanwhile were consolidated to a total number of patent applications. For each organisation, four types of information are presented:

- the KETs area in which the organisation is among the top-15 patent applicants;
- other KETs areas in which the organisation shows a significant patent activity (of at least 25 percent of the number of patents of the 15th largest applicant in the respective KET area);

- country where the headquarters of the organisation is located;
- European countries in which major R&D or manufacturing activities are located (excluding the headquarters country in case of an organisation headquartered in Europe).

Table 4 presents the organisations with the largest number of KETs patents in alphabetical order containing a total of 57 different organisations. 23 organisations have their headquarters in Japan, 15 in the USA, 17 in the EU 27 (8 in Germany, 4 in France, 3 in the Netherlands, one in Denmark and one has joint headquarters in the UK and the Netherlands) and 2 in Korea.

Most of them are large companies while nine are research organisations or public organisations with a strong research focus (AIST, CEA, CNRS, Fraunhofer, JSTA, LAM Research, MIT, SEL, and University of California). For most of the large companies, KET-related activities represent only one of several business activities, and often KETs activities are only a minor part of their total business.

Table 4: Organisations with the highest number of patent applications in KETs

Name of organisation	Photo-nics	Nano-tech-nology	Industrial bio-technology [1)]	Advanced mate-rials	Micro- and nano-electronics	AMT for KETs [2)]	Head-quar-ters	Major R&D and production sites in Europe (excl. HQ country)
3M	X	X	X	X	o	o	US	BE, DE, ES, FR, IT, NL, PL, SE, UK
AIST	o	o	X	o	o	o	JP	-
Ajinomoto			X				JP	BE, FR
Applied Materials	o	o		X	X	X	US	
Asahi Glass	o	o		X	o	o	JP	BE, CZ, NL
BASF		o	X	X		o	DE	BE, CH
Bayer			X	X			DE	BE, ES
Canon	X	X	o	o	o	o	JP	DK, FR, NL, PL
Carl Zeiss	X						DE	CH, ES, FR, SE
CEA	o	X	o	o	o	o	FR	-
CNRS	o	X	X	o		o	FR	-
Corning	X	o					US	DE, FR
Dow				X			US	CH, DE, ES, NL
DSM			X				NL	AT, CH, DE, ES, FR, IT, UK
DuPont	o	o	X	X	o	o	US	BE, DE, ES, IT, NL, PL, SE, UK
Evonik		o	X	o			DE	AT, BE, ES, FR, HU, IT, NL, SK, UK
ExxonMobil				X			US	DE, NL
Fraunhofer	o	o		o	o	X	DE	-
Fujifilm	X	o		o	o	o	JP	NL
Fujitsu	o	X			X	o	JP	DE
General Electric		o		X	o	X	US	DE, IE
Hewlett Packard	o	X			o	o	US	UK
Hitachi	o	o		o	o	X	JP	-
Honeywell						X	US	CZ, DE, FR, RO, UK
IBM		o			X	o	US	CH, DE, IE, RO, UK
Infineon	o	o			X	o	DE	AT, HU, IT, NO, UK
Intel	o	o			X	o	US	AT, DE, FI, FR, IE, NL, UK
JSTA	o	X	X		o	o	JP	-
Kaneka			X	o			JP	BE, DE
Konica Minolta	X			o	o		JP	-

Name of organisation	Photo-nics	Nano-tech-nology	Industrial bio-technology. 1)	Advanced mate-rials	Micro- and nano-electronics	AMT for KETs 2)	Head-quar-ters	Major R&D and production sites in Europe (excl. HQ country)
LAM Research					o	X	US	-
LG	X			o	X		KR	PL
LyondellBasell				X			NL	DE, IT
MIT	o	X	o			o	US	-
Mitsubishi Chemical				X		o	JP	DE, IT
Murata					o	X	JP	-
NEC	o	X			X	o	JP	DE, UK
Nikon	X	o			o	o	JP	-
Novozymes			X				DK	DE, UK
Panasonic	X	X		o	X	X	JP	DE
Philips	X	X		o	X	X	NL	DE, UK
Robert Bosch	o	X			o	X	DE	AT, CH, FR, HU, IT, NL
Samsung	X	X			X	o	KR	DE, PL, UK
SEL	o				X	o	JP	-
Sharp	X	o			X	o	JP	FR, PL, UK
Shell			X				UK/NL	DE
Shin-Etsu				X	o	o	JP	DE, NL, PT, UK
Siemens	X	o		o	X	X	DE	AT, CH, ES, FR, HU, IT, NL, PT, UK
Sony	X	X		o	o	o	JP	BE, DE, ES, FR, HU, SK, UK
Saint Gobain	o			X			FR	BE, DE, ES, IT, PL, UK
STMicroelectronics					X	o	FR	BE, CH, CZ, ES, IT, MT, UK
Sumitomo Chemical	X	o	X	X		o	JP	BE, ES, FR, PL, SK, UK
Texas Instruments					o	X	US	FR, UK
Tokyo Electron				X	o	X	JP	-
Toshiba	o	o			X	X	JP	UK
Ulvac				o	o	X	JP	-
Univ. of California	o	X	X		o	o	US	-

X: among the top-15 patent applicants; o: significant patent activity (at least 25 percent of the number of patents of the 15th largest applicant in the respective KET area.

1) Excluding organisations that are exclusively engaged in the pharmaceutical or agro-chemical business.

2) Only organisations that manufacture and trade advanced manufacturing technologies.

Source: PATSTAT, ZEW calculations

A main finding is that 23 out of 57 listed organisations are among the top-15 patent applicants in more than one KET area. Three companies (3M, Panasonic and Philips) are in 4 KETs among the top-15, four are in three KETs areas in the top-15, and 16 are in two KETs areas among the top applicants. There is no clear pattern of combinations of KETs areas for those organisations that are in the top-15 for more than one KET. Most organisations that are top-15 ranked for only one KET area have significant patent activities in at least one other KET area. Only 9 organisations appear as among the top-15 in one KET area and do have no significant activities in any of the five other areas. Four of these organisations are from industrial biotechnology which shows that this KET tends to be less related to the five other KETs. This result is revealed by the fact that only three companies which are top-ranked in one of the five other KETs do also have significant activities in industrial biotechnology (and two of these organisations are large public research organisations). For all other five KETs areas, the number of non-top-15 organisations with significant patent activities in the respective area is between 16 and 27.

When looking at the main R&D and production sites within Europe, 12 non-European organisations do not have any major research or manufacturing activity in Europe (of which 6 are research organisations). The European country with the largest number of major R&D or manufacturing locations of main KETs actors (including the headquarters location of European-based organisations) is Germany (31), followed by UK (23), France (19), the Netherlands (16), Spain (12), Belgium and Italy (11 each), Poland and Switzerland (8 each), Austria (6), Hungary (5), Czech Republic, Ireland, Sweden and Slovakia (3 each), Denmark, Portugal and Romania (2 each), and Finland, Malta and Norway (1 each). One should note here that not all of these major R&D and production sites are necessarily engaged in KETs.

3.2.6 Robustness checks

A first robustness analysis investigates the validity of the identification of KET patents by the chosen list of IPC codes. For nine companies that are known to produce and commercialize some type of KET products in the fields of industrial biotechnology, nanotechnology, advanced materials, photonics or micro-/nanoelectronics, their patent portfolio was analyzed and classified to KETs11. The results (Table 5) show that for the majority of selected firms, their patent portfolio falls in relevant KET areas. SOITEC, a leadings producer of nanoelectronics materials, has 98 percent of all patents in KETs, with micro- and nanoelectronics and advanced materials as the dominating areas. For two companies in the field of photonics (Fagerhult and Oclaro), almost all patents were assigned to the field of photonics. Cambridge biopolymers, an industrial biotechnology company specialised on biopolymer, has three out of four patents in KETs, mostly in the area of advanced materials. VTI Technologies[12] is a producer of silicon-based sensors. Half of its patents are assigned to KETs while the other half relates to more complex sensor and measuring technologies which uses KETs, but are not KET technologies as such. For two other companies, Novozymes and SAES Getters, slightly less than half of their patents are classified as KET patents. However, this result is consistent as Novozymes, a leading industrial biotechnology company, has a strong focus on biotechnology solutions for agriculture and pharmaceutical applications, which both are not considered as industrial biotechnology in this study. SAES Getters is producing advanced materials in the area of metallurgy for a wide variety of application areas. Many of their patents that have not been classified as KET either relate to process technology for producing advanced materials and processing them in the manufacture of more complex products or to material technologies that are not considered as advanced materials in this study (e.g. gas purification).

[11] This robustness check was made for five of the six KET areas as Advanced Manufacturing Technologies covers process technology that is used to produce any of the other five KETs as defined in the definition of a KETs-based product. *A KETs-based product is: (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, but not limited to (c) produced by advanced manufacturing technologies. (EC Communication "A European strategy for Key Enabling Technologies – A bridge to growth and jobs').*

[12] This company was taken over by Murata at the end of May 2012 and is now Murata Electronics Oy.

Table 5: Patent activity by KET of firms with a strong focus on the production and commercialization of KETs

Company	Main KET activity	Total # of patents[1)]	Share of patents in (percent) Nano-technology	Micro-/Nanoelectronics	Industrial Biotechnology	Photonics	Advanced Materials	All other fields
Intrinsiq Materials	Nano-technology	63	0	0	0	0	6	94
SOITEC	Micro- and nanoelectronics	962	1	48	0	2	47	2
VTI Technologies		177	24	19	0	1	7	50
International Biodiesel	Industrial Biotechnology	1	0	0	0	0	0	100
Cambridge biopolymers		33	0	0	12	0	64	24
Novozymes		6,366	0	0	37	0	3	61
Fagerhult	Photonics	25	0	0	0	100	0	0
Oclaro		92	0	1	0	83	0	16
SAES Getters	Advanced Materials	1,944	2	9	0	5	28	56

1) Patent applications at national offices, EPO and through PCT, 2000 to 2010.

Source: CEA, Patstat, ZEW calculations

There are just two companies for which the patent assignment does not seem to work. One company, BioDiesel International, simply does not patent but focuses on commercialising purchased technology to produce bio-fuels. Intrinsiq Materials is a company fully specialised on a certain field of nanotechnology. Though all their patents relate to nanotechnology we could not assign a single patent of this company to nanotechnology because the company did not apply patents at EPO or through PCT, but primarily at the national patent office in the UK. The tag code for nanotechnology which is used to identify nanotechnology patents is available only for patents directly applied at EPO or which are forwarded to the EPO through a PCT application, however. This is no problem as long as only EPO/PCT patents are used (which is the case for the analyses in steps 1 to 3). As the present analysis also includes patents from national offices, the method used to identify nanotechnology patents does not work. But this does not underpin the method used for EPO/PCT patents.

The second group of companies with a focus on certain areas of KETs are companies engaged in separator and electrolyte technologies for batteries to be used in electric vehicles. Most of these companies are large, diversity corporations that applied many thousands patents over the past decade. Battery technology is only a marginal business for most of these companies. As a result, most of the companies' patent activities are outside of KETs (Table 6)[13]. A high share of KET patents is reported for Sumitomo Chemical, Samsung Chemical and Mitsui Chemical. All three companies are strongly engaged in the development of advanced materials, and Sumitomo has also some priority in micro-/nanoelectronics and in photonics. For four other large companies (Mitsubishi Chemical, Asahi Kasi, Ube Industries and TonenGeneral), the share of KET patents is between 39 and 45 percent, which is a high

[13] As no companies focused on Advanced Manufacturing Technologies appear in Table 6, we did not include a column on Advanced Manufacturing Technologies.

share given the large variety of products and business fields these companies are engaged in. For the two smaller companies in the list that are specialised on separator materials - Entek and Celgard - the share of KET patents is rather low (4 and 29 percent, respectively). In case of Entek, this is because this company focuses on cost-efficient production and global marketing of its core separator technology. Most R&D effort is to increase production efficiency rather than in further developing separator technology as such. The low share of KET patents for this company is thus correct and shows that firms focusing on the commercialisation of KET-based products will no longer be identified as producers of the underlying technologies, which is in line with the value chain approach we follow in this project. Celgard is a similar case as this company also puts much emphasis on the expansion of production capacity for separator material, a technology which initially was developed in the 1960s and since then has been further developed until the 1990s. Since most patents of Celgard refer to process technology, the low share of KET patents is consistent.

Table 6: Patent activity by KET of firms leading in separator and electrolyte technologies for advanced batteries

Company	Total # of patents[1)]	Share of patents in (percent)					
		Nano-technology	Micro-/Nanoelectronics	Industrial Bio-technology	Photonics	Advanced Materials	All other fields
Separator							
Entek	152	0	1	0	0	3	96
Celgard	286	0	2	3	0	24	71
TonenGeneral	1,714	0	1	2	0	38	59
Ube Industries	7,018	0	6	2	2	29	61
Sumitomo Chemical	5,360	0	14	4	14	27	40
Asahi Kasei	1,642	0	5	6	4	29	55
Electrolyte							
Samsung Chemical	149	1	1	7	5	47	40
Mitsubishi Chemical	4,963	0	8	5	8	27	52
Mitsui Chemical	2,284	0	5	5	8	44	39
BYD in-house	4,165	0	1	0	3	7	89

1) Patent applications at national offices, EPO and through PCT, 2000 to 2010.

Source: CEA, Patstat, ZEW calculations

A special case is BYD in-house which is a company that originally specialised in battery technology but later became a manufacturer of electric cars. Most of their patents now relate to car manufacturing, which is an important application area of KETs, but according to our KET definition, no KETs as such. **The low share of KET patents found for this company is therefore correct and thus does not devalue the chosen approach to identify KET patents.**

A second robustness check looks at the sectors of organisations which show a very high share of KET patents, i.e. organisations that focus in their technological activities primarily or entirely on KETs ('KET-focused' applicants). The vast majority of these organisations are engaged in advanced materials or micro/nanoelectronics, and many applicants have a focus in both KET areas. There is not a single 'KET-focused' applicant that has its priority in nanotechnology. This result mainly reflects that the absolute number of nanotechnology patents is much smaller than for any of the other four KETs, and that most nanotechnology patents are also assigned to another KET area (advanced materials, micro-/nanoelectronics or photonics). Applicants with some nanotechnology companies typically have much more other patents in one of the three related KET areas. There are a few 'KET-focused' applicants that patent primarily in industrial biotechnology. Most of them are dedicated biotechnology firms. There are more applicants with a significant share of photonics patents. Many of them show also significant patent activity in micro-/nanoelectronics and/or advanced materials. 'KET-focused' applicants with an exclusive focus on photonics typically come from the optical or lighting industries.

From the list of KET-focused patent applicants, one can calculate the sector composition of KET patents for this group of organisations (see Table 7). Since the list of KET-focused applicants includes only 120 different organisations, the number of different industry codes is smaller than for the main analysis on KET-sector links in step 1 to 3. Consistent with this main analysis, it is again companies from that manufacture basic chemicals (i.e. NACE 4-digit codes 2012, 2013, 2014 and 2016) and the manufacture of electronics and electronic equipment (i.e. NACE 4-digit codes 2611, 2620, 2630 and 2640) which contribute most. In advanced materials, 49 percent of all patents applied by KET-focused applicants come from companies in the basic chemicals sector. In the main analysis, this figure was 40 percent. For industrial biotechnology patents, their share is 61 percent (main analysis: 28 percent), for nanotechnology patents 17 percent (main analysis: 9 percent) and for micro- and nanoelectronics, photonics and AMT patents 20, 13 and 18 percent, respectively (main analysis: 9, 11 and 19 percent, respectively).

Manufacturer of electronics and electronic equipment account for 33 percent of all micro- and nanoelectronics patents by KET-focused applicants, compared to 40 percent in the main analysis. They also show a high share for photonics (35 percent), AMT (28 percent) and nanotechnology (22 percent).

Table 7: KETs patents by sector of KET-focused applicants

NACE rev. 2		Photonics	Nanotechnology	Industrial Biotechnology	Advanced Materials	Micro- and nanoelectronics	AMT
1920	Manufacture of refined petroleum products	1.0	0.6	0.7	1.0	0.8	0.3
2013	Manufacture of other inorganic basic chemicals	7.3	15.1	26.9	18.8	8.7	8.0
2014	Manufacture of other organic basic chemicals	1.2	1.5	10.2	8.0	3.1	4.1
2016	Manufacture of plastics in primary forms	4.4	3.3	24.0	22.7	5.1	6.3
2030	Manufacture of paints, varnishes, coatings, printing ink, mastics	1.5	0.3	0.3	1.1	0.6	0.6
2059	Manufacture of other chemical products	3.0	0.9	0.5	1.9	1.5	1.2
2311	Manufacture of flat glass	4.9	6.1	5.1	9.0	2.4	3.0
2344	Manufacture of other technical ceramic products	2.4	2.0	2.7	1.9	0.5	1.0
2410	Manufacture of basic iron and steel and of ferro-alloys	0.1	0.2	0.4	3.9	0.1	2.6
2442	Aluminium production	0.0	0.0	0.0	0.2	0.1	0.5
2443	Lead, zinc and tin production	0.0	0.0	0.0	0.8	0.2	0.5
2444	Copper production	0.0	0.0	0.0	0.8	0.2	0.5
2611	Manufacture of electronic components	6.2	12.7	0.7	5.0	19.8	17.6

NACE rev. 2		Photonics	Nanotechnology	Industrial Biotechnology	Advanced Materials	Micro- and nano-electronics	AMT
2620	Manufacture of computers and peripheral equipment	1.4	4.1	0.0	2.1	3.8	4.2
2630	Manufacture of communication equipment	2.2	1.5	0.6	0.6	1.4	1.0
2640	Manufacture of consumer electronics	25.2	4.1	1.4	1.4	8.0	5.5
2651	Manufacture of instruments for measuring/testing/navigation	0.5	3.6	0.1	0.3	2.8	1.1
2670	Manufacture of optical and photographic instrument	23.7	17.9	7.3	5.3	11.2	10.1
2731	Manufacture of fibre optic cables	1.0	1.1	0.6	0.5	0.7	0.8
2740	Manufacture of electric lighting equipment	1.0	0.5	0.0	0.0	0.8	0.2
2899	Manufacture of other special-purpose machinery	2.3	12.7	0.4	10.7	16.4	21.4
7219	Other R&D on natural sciences and engineering	5.6	9.5	17.5	2.4	7.0	6.2
9700	Activities of households	5.2	2.5	0.6	1.6	4.5	3.4
	Total	100.0	100.0	100.0	100.0	100.0	100.0

* Hirschman-Herfindahl-Index, calculated based on all NACE 3-digit codes.

Some relevant deviations from the main analysis are as follows: First, we find a high share of other special purpose machinery (NACE 2899) among the KET-focused applicants in the field of micro- and nanoelectronics. This is mainly due to a few manufacturers of equipment for producing semiconductors. For these companies, almost all of their patents are classified as micro- and nanoelectronics patents. This group represents a relevant share in all KET-focused applicants while their significance in the main analysis is limited. In addition, many KET-focused applicants come from the optical industry (NACE 2670) which has a share in total patents by KET-focused applicants of 12 percent, while the share of this sector is only 6 percent in the main analysis. **All in all, the analysis of KET-focused applicants largely confirms the results of the main analysis of the sector contribution to KETs patents.**

For the third robustness check, a text search in patent abstracts was conducted for the field of photonics and compared with the finding from the list-based approach to identify photonics patents (see box 2). Based on the initial text search algorithm shown in Box 3, the analysis revealed a rather small overlap between the photonic patents identified through IPC codes and the photonics patents identified by text search. Out of all photonics patents identified through IPC codes, just 20 percent were found by the text search. The text search identified a significant number of patents that were not assigned to photonics by IPC codes. Their number amount to 58 percent of the number of patents identified through IPC codes. When analysing these patents in more detail, it turned out that 35 percent were in fact not photonics patents. This group include technologies that apply photonics in more complex products such as medical equipment, machinery or electrical and electronics equipment. Another, smaller part of this group is patents on materials that may be used for photonic applications. A further 10 percent of the additionally found patents by the text search are patents on lighting and optical technology that is not regarded as part of photonics as a KET in this study. The remaining 55 percent were indeed photonic patents that were not found by the IPC-based method (which equals 20 percent of the initial number of photonics patents). Most of these patents belong to subclasses of technologies that are not photonics technologies as such. These subclasses typically represent the use of photonics technology in the context of other technology areas such as measuring and testing, semiconductors, computers, telecommunication and television. These subclasses have been added to the list of IPC codes to identify photonics patents.

Similar checks for other KETs could be used to further refine the list of IPC codes. One should be aware; however, that such a text search is only feasible for KETs that are based on a set of technologies that can be easily identified by distinct words or combination of words. This holds for photonics and micro- and nanoelectronics. For the other four KETs, text search is more difficult since the scope of technologies that need to be covered by a text search is much broader for advanced materials, industrial biotechnology, nanotechnology and AMT for other KETs. Text searches for these KETs would require a large effort to define and refine the text search algorithm in order to avoid false positives. The extent of refinement of the list of IPC codes based on text search results would most probably by quite limited. For micro- and nanoelectronics, a text search does not seem to be necessary since this technology can be easily identified through IPC codes that directly refer to micro- and nanoelectronics.

The text search result was also used to double-check the list of IPC codes in terms of entries that may not adequately represent photonics. For this purpose, the patents identified through IPC codes but not through text search were examined in more detail. It turned out that almost all of these patents were in core IPC classes of photonics and were correctly assigned to the field of photonics. Only for a few some sub-classes within IPC 4-digit photonics classes, we decided to exclude them because they referred to processes to manufacture photonics technology, to pure material technology or to rather conventional optical or lighting technology.

The fact that the text search did not find a large part of photonics patents points to a main shortcoming of the text search approach. In a complex field of technology such as photonics, patents can refer to very different individual technical inventions that may be described in patent abstracts with very different technological terminology. To cover all these patents by a text search would require to enlarging the key words to be searched for considerably beyond those we used in our search. However, using more key words will always result in an increase of false positives. This unavoidable trade-off limits the feasibility of text search approaches, particularly if one wants to cover patents from complex and diversified fields of technology. We therefore decided to retain the IPC-based approach to identify KET patents. This approach has the further advantage that it is less subject to changes in technology over time, whereas text search algorithms would have to be adjusted to changes in the technological dynamics in each field.

Summing up, the robustness checks did not provide evidence that the IPC code based approach of identifying patent activity in a certain KET is misleading or produces incorrect results. The deviations found between the main results (based on IPC codes) and the results of the robustness checks are rather minor and partially attributable to limitations of the approaches used for robustness checks.

3.3 Component approach

The aim of the component approach is to identify KETs components and companies active in the development and production of these components. The premise underlying the component approach is that products are made out of components, and whereas products may evolve rapidly over time, components in comparison develop and change at a slower pace. This is indeed a slight simplification/generalisation, as this may differ per technology and sector. After identification of components, companies can be linked to these components and an assessment of their economic characteristics can be made using available statistical information. The crucial element to this approach is the identification of components and associated companies. The following sections will provide insight in the compilation of the lists of components for all six KETs. The compilation of the list of companies is discussed in section 4.5.1. More detailed information on the component approach can be found in Appendix 6.

The initial identification of components is based on existing literature, web searches and experts views[14]. Two strategies have been pursued in applying this approach. With regard to industrial biotechnology and nanotechnology, we have focused on the identification of promising areas in these two KETs in order to check the feasibility of employing the component approach in emerging, new KETs areas. Initially, the consortium identified components and KETs-based products that are commercially available today and in the near future for industrial biotechnology and nanotechnology. In order to identify the companies, the consortium used the list of identified components and not the list of KETs-based products.

For micro- and nanoelectronics, photonics, advanced materials, and advanced manufacturing technologies we have departed from existing classifications/taxonomies in order to check the feasibility of using existing classifications for the identification of components, KETs-based products and companies. A proper taxonomy allows for the coverage of the entire technology field by means of a limited number of abstracted entries. It subsequently provides a powerful approach to map and retrieve unstructured data, in order to allow efficient solutions in the management of knowledge as it offers instant access to the right information within todays exponentially growing volumes of data. For the definition of different taxonomies, we rely on existing literature and experts' insights. For photonics for example, we build on the SPIE taxonomy. In order to identify the companies, the consortium used the list of identified components and not the list of KETs-based products.

Based on the identification of components, an initial list of PRODCOM codes, HS codes and companies involved in the development and production of these components has been compiled for each KET. These initial lists of PRODCOM codes, HS codes, and companies have been further refined (see section 4.3.1 and 4.5.1 for more information) and form the basis to calculate the indicators using existing databases. The component lists that are displayed in the next sections are not exhaustive and need to be further refined by technical experts. Figure 5 provides an overview of the different analytical steps taken in the component approach. **The component approach provides input for the calculation of the**

[14] We consulted scientific literature, next to foresight studies and reports published by diverse organizations such as European Commission, OECD, BMBF, DOE.

production, demand, trade and business indicators. In the following sections, the refined component approach is being discussed.

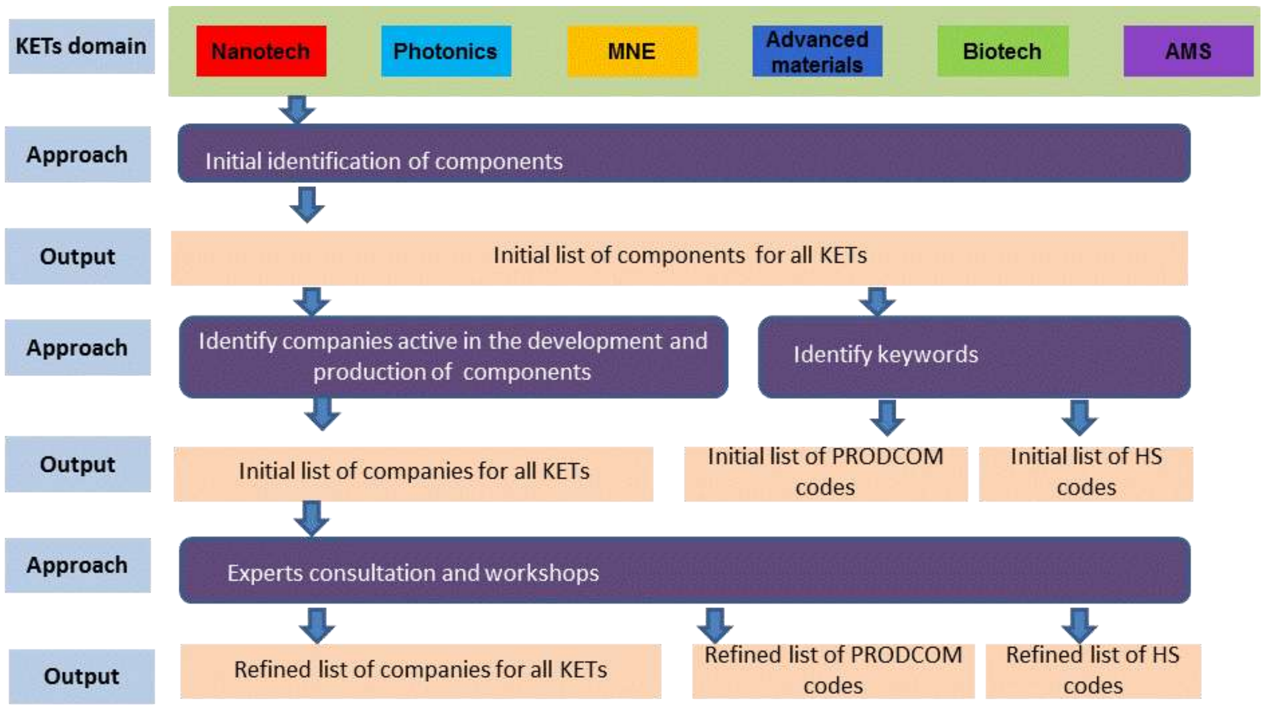

Figure 5: Overview of the different steps of the component approach

3.3.1 Industrial biotechnology

The European Commission has identified industrial biotechnology as one of the Key Enabling Technologies. The HLEG has defined industrial biotechnology as "*the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using micro-organisms or components of micro-organisms like enzymes to generate industrially useful products, substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide*[15]*.*"

Industrial biotechnology companies use life science techniques to find and improve nature's enzymes or develop diverse microbial systems – from bacteria, yeasts, and fungi to marine diatoms and protozoa – for use in industrial applications. A 2010 report from the World Economic Forum[16] notes that mandates for biofuel production around the world drive the market for biofuels, while economics and sustainability criteria drive the smaller market for renewable chemicals. Biorefineries are dedicated facilities that convert the sugars, oils and proteins derived from renewable biomass into biofuels, chemicals and

[15] HLEG, KET – Industrial biotechnology, June 2011

[16] King, D., Inderwildi, O. R., Williams, A., The Future of Industrial Biorefineries. World Economic Forum, June 2010.

materials such as plastics and polymers[17]. In 2004, the U.S. Department of Energy (DOE) conducted an initial screening and categorization of renewable chemicals that could be co-produced as side streams of biofuels and bioenergy[18]. The analysis yielded a list of 30 potential monomers with up to six carbon atoms that could be fermented from the sugars in biomass and serve as building blocks for more complex chemicals. In our analysis, we used the C1-C6 chemical building blocks as a basis to identify KETs-based products that are commercially available today and in the near future.

In addition, specialty and fine chemicals are included e.g. special fine chemicals, vitamins; and bio-based polymers. Also enzymes are included as due to recent advances in industrial biotechnology, it is now also possible to produce very specific enzymes with particular characteristics, which opens the way to some innovative and emerging applications. Table 8 gives an overview of several chemicals that are produced today or will be produced in the (near) future through the use of diverse industrial biotechnology techniques. These (bio) chemicals can be used as such, transformed via chemical or biochemical processes into other chemicals, or transformed into biopolymers. Initially, we identified components and KETs-based products that are commercially available today and in the near future for industrial biotechnology. In order to identify the companies, we used the list of identified components and not the list of KETs-based products.

Components	KETs-based product commercially available today	KETs-based product commercially available in near future
C1	methanol	formic acid
C2	acetic acid	lignocellulosic ethanol
	ethylene (from bioethanol)	glycolic acid
		ethyl acetate
C3	lactic acid	propylene (from bio-ethanol)
	1,2-propanediol (propylene glycol)	acrylic acid
	1,3-propanediol (pdo)	3-hydroxy-propionic acid
	ethyl lactate	n-propanol
	glycerol	isopropanol
C4	1-butanol	succinic acid
	isobutanol	isobutene
		1,4-butanediol
		methyl methacrylate
		3-hydroxybutyrolactone
C5	glutamic acid	itaconic acid

17 Erickson, B., Nelson, J. & Winters, P., Perspective on opportunities in industrial biotechnology in renewable chemicals, Biotechnology Journal, 2012

18 Werpy, T., Petersen, G., Top Value Added Chemicals From Biomass. Volume I: Results of Screening for Potential Candidates from Sugars and Synthesis Gas. Pacific Northwest National Laboratory (PNNL) and National Renewable Energy Laboratory (NREL), Aug. 2004.

Components	KETs-based product commercially available today	KETs-based product commercially available in near future
	xylitol	levulinic acid
		isoprene
		adipic acid
C6	citric acid	glucaric acid
	isosorbide	fdca
	sorbitol	adipic acid
		caprolactam
		furan dicarboxylic acid
special fine chemicals		shikimic acid
		quinic acid
		hyaluronic acid
		terpenes
polymers	polyhydroxyalkanoates (pha)	para-xylene
	polyhydroxybutyrate (phb)	
	dicaroxylic acids	
vitamins	vitamin C (ascorbic acid)	pantothenic acid
	vitamin B2 (riboflavin)	biotin
hydrolysing carbohydrates	glucoamylase	
	amylase	
	glucanase	
	betaglucanases and arabinoxylanases	
	alyloglucosidase	
	pullulanase	
	lactases	
	cellulose	
	pectinase	
	hemicellulose	
	xylanase	
		cellulosic enzyme cocktails
		thermostable cellulases
		low temperature, neutral ph cellulases and hemicellulases
		low temperature, alkaline ph cellulases and hemicellulases
	alpha-galactosidase	
hydrolysing proteins	protease	proteases
		cold-active proteases
	microbially produced rennine	

Components	KETs-based product commercially available today	KETs-based product commercially available in near future
hydrolysing lipids	lipases	lipases

Table 8: Overview of components and chemicals being produced today or in the near future in industrial biotechnology

3.3.2 Nanotechnology

Nanotechnology is a very diverse, naturally multidisciplinary cross-cutting concept that covers a wide range of developments from novel approaches for the development of new materials to structures with tailor-made unique properties[19]. Nanotechnology is fundamentally changing the way materials and devices will be produced in the future. The ability to synthesize nanoscale building blocks with precisely controlled size and composition and then to assemble those into larger structures with unique properties and functions will not only revolutionize segments of the materials manufacturing industry[20]

Obtaining a precise definition of the scope of nanotechnology is a non-trivial task. According to Roco, Mirkin and Hersam (2010) nanotechnology is the control and restructuring of matter at the nanoscale, at the atomic and molecular levels in the size range of about 1 to 100 nm, in order to create materials, devices, and systems with fundamentally new properties and functions due to their small structure[21]. The HLEG working group has applied the definition of nanotechnology from the BMBF: “Nanotechnology is the study of the controlling of matter on the nanoscale. Generally nanotechnology deals with structures sized between approximately 1 and 100 nanometre (10-9 metres) in at least one dimension, and involve developing materials, structures or devices within that size.”[22]

Within the context of the discussion on Key Enabling Technologies (KETs) the nanotechnology theme has a unique position as it is, de facto, a cross cutting KET for the other five defined KETs themes: micro and nanoelectronics; photonics; advanced materials; biotechnology and advanced manufacturing technologies[23]. As an “enabling technology”, nanotechnology is applied early on and a key element in the value chain, being used to realise smaller, quicker, more powerful, or more “intelligent” intermediates and systems components for products with significantly improved or even completely new functions[24].

The identification of components and KETs-based products is based on five key node areas as identified in the NANOfutures project[25]:

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[19] HLG KET Working Document on Nanotechnology, December 2010
[20] http://www.observatorynano.eu/project/document/1942/
[21] Nanotechnology Research Directions for Societal Needs in 2020
[22] Nano.DE report, Status Quo of Nanotechnology in Germany BMBF, 2009 http://www.bmbf.de/pub/nanode_report_2009_en.pdf
[23] HLG KET Working Document on Nanotechnology, December 2010
[24] http://www.bmbf.de/pub/nano_initiative_action_plan_2010.pdf
[25] http://www.nanofutures.eu/

1. Design, modeling and testing of materials
2. Nano-Micro scale manufacturing
3. Safety & Sustainability
4. Nanostructures & Composites
5. Nano-Enabled Surfaces

For each key node area, a group of high level experts has developed specific value chains and roadmaps within the NANOfutures project. The information obtained during this exercise is comprised in the tables below. In addition, web searches and available literature have been consulted. Some KETs-based products in nanotechnology are already available today, but many more KETs-based products in nanotechnology will become available in the near future. Table 9 gives an overview of components and KETs- based products in nanotechnology that are available today. This list is not exhaustive. Initially, we identified components and KETs-based products for nanotechnology. In order to identify the companies, we used the list of identified components and not the list of KETs-based products.

Components	KETs-based product available today
Metal-foam sandwich panel structures	Nickel and iron foams
	Aluminium foams (powder route)
	Aluminium honeycomb core
	Metal foam material
	Foams for electrical connections in high power circuits
	Porous cast aluminium
	Aluminium foams by powder-metallurgy
	Stable, light and multifunctional cellular materials
	Metcomb aluminium foam (liquid metal route)
	Aluminium foams
	Cast metal sponges with open cells
	Aluminium foam sandwich (AFS)
	Open cell metal foams of Nickel and Nickel alloys. Sheets and products
	Porous metals and porous metallic surfaces
	Composites Al foam + CFRP
	Aluminum Foam Sandwich (AFS)
	Tools for evaluation of cellular materials
Quantum dot systems for optoelectronics	Fluorescent semiconductor nano-particles
	CdTe luminescent inorganic nanocrystals
	Cryostats, scanning probe microscopy and attocube systems
	High-precision positioning devices
	Micro arrays imaging
	Semiconductor plasma detectors

Components	KETs-based product available today
	UHV thin film deposition
	Metal-Organic Chemical Vapour Deposition (MOCVD)
	Deep plasma etching systems
	High-performance quadrupole secondary ion monitoring devices
	Custom replicated mirrors and lenses
	Holographic diffraction gratings
	Diffractive optical systems
	E-beam, Ion-beam and Transmission Electron Technology
	Quantum cascade lasers
	Contrast-enhancing sample substrates (Surfs)
	Molecular beam epitaxy systems
	Low Energy Electron Diffraction (LEED)
	MEM (Mirror Electron Microscopy)
	RHEED (Reflection High Energy Electron Diffraction)
Carbon Nanotubes (CNT)	Single wall carbon nanotubes (SWNT)
	High purity single-wall carbon nanotubes
	Double wall carbon nanotubes (DWNT)
	Bundled thin wall and Herring bone nanotubes
	Multi-Walled carbon nanotubes (MWNT)
	short Multi Wall Nano Tubes (sh-MWNTs)
	Split MWNT
	arc-type multi wall nanotubes
	Functionalized nanotubes
	CNT Catalysts
	Modelling software for CNT
Polymers films	Silicone Elastomere films
	Ultra-thin film technologies
	Porous Polymers
	Printable Polymer-Based Memory Products
	Monomer & Polymer Adjuncts
	piezoelectric thin films
	Biodegradable Polymers
Nanoalloys and composites	Metal alloys
	Gas atomized metal powders
	Metal matrix nanocomposites
	Light alloys
	Cemented carbides
	High strength coppers

Components	KETs-based product available today
	Titanium powders for coatings
Microelectromechanical systems (MEMS)	Pressure related sensors
	Speed and oscilation sensors
	Silicon interposers
	Chemical sensors
	Biosignals sensors
	CMOS wafer MEMS
	Microfluidics MEMS
	Wafer tech
	MEMS Foundry
	Micro-filtration sensors
	Silicon based 3D-MEMS
	Encapsulation Tech
	Silicon etching
	Maskless lithography
	Fluidic Multi Chip Module technology
	Plastic-based MEMS
	Through-silicon vias (TSVs)
Micro fibres	Photonic crystal fibres
	Highly doped fibres
	Multi-mode optical fibre
	Laserinterferometric precision metrological instrumentation
	Titanium dioxide synthetic fibres,
Functional coatings	Self-Cleaning coatings
	Nanolayers - Optical Coatings
	Heavy Duty Coatings
	Doped coatings
	High temperature coatings
	Anti-static coatings
	Aerosol coatings
	Protective coatings
	Conductive coatings
	Sol-Gel-Coatings
	Nanoparticle stable dispertion coatings
	Spherical coatings
	Viscous coatings
Graphene bearing Nano Powders (GNP's)	Single-layer graphene
	Graphene Flakes and Graphene bearing Nano Platelets

Components	KETs-based product available today
Nano catalysts	Polyethylene catalysts
	Tetraethylammonium Hydroxide (TEAH) catalysts
	Catalyst micro reactors
	Split Plasma catalysts

Table 9: Overview of some components and KETs-based products of nanotechnology

3.3.3 Micro- and nanoelectronics

The European Commission has identified micro- and nanoelectronics (MNE) as one of the Key Enabling Technologies. The actual area of application is large. The micro and nanoelectronics Sherpa Team states: "*In all aspects of our connected lives, from the digital world to the green economy, micro and nanoelectronics act as the building blocks of products and services, which perform breakthrough functions in the home, in the office and in society in general*".

During the project, the EC has requested to limit the scope of MNE components to chips with within the framework of the feasibility study for the KETs Observatory. On the basis of an assessment of the ITRS roadmap 2012 and recent work done by the Eureka-Catrene programme, we have identified the following categorisation and corresponding selection of components: **1) System architecture**. This includes the different types of configuration of building blocks in electronic systems. Next, the individual building blocks that create the actual system can be divided into two categories: **2) Micro-processor units**, processing electronic signals; and **3) Computer memory**, storing data (see Figure 6).

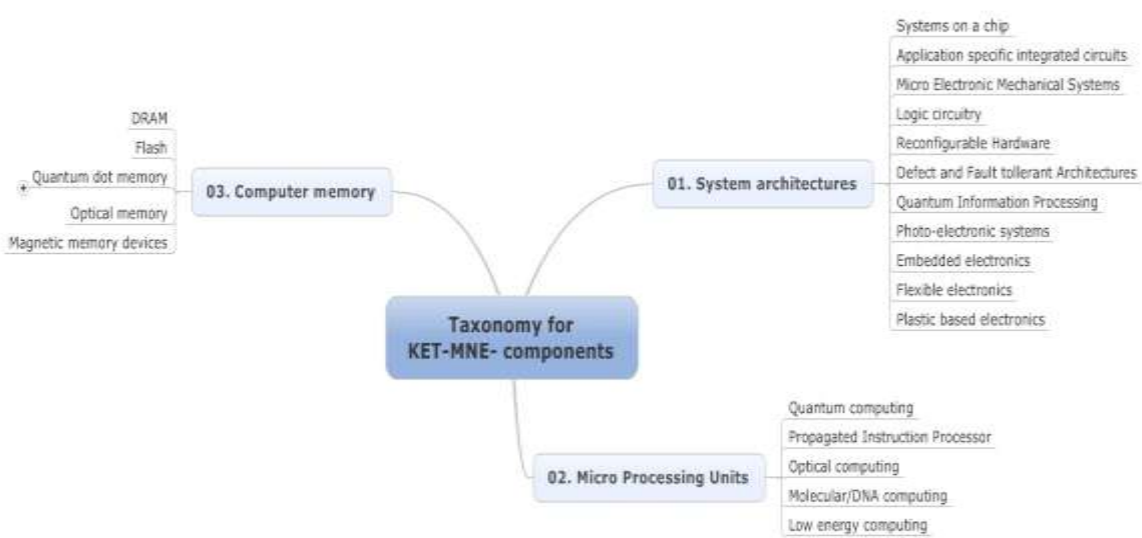

Figure 6: Components in micro- and nanoelectronics

3.3.4 Photonics

The European Commission has also identified photonics (PHOT) as one of the Key Enabling Technologies. The KET working group on photonics uses the following definition of Pierre Aigrain to demarcate the field of photonic technologies:

> *"Photonics is the science of harnessing light. Photonics encompasses the generation of light, detection of light, management of light, through guidance, manipulation, and amplification, and most importantly, its utilization for the benefit of mankind"*

This definition of photonic technologies is useful, however not yet suitable to demarcate the field of photonics KETs-based components. The KET working group did not further explore the definition, other than a description of possible fields of application. For our feasibility study into the set-up of a KETs Observatory, an existing taxonomy was adopted, developed by SPIE (Society of Photographic Instrumentation Engineers http://spie.org)[26]. The SPIE taxonomy has been developed originally for tagging publications. It is based on distinction between technologies and application fields and subsequently covers the complete technology field and its application domain. The SPIE taxonomy is a well-balanced overview of photonics components which is accepted and adopted by the actors in the technology field. Figure 7 provides an overview of the components and several applications areas based upon the SPIE taxonomy.

[26] This international society for optics and photonics was "[…] founded to advance an interdisciplinary approach to the science and application of light" (see http://spie.org).

Figure 7: Components in photonics

3.3.5 Advanced materials

Also advanced materials (AM) was identified by the European Commission as one of the Key Enabling Technologies. But it is not strange that the KET Working group on advanced materials starts it's working document with the phrase "The advanced materials domain is very broad and its boundaries are not clearly defined". Materials are perhaps the most applied domain of technologies within our society, as they are the building blocks of every physical product. Their solution to the demarcation issue is to describe aspects of the domain with examples, rather to provide a sharp definition. However, within this project this definition and demarcation is needed to filter the economic data and make the operationalization of the method possible.

The adjective of "advanced" provides some clues to further refine the definition. The UK Technology Strategy Board in 2008 defined advanced materials as "materials, and their associated process technologies, with the potential to be exploited in high value-added products, are both a multidisciplinary area within itself and cross-cutting over both technology areas and market sectors". In this project, we define AM-KETs-based products as follows:

> *Enabling products with strong economic, social and/or environmental benefits, where the use of advanced materials is crucial in their functionality. These new and innovative (advanced) materials show continuous development and are not yet in their final form of application.*

The KET Working Group on advanced materials uses a value chain approach, where they include research, manufacturing and use (B2B and B2C). They also conclude that the overlap with other KETs is strong. The definition used focuses on the KETs-based products where advanced materials are used.

The first step is to identify a systematic list of AM components and KETs-based products that can be used to identify companies. However, looking at the domain of advanced materials, hundreds or even thousands of AM-based product types are available on the market. This is the consequence of being present in several physical products.

However, the number of types of AM-components within those products is limited. Looking at the UK Technology Strategy Board report on advanced materials and other roadmaps (i.e. internal TNO reports) on advanced materials, a limited number of categories of components can be distinguished. Core to this approach are the different categories of functional materials. Looking at developments in materials, a first functional category are **1) Lightweight & ultra-strong materials**. A second category includes **2) materials that are capable to resist aggressive environments**. The third category shifts towards coatings and surface technologies and include **3) Surface materials and coatings**. The fourth category could be seen as core input to the KET MNE and include **4) Electronic and photonic materials**. The fifth category includes materials that are **5) Smart, multifunctional devices and structures**. A special category is included that is more environmental and biological: **6) Biomaterials**. The last category finds its core in the industrial applications, but also incorporates other materials not else mentioned: **7) Industrial and other materials**. Figure 8 provides an overview of the components for advanced materials.

Figure 8: Components in advanced materials

3.3.6 Advanced manufacturing technologies

The European Commission has identified advanced manufacturing technologies as a crosscutting additional Key Enabling Technology, that is of critical relevance to the other five KETs. This KET focuses on the development of the needed technologies and innovations that can be seen as a crucial driving force for the actual creation of the KETs-based products that are enabled in the other KETs. To illustrate the importance of manufacturing, around one in ten (9.8 %) of all enterprises in the EU-27's non-financial business economy were classified to manufacturing in 2009, a total of 2.0 million enterprises. The manufacturing sector employed 31 million persons in 2009, generated 5.812 billion Euro of turnover and 1.400 billion Euro of value added. By these measures, manufacturing was the second largest of the

NACE sections within the EU-27’s non-financial business economy in terms of its contribution to employment (22.8 %) and the largest contributor to non-financial business economy value added, accounting for one quarter (25.0 %) of the total (source: Eurostat). Furthermore, SMEs are the backbone of the manufacturing industry[27].

Advanced manufacturing technologies (AMT) has been defined by the HLG as:

> *“Comprising production systems and associated services, processes, plants and equipment, including automation, robotics, measurement systems, cognitive information processing, signal processing and production control by high-speed information and communication systems”.*

Hence, AMT are more concerned with new processes than new products. The HGL has provided a sound definition, even including an overview of important technologies. As a consequence, the component approach needs to be adjusted for AMT as it is not so much components and KETs-based products that can be identified with regard to AMT, but rather processes and services. However, this definition must be further made operational to filter economic data. Within the demarcation of AMT, the enabling character to the five KETs is of importance. However, there are some components that are applicable for manufacturing in general. So to further refine the characteristics of AMT, also a more generic approach can be taken keeping in mind the definition of KETs-based product.

Within the approach to analyse AMT components, the following methodological philosophy is used: The AMT KET plays a crucial role in the manufacturing of KETs components with specific processes and systems. After identification of these KETs-processes and systems, companies can be linked and an assessment of their economic characteristics can be made using available statistical information.

The first step is to identify a systematic list of AMT based processes and systems that can be used to profile the organizations. However, also in this KET, an overload of possible processes and systems can be seen, as AMT focuses on the manufacturing side of the industry. The demarcation of the KET AMT is made by limiting to the actual production of products and systems that are crucial to this production process: design, organization, internal logistics, quality control, maintenance and communication.

Looking at the other five KETS, the actual production can be divided into **Manufacturing technologies for micro-electronics and PV**, **(bio)Chemical process technologies** and more general **High performance manufacturing** directly used for production. The more supporting technologies and systems include **Modeling, design and simulation of products and processes**. A more “soft” part of the production system is **Innovations in the organization of the manufacturing process**. A crucial element of the manufacturing process is the use of **Advanced metrology and testing** in order to test quality and control of the manufacturing process. The AMT KET is completed by systems that focus on the **Maintenance and repair** of the manufacturing process[28]. Figure 9 provides an overview of the components linked to our suggestion for a definition on AMT.

[27] Factories of the Future 2020 Roadmap, Consultation document
[28] Sources: The future of manufacturing in Europe 2015-2020, Factory of the Future roadmap 2010, HLG report on AMT.

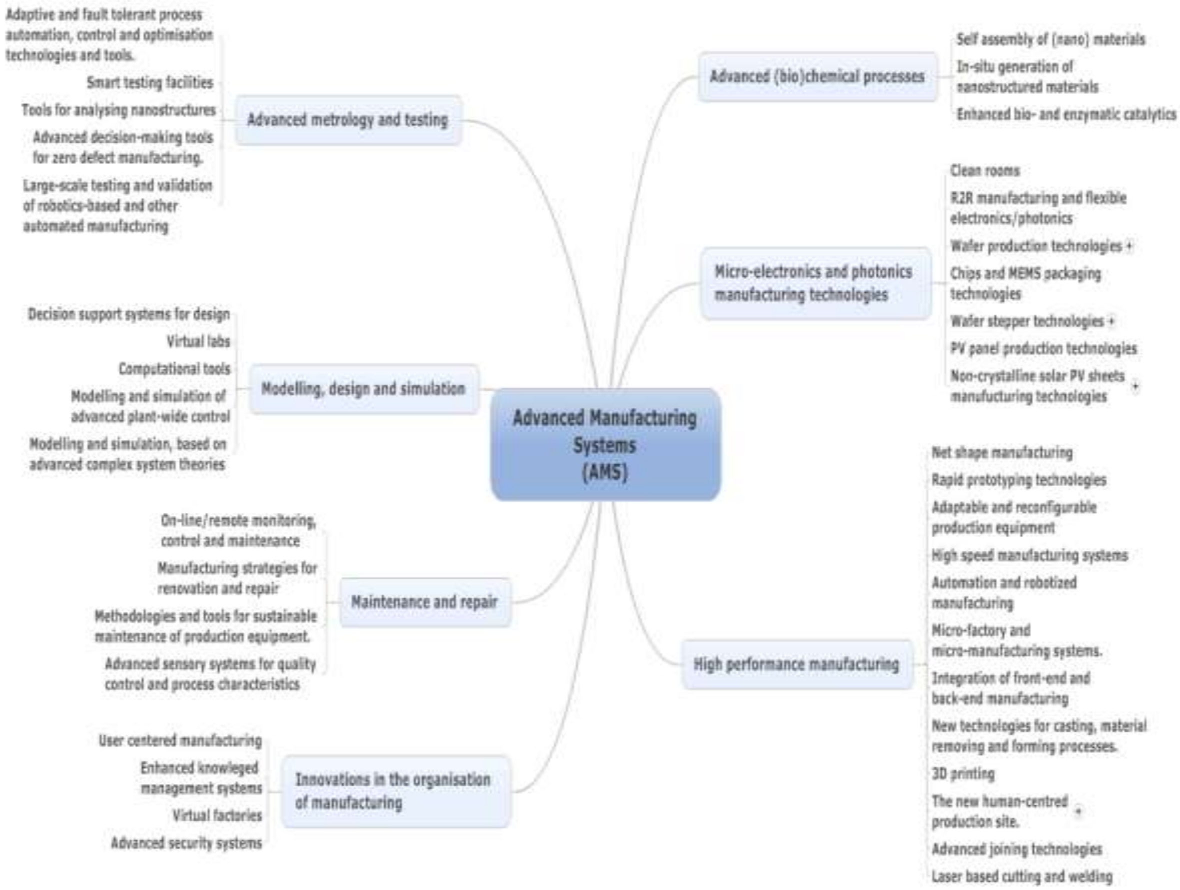

Figure 9: Components in advanced manufacturing technologies

3.4 Value chain approach

In the value chain approach a list of final products is established that depend *a priori* heavily on the development of KETs and are thus representative for measuring the success of the KETs deployment. This approach uses a right to left analysis of the value chain and consists in identifying the underlying patterns of these final products relying heavily on KETs technology. We believe that this approach is particularly suited to take into account the value creation induced by the innovative combination of KETs, thus the multi-KETs nature of specific final products. The approach aims to identify KETs components and KETs-based products, and to link them to companies involved in those technologies. These companies and components can then be used as an entry for the indicator framework. Figure 10 provides an overview of the different analytical steps taken in the value chain approach.

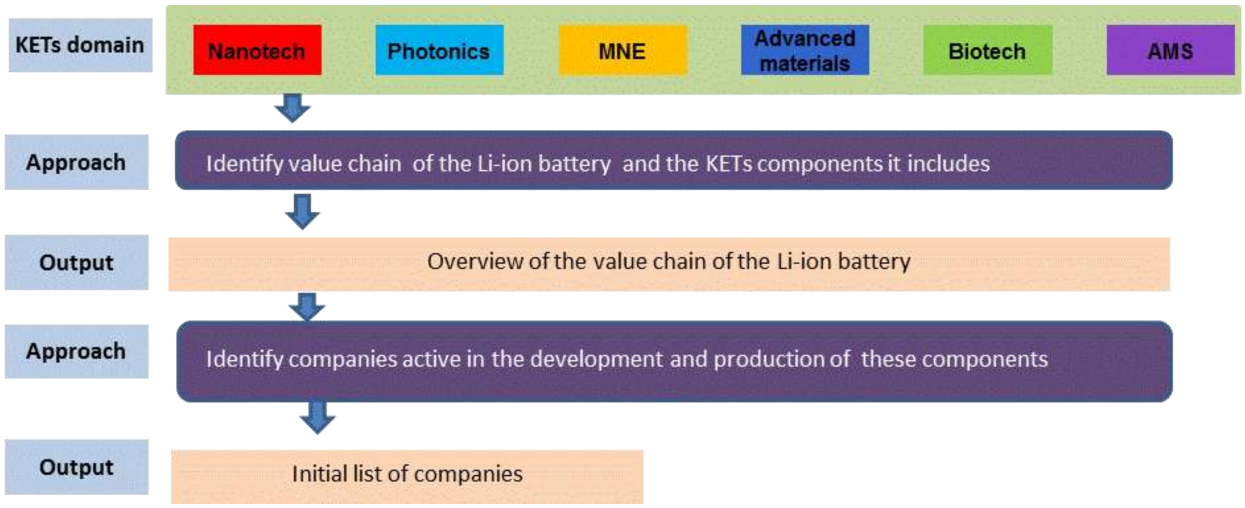

Figure 10: Overview of the different steps of the value chain approach

3.4.1 Choice of final product

The final product that was chosen for the scope of this feasibility study is the **full electrical vehicle**. There are a number of battery technologies that can be used in a vehicle (NiCd, NiMH, Li-ion, etc). In this study, the **Li-ion battery** has been selected as this is the current choice of the industry for the future battery electrical vehicle market.

3.4.2 Methodology and prerequisites

Three main steps have been followed to analyse the product "Li-ion batteries". The first step consists of interviews with technical experts at different points of the value chain. The main reason for doing so and for needing several experts is that the expertise required to develop the value chain for a final product is fairly different if one is looking at:

- The system level, trying to identify the subsystems part of the complete system,
- The manufacturing aspects which require knowledge on specific machinery and processes,
- The components of a subsystem which can be very specific requiring specialized skills,
- The materials involved in the different components which require the most specialised skills.

After this expert consultation, in a second step, market reports specialized for a given particular technology have been analysed, in our case the 19th Edition of the Battery Market Survey from Avicenne. The third and final step consists of linking all the acquired information to companies as for these companies, data from business databases such as OneSource can then be retrieved.

3.4.3 Building the value chain

The first step in building the value chain for the electrical vehicle was to list the subsystems included in this final product. Figure 11 is a representation of these subsystems. This list is non-exhaustive; it is a mix of existing subsystems and foreseen ones. The subsystems can be ordered in three categories, the ones participating in the generation of motion, the ones which aim at lowering cost and weight which are two aspects that heavily need to be improved and the ones necessary for building value added services.

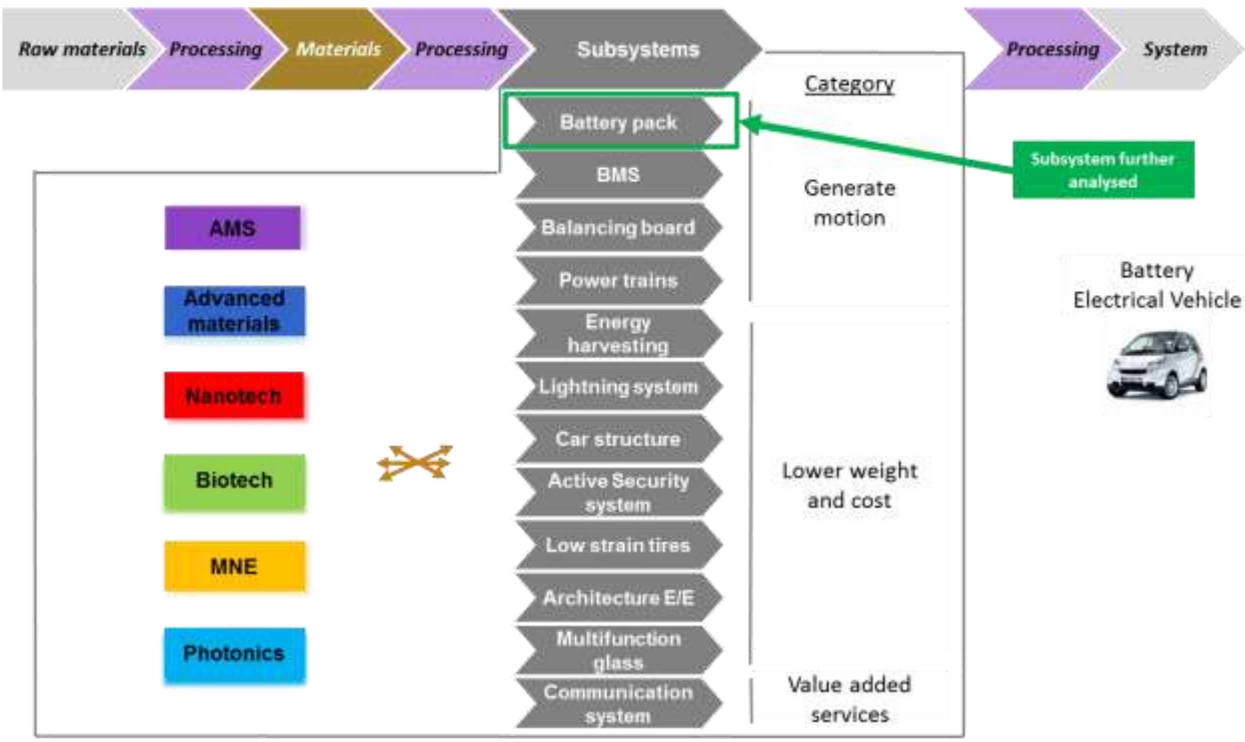

Figure 11: Subsystems of the electrical vehicle

All six KETs will be present in at least one of these subsystems of the electrical vehicle. Telling precisely which KET will be part of which subsystem requires a detailed analysis and this was done only for the Battery Pack as highlighted in the picture above.

Figure 12 present the value chain that was built for the Battery Pack subsystem. It is a complex chain that includes many manufacturing steps, intermediate subsystems (or components) and the integration of materials at different locations in the chain. Advanced manufacturing technologies and advanced materials are obvious KETs for the battery pack. What does not appear above is that some of the advanced materials can be based on nanotechnologies.

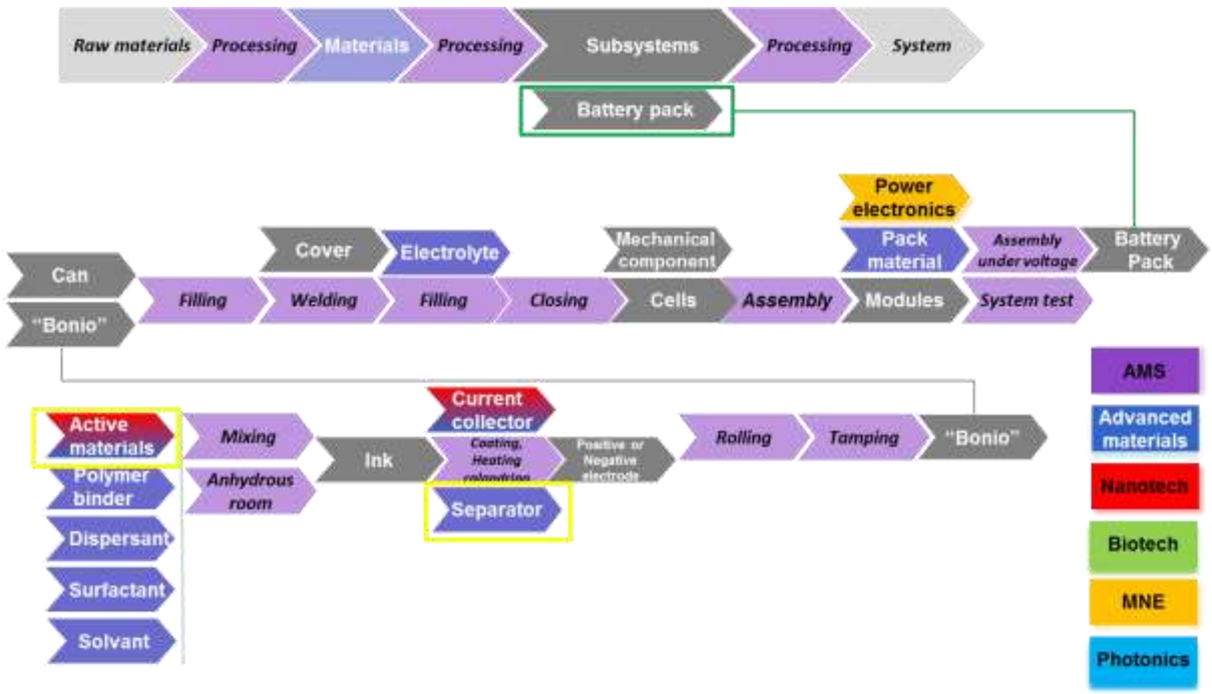

Figure 12: Value chain of the battery pack

3.4.1 Identifying key players for a particular KET

The last step taken into this approach was to look for leading companies worldwide for advanced materials identified in the value chain. The example of the separator was taken as shown in the Table 10.

Separator		
Company name	**Head quarters**	**Industry codes**
Entek	USA	Industry Electronic Instruments and Controls ANZSIC 2006: 2439 - Other Electrical Equipment Manufacturing NACE 2002: 3162 - Manufacture of other electrical equipment not elsewhere classified NAICS 2002: 335999 - All Other Miscellaneous Electrical Equipment and Component Manufacturing UK SIC 2003: 3162 - Manufacture of other electrical equipment not elsewhere classified US SIC 1987: 3699 - Electrical Machinery, Equipment, and Supplies, Not Elsewhere Classified

Celgard	USA	Industry Electronic Instruments and Controls ANZSIC 2006: 2439 - Other Electrical Equipment Manufacturing NACE 2002: 3140 - Manufacture of accumulators, primary cells and primary batteries NAICS 2002: 33591 - Battery Manufacturing UK SIC 2003: 3140 - Manufacture of accumulators, primary cells and primary batteries US SIC 1987: 3691 - Storage Batteries
Tonen	Japan	No data
Ube Industries	Japan	Industry Chemicals - Plastics and Rubber ANZSIC 2006: 1821 - Synthetic Resin and Synthetic Rubber Manufacturing NACE 2002: 2416 - Manufacture of plastics in primary forms NAICS 2002: 325211 - Plastics Material and Resin Manufacturing UK SIC 2003: 2416 - Manufacture of plastics in primary forms US SIC 1987: 2821 - Plastics Materials, Synthetic Resins, and Nonvulcanizable Elastomers
Sumitomo Chemical	Japan	Industry Chemical Manufacturing ANZSIC 2006: 1812 - Basic Organic Chemical Manufacturing NACE 2002: 2414 - Manufacture of other organic basic chemicals NAICS 2002: 32511 - Petrochemical Manufacturing UK SIC 2003: 2414 - Manufacture of other organic basic chemicals US SIC 1987: 2869 - Industrial Organic Chemicals, Not Elsewhere Classified
Asahi Kasei	Japan	Industry Chemical Manufacturing ANZSIC 2006: 1812 - Basic Organic Chemical Manufacturing NACE 2002: 2414 - Manufacture of other organic basic chemicals NAICS 2002: 32511 - Petrochemical Manufacturing UK SIC 2003: 2414 - Manufacture of other organic basic chemicals US SIC 1987: 2869 - Industrial Organic Chemicals, Not Elsewhere Classified

Table 10: Key players for separator

This table was built using data from a market research from Avicenne (19th Edition of the Battery Market Survey) and looking into OneSource for information on each company.

It is to be noticed that the NACE codes identified for those firms are not homogenous. This is mainly due to the fact that NACE codes are attributed in accordance to the main activity of a firm which can be quite different for firms which all produce separators. There are also several separator types and that can also explain the diversity of codes. This shows the limitations of using NACE codes. The Consortium has therefore opted to use databases that contain data on a more detailed level (PATSTAT, PRODCOM, UN COMTRADE, and AMADEUS; for more information see section 3.1).

3.4.2 Conclusion of this approach

The output of this approach is:

- A list of sub-systems that constitute the final product
- A detailed value chain for one subsystem
- A list of KETs components and KETs companies and manufacturing steps along this value chain

The main benefit of this approach is that it is very accurate in identifying KETs components and KETs companies. However, it is time consuming and identifying a representative number of KETS components and KETs companies would require running the approach for a large number of final products and their subsystems. We understood in the scope of this feasibility study that the effort of using the approach for setting up the KETs Observatory would be too high and too costly.

We identified that it would be valuable to use the approach (within the scope of the feasibility study) as a source of information for conducting sanity checks for the other approaches. For example, we could verify that six out of seven companies listed in Table 10 are present in the list of companies that is the output of the technology diffusion approach. This implies that the accuracy of the technology diffusion approach is very good. In addition, we checked if all advanced materials and advanced manufacturing technologies that were identified for the battery pack (see Figure 12), were included in the components identified for advanced materials (see Figure 8) and advanced manufacturing technologies (see Figure 9), which was the case. In general, we conclude to not recommend using the value chain approach for setting up the KETs Observatory.

3.5 Expert approach

In order to diversify our approach towards the set-up of a monitoring system for Key Enabling Technologies, the possibility of collecting data “bottom-up”, from “actor level” in the value chain has been analysed. More specifically, the possibility of collecting information from the actors in the innovation system is assessed in order to generate relevant KETs-related deployment data. This approach focusses on the actual collection of information from industrial actors as a basis to compile representative and consistent data on the deployment of KETs. This approach has not been used to verify the outcomes of the other approaches.

Concerning the possibility of collecting data on actor-level (i.e. the bottom-up approach), we conclude that: [29]

- Industrial actors are reluctant to share information which could provide/reveal insight in their market position or strategy if confidentiality and anonymity are not guaranteed.
- Actors in the value chain in general do not classify their activities (e.g. production) according to specific technologies (such as KETs). It is subsequently difficult to link indicators to KETs, but it does not seem unfeasible.
- The actors in the value chain are very much interlinked with regard to their development and production. This complicates the collection of relevant information on component-level. As an example, ASML (as the main actor in the value chain of lithography systems for the semiconductor industry) is part of (leads) a cluster of 200 companies, which all have a role on the value chain of chip-producing machines.
- In general, the predominant development strategy of high-tech (such as KETs) end-producers is to outsource the R&D for components to actors to their left in the value chain. Collecting data (on for example research and innovation) for a specific KETs-based product subsequently requires collecting input from all actors involved.
- The actors in the value chain (especially the international actors) have a good knowledge of/insight in the characteristics of the market they operate in (especially those on the left of the value chain, providing essential elements in the production process). They are however reluctant to share/disclose this information.

Because of the problems with "bottom-up" data collection it was decided to first pursue the other approaches described previously in this report. In consultation with the Commission, it was decided not to pursue this particular approach as the other approaches allow obtaining relevant data in a more straightforward way. Note that we reject consultation of experts only for the direct collection of primary data. We do embrace consultation of experts as a way to validate important steps in the process of data gathering, as well as for the validation of indicators and their values (see next chapters).

[29] For our interviews with the knowledge infrastructure we contacted the following TNO experts: Nils Erkamp and Anton Duisterwinkel. For our interviews with representatives from the main industrial actors involved in the production of the KETs-based products we approached the three prominent actors in the Netherlands (i.e. ASML, Philips Research Healthcare and Siemens Healthcare (Nederland)). In order to verify our approach, and our conclusions and recommendations concerning our findings, we have also been in contact with representatives from the Dutch National Statistics Office (CBS): Ruurd Schoonhoven, Andries Kuipers and Hen van de Bosch.

4 Indicators on KETs deployment

4.1 Indicator framework

The different approaches can be used to identify KET-related economic activities in existing statistical information systems and to derive indicators on KETs deployment of countries over time from these statistics. These indicators can give a better understanding of the deployment of KETs. For this purpose, KET-related activities are linked to existing classifications that are used in conventional statistics.

The first approach, the technology diffusion approach, aims to determine the economic sectors of organizations that are engaged in the development and exploitation of new technologies in the field of KETs using patent data. The first output of the technology diffusion approach is a sector breakdown of applicants of KETs patents. A total of 29 different 3-digit sectors (out of 272 individual 3-digit codes present in NACE rev. 2.0) represent about 96 % of all KETs patents. Summing up across all six KETs, the chemical industry (201 to 205) and the electronics industries (261 to 264) appear as the two single most important industries for producing KETs. The second output of the technology approach is the share of patents that organisations from a certain sector apply in the field of KETs. These outputs provide valuable information when it comes to using weights for the significance of KETs activities for certain economic activities. The third output of this approach is a list - for each KET- of the organisations that appear among the 15 largest applicants of KETs patents based on EPO/PCT patent applications in the period 2000 to 2010.

This list of IPC codes will be used to calculate technology indicators for each KET. The results of the KET-to-sector matrix (see Table 2 and Table 3) are used as an input for the calculation of production indicators and trade indicators based on a first approach to classify KETs components using PRODCOM (classification of goods used for statistics on industrial production in the EU) and HS (Harmonized Commodity Description and Coding System) classifications. In addition, the list of 'KET-focused' applicants is used as an input for establishing a list of companies that are strongly engaged in the development, production and commercialisation of KETs.

The component approach has the aim to identify lists of components as these lists can then be used to identify companies and keywords in order to link these keywords to existing classifications such as PRODCOM and HS[30]. In matching the keywords to the PRODCOM and HS codes, we noticed that a lot of PRODCOM and HS codes were selected. For example, in case of nanotechnology, more than 500 PRODCOM codes were selected. As the selected lists of PRODCOM and HS codes are too extensive, expert validation has been used to further refine the lists.

The output of this approach is a list of components for each KET, a list of companies engaged in developing and producing these components, and a preliminary list of relevant PRODCOM and HS codes. The latter lists are subsequently used to extract data from the PRODCOM and UN COMTRADE database.

[30] Initially, the consortium identified components and KETs-based products that are commercially available today and in the near future in the component approach. In a subsequent phase, the consortium decided to focus on the list of components to identify an initial list of companies, PRODCOM and HS codes.

The data obtained from the PRODCOM database serves as an input for the calculation of production and demand indicators, while the data from the UN COMTRADE database is used as input for the calculation of trade indicators. Finally, the list of companies serves as an input to calculate the business indicators. The list of companies derived from the component approach has been merged with the list of companies of the technology diffusion approach in order to come to one initial list of companies. These initial lists of companies have been enhanced through consultation of internal and external experts (see section 4.5.1 for more detailed explanation). The refined lists of companies serve as an input to calculate the business indicators.

The value chain approach is the most exhaustive approach. This approach allows identifying all components, KETs-based products and companies involved in a well-chosen end-product. The disadvantage of this approach is that it is quite time consuming and thus restricted to a few product examples. Hence, this approach is used for a sanity check of the technology diffusion and the component approach. For example, we could verify that six out of seven companies listed in Table 10 are present in the list of companies that is the output of the technology diffusion approach. This implies that the accuracy of the technology diffusion approach is very good. In addition, we checked if all advanced materials and advanced manufacturing technologies that were identified for the battery pack, were included in the components identified for advanced materials and advanced manufacturing technologies, which was the case. The value chain approach hence does not provide direct input for the calculation of deployment indicators.

The expert approach as a bottom-up approach to collect data on an actor-level has not been pursued. Hence, this approach does not provide input for the calculation of deployment indicators. Experts have been used to refine and validate the lists of PRODCOM codes, HS codes, and companies.

The technology diffusion and the component approach provide the input necessary to obtain KETs relevant data from existing databases. This data can then be used to calculate indicators that provide insight in the deployment of KETs. This results in an indicator framework as presented in Figure 13. For technology and trade indicators, a EU27 aggregated value has been calculated to allow for a comparison with other countries such as the US, China, Japan and South-Korea. The indicators are explained in more detail in the next sections.

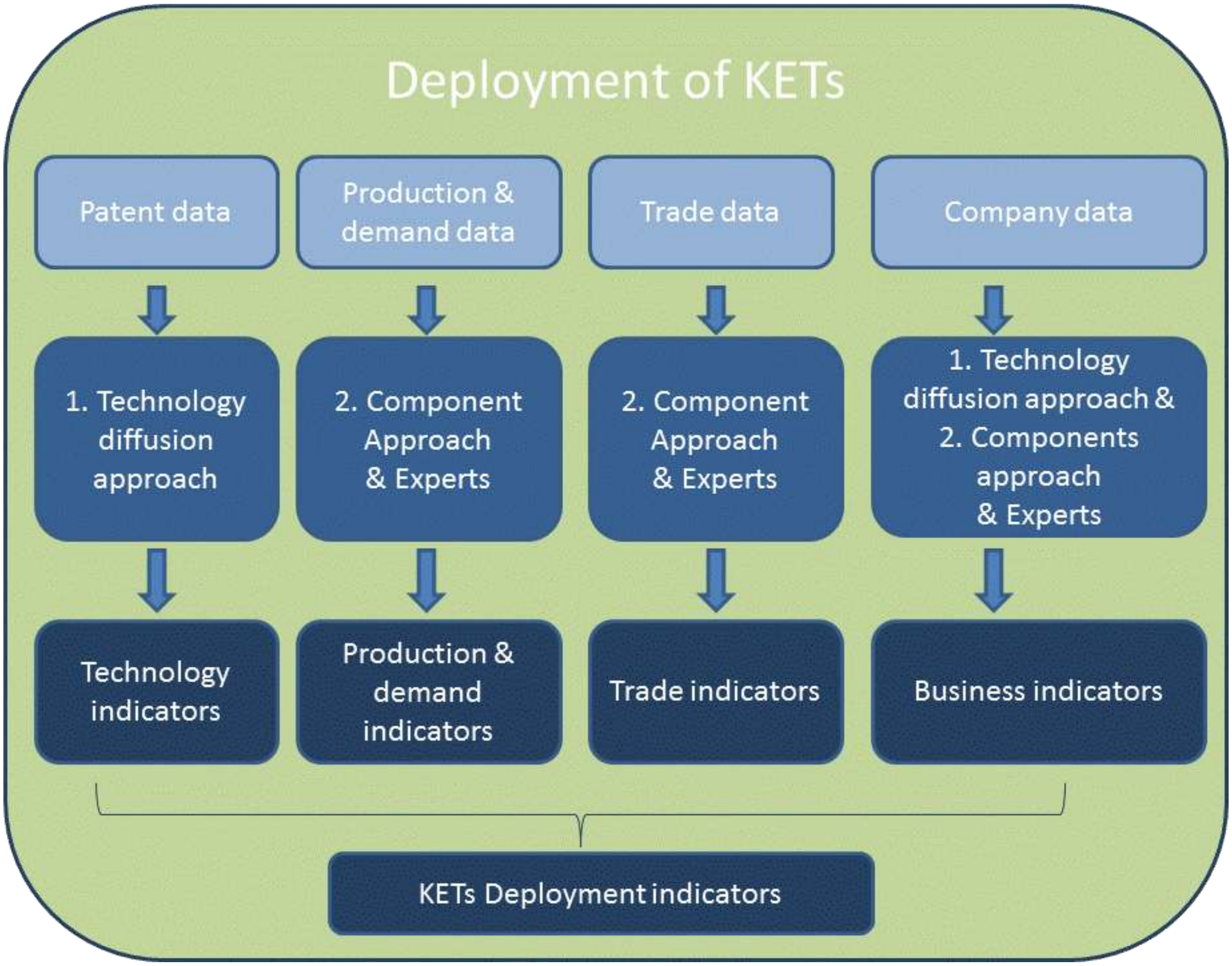

Figure 13: Indicator framework

4.2 Technology indicators

4.2.1 Data input and calculation

Technology indicators are intended to capture the performance of countries in producing new technological knowledge in the field of KETs that is relevant for industrial application and commercialisation. Patent data are the best data source on such activities for several reasons: they are readily available through the PATSTAT database of EPO which covers patent activities globally at low costs, they are internationally comparable, they are available for all countries and a long time series, they can be broken down by regions (based on the place of residence of inventors), and they can be easily assigned to fields of technology through the use of IPC (International Patent Classification) codes which are assigned to each patent. Though there are various shortcomings of patent data resulting, among others, from different patent regulations by country, strategic patenting of companies, a high variation in the economic value of individual patents, and the fact that not all new technological knowledge is patented, this data source has been chosen in the absence of any better suited information that allows a continuous, up-to-date[31] comparison of technological performance across countries and fields of technology for a regular monitoring system.

For the KETs Observatory, patent applications at the European Patent Office (EPO) and through the so-called Patent Cooperation Treaty (PCT procedure) at the World Intellectual Property Organisation (EPO/PCT patents) are considered only because they are best comparable across countries. Patent application data are preferred over data on granted patents because of the higher punctuality of application data. While patent applications are disclosed 18 months after the date of application, information on granted patents is often available only several years after application date. The use of application data does not affect the quality of the results since the vast majority of patent applications at EPO and through PCT are granted, and there is no systematic bias between applications and grants at the level of technologies, countries or over time (see Section 3.2.2 for more details).

EPO/PCT patents are assigned to countries based on the location of the applicant. In case a patent has applicants from more than one country, fractional counting is applied. The applicant can either be an enterprise, a public organisation, a non-profit organisation (such as universities or public research institutes) or a private individual. We choose applicant location instead of inventor location for country analysis since it is the applicant that is most likely to deploy and commercialise new technology. Note that most of large, multinational corporations apply patents developed at foreign subsidiaries under their subsidiary organisations (which are legally independent enterprises). In total, 43 different countries are considered (EU 27 as well as US, Japan, South Korea, China, Taiwan, Canada, Switzerland, Brazil, Norway, India, South Africa, Russia, Israel, Croatia, Iceland and Singapore).

For regional analysis on NUTS 3 level, we apply a different approach and use the location of inventors (and not the location of the applicant) since this best informs about the regional origin of the new technological knowledge underlying a patent application. Though locations of applicants and inventors tend to be similar the results will differ particularly for large organisations which conduct R&D outside their headquarters location. Regional information is available for EPO patents only since inventor information in PCT patents is often missing.

Patents are assigned to KETs using a list of IPC codes (see Box 2 in section 3.2.1). Patents that are assigned to more than one KET are counted as one patent for each KET. Each patent is allocated to the year of its priority date. In order to determine a patent's priority date, patent family information is used. This means for instance that a patent that was first applied at a national patent office and has later been transferred to EPO or PCT will be assigned to the year of the priority date of the initial application at the national office.

The PATSTAT database of EPO is used to calculate technology indicators. Figure 14 provides an overview of the different steps taken to calculate the technology indicators.

[31] Patent applications are only disclosed 18 months after the date of application.

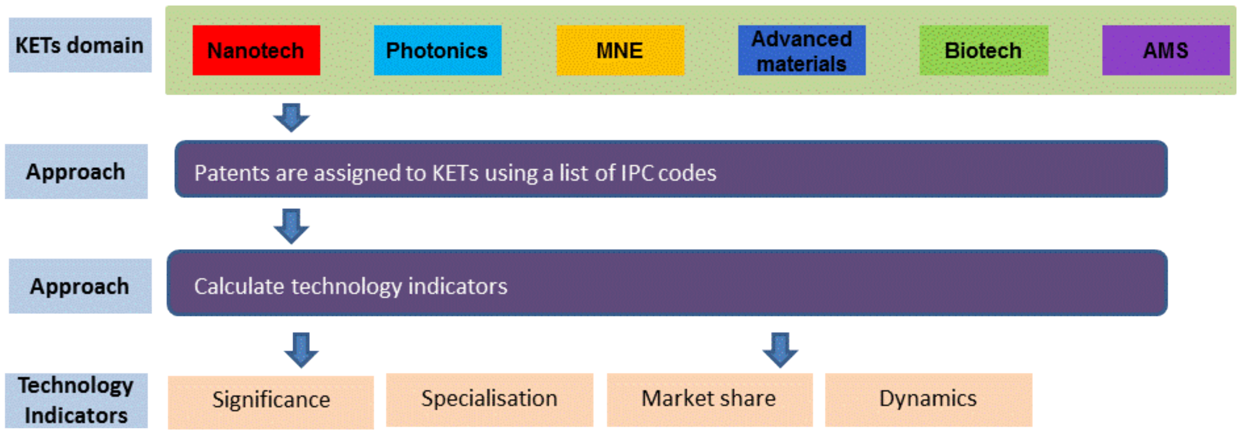

Figure 14: Overview of the different steps taken to calculate the technology indicators

Four technology indicators are used in the KETs Observatory to capture a country's performance in the production of new technological knowledge in each KET area. The indicators represent significance, specialisation, market share and dynamics.

The share of a certain KET in total patenting activities of a country informs about the **significance** of this KET in a country's technological portfolio. A high value indicates that the country dedicates a substantial share of its resources into the respective KET. The indicator is defined by the number of patent applications in a certain KET area divided by the total number of patent applications across all fields of technology and is calculated for each country separately.

- Significance (*SG*) of a certain KET *k* in total patent activities (T) of country *i* in year *t*: $^{T}SG_{kit} = T_{kti} / T_{it} * 100$

Another indicator refers to **specialisation** and relates the significance of a certain KET in the country considered to the average significance of that KET in all countries[32]. The indicator thus tells whether a country puts more or less focus on this KET than other countries does. As the indicator relates two shares, it can be subject to extreme values, particularly if the average significance of a KET is very low but a few countries invest quite a lot in developing new technical knowledge in that KET. In order to trim extreme values, we take the natural logarithm (ln) of the relation of the two shares.

- Specialisation (*SP*) of country *i* on the production of patents in a certain KET *k* in year *t* measured by revealed technological advantage (i.e. the significance of a certain KET in a country's total patent activity over the significance of that KET in global patent activity): $^{T}SP_{ki} = ln\ [(T_{kit} / T_{it}) / ((T_{kt} / T_{t})] * 100$

[32] "All countries" include all countries of the world, and not just the 43 countries considered for this study.

The **market share** of a country in total production of patents in a certain KET area indicates the relevance of that country in the respective technology market. This indicator, in contrast to the other indicators used, is strongly influenced by the size of a country as larger countries are more likely to produce more patents than small countries. The indicator is measured by dividing the number of patent applications of a certain country by the total number of patent applications in the respective KET area.

- Market share (*MS*) of country *i* in the global[33] output of patents for each KET *k* in year *t*: $^{T}MS_{kit} = T_{kit} / T_{kt} * 100$

Finally, the **dynamics** of patent activity shows whether a country is on an upward or downward trend. One technical challenge for producing meaningful dynamics data based on patent applications refers to the often very small absolute number of applications per KET in smaller countries, which can lead to very high rates of change while the change in absolute numbers is low. In order to avoid extreme values for the dynamics indicator, only medium-term dynamics is considered, i.e. the change in the number of patent applications between two multi-year periods. In addition, the rate of change is weighted by a country's share in the total (positive or negative) change in the number of patent applications per KET between the two periods.

- Medium-term dynamics (*MD*) in the production of KET patents measures the rate of change in the number of patent applications between two periods *p-1* and *p (p-1* represents 2000-04 and *p* 2005-09) weighted by a country's share in the dynamics of patenting between p-1 and p across all countries considered[34]: $^{T}MD_{kip,p-1} = (T_{kip} - T_{ki,p-1}) / (T_{ki,p-1}) * (|T_{kip} - T_{ki,p-1}| / |T_{kp} - T_{k,p-1}|) * 100$

4.2.2 Output

The technology indicators provide complete data on technology performance by KETs for all countries of the world for each year of the period covered, which is 2000 to 2009)[35]. The output of the technology indicators can be consulted at the KETs Observatory website (https://webgate.ec.europa.eu/ketsobservatory/[36]). In order to illustrate the output, the four indicators are presented for two KETs, nanotechnology and for advanced materials. The first three indicators refer to the average for the 2000 to 2009 period, while the forth indicator on dynamics represent the change in patent activity between 2000-2004 and 2005-2009.

The significance indicator reports the share of patent applications in a certain KETs in a country's total patent applications across all technologies (KETs and non-KETs). Figure 15 shows the indicator value for

[33] „Global"refers to all countries of the world and not just the 43 countries considered for this study

[34] Alternatively, one could calculate medium-term dynamics simply by a not-weighted rate of change: $^{T}MD_{kip,p-1} = (T_{kip} - T_{ki,p-1}) / (T_{ki,p-1})$. However, this simple rate of change can be subject to extreme values, particularly for countries with a very low number of patents per KET and period. We therefore recommend using the weighted rate of change, though the interpretation of the values is not straightforward.

[35] For the analysis in Section 3.2, patent applications up to 2010 were considered. Since data on 2010 applications were not complete at the time of writing this report (due to a time lag between the priority date of a patent and an international application at EPO or through PCT of patents that were applied first at a national patent office of 24 months), technology indicators only consider years with full data availability.

[36] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

the average of the 2000-2009 periods for the two KETs considered here. For nanotechnology, Singapore clearly shows the highest values. About 3 percent of all patents applied by applicants from Singapore at EPO or through PCT were in the field of nanotechnology. In the EU27, this share is only 0.8 per cent. Other countries with a high share of nanotechnology patents in their total patent activity are Cyprus and the US. In advanced materials, Japan and Belgium show very high shares of more than 9 per cent while in the EU27, 4.1 per cent of all patents are in the field of advanced materials. EU countries with higher shares include, in addition to Belgium, Germany, Austria, France and the Netherlands, which come close to the share of the US (4.8 per cent).

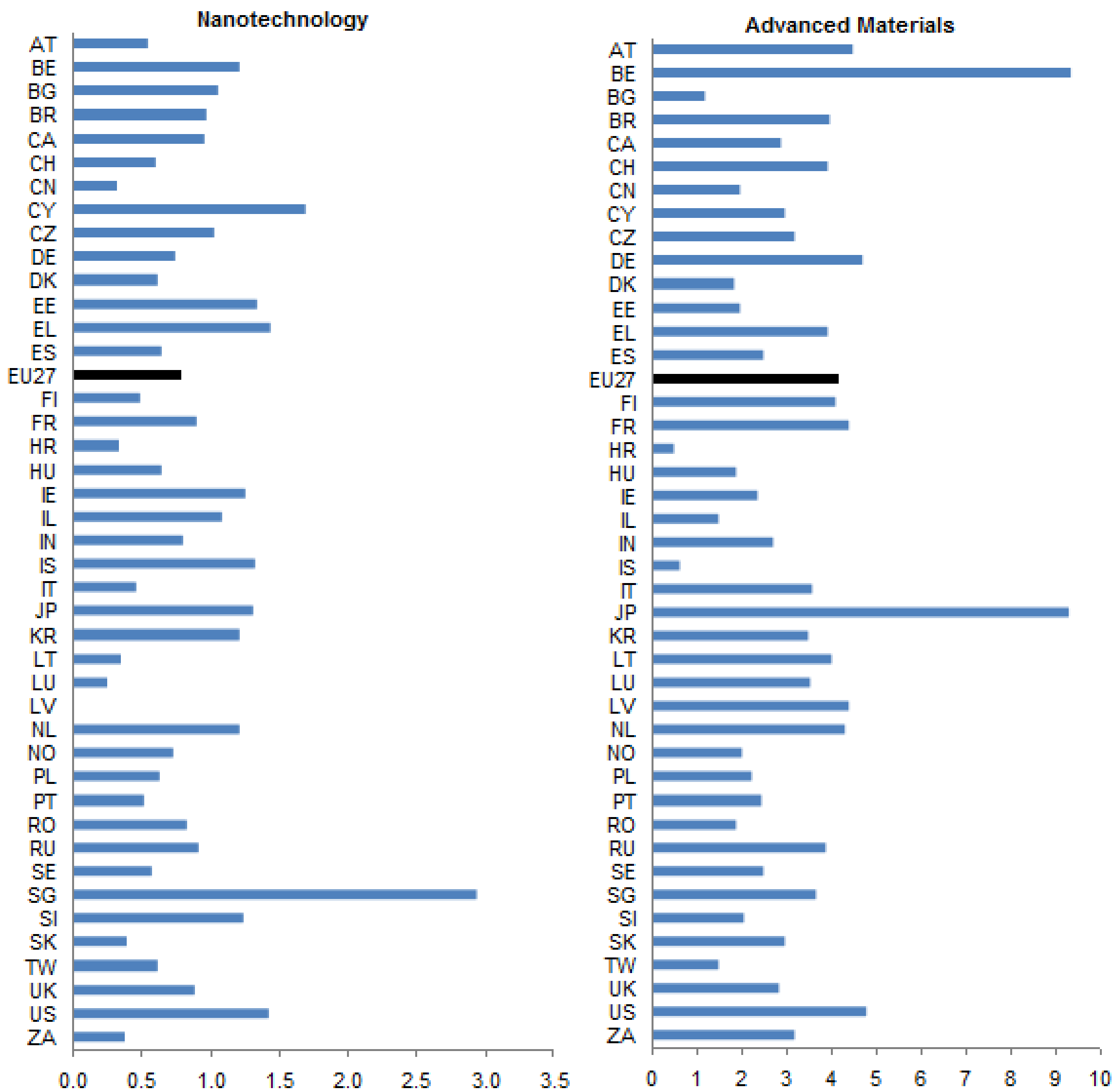

Figure 15: Significance of nanotechnology and advanced materials in total patent applications, 2000-2009 (in %)

Source: EPO: Patstat, calculations by ZEW.

A related indicator is the specialisation index. The index relates the significance of KETs patents in a country's total patent activity to the respective significance for all countries considered. A positive index shows that the country is putting more emphasis on the KET than other countries do. In nanotechnology, small countries in terms of total patent output such as Cyprus, Estonia, Greece, Iceland, Ireland and Slovenia show a positive specialisation values while lowest values are reported for Luxembourg, China, Lithuania, Singapore and Croatia (Figure 16). Among the larger patent applicant countries, Japan, South Korea and the US report positive values while the EU-27 is not specialised on nanotechnology patenting. In advanced materials, a rather special situation emerges with only two countries showing a positive specialisation, Japan and Belgium while all other report negative specialisation[37]. The reason for this peculiar result lies in the fact that Japan is by far the largest patent producer in advanced materials (about 30,000 EPO/PCT patents over the 2000-2009 periods, compared to about 26,000 in the EU27 and in the US, each). Japan therefore has a significant impact on the average share of advanced materials patenting in total patenting. As Japan is highly specialised on this KET, the country drives the average share to a value which is higher than the share for almost all other countries, resulting in a negative specialisation index for these countries.

When interpreting the specialisation index, one should be cautious for small countries that only have a limited number of patent applications. For these countries, even a very small number of patent applications in one KET can lead to a high specialisation index in case this KET has a low share in the total number of patent applications for all countries. This is particularly the case for nanotechnology, which represents only a small percentage in total patent activity.

[37] The high value for both countries is built upon the strong position of basic chemical research in the countries' technology portfolio. Basic chemical research is not only conducted by firms from the chemical industry, but also by firms from other material processing industries, such as electronics.

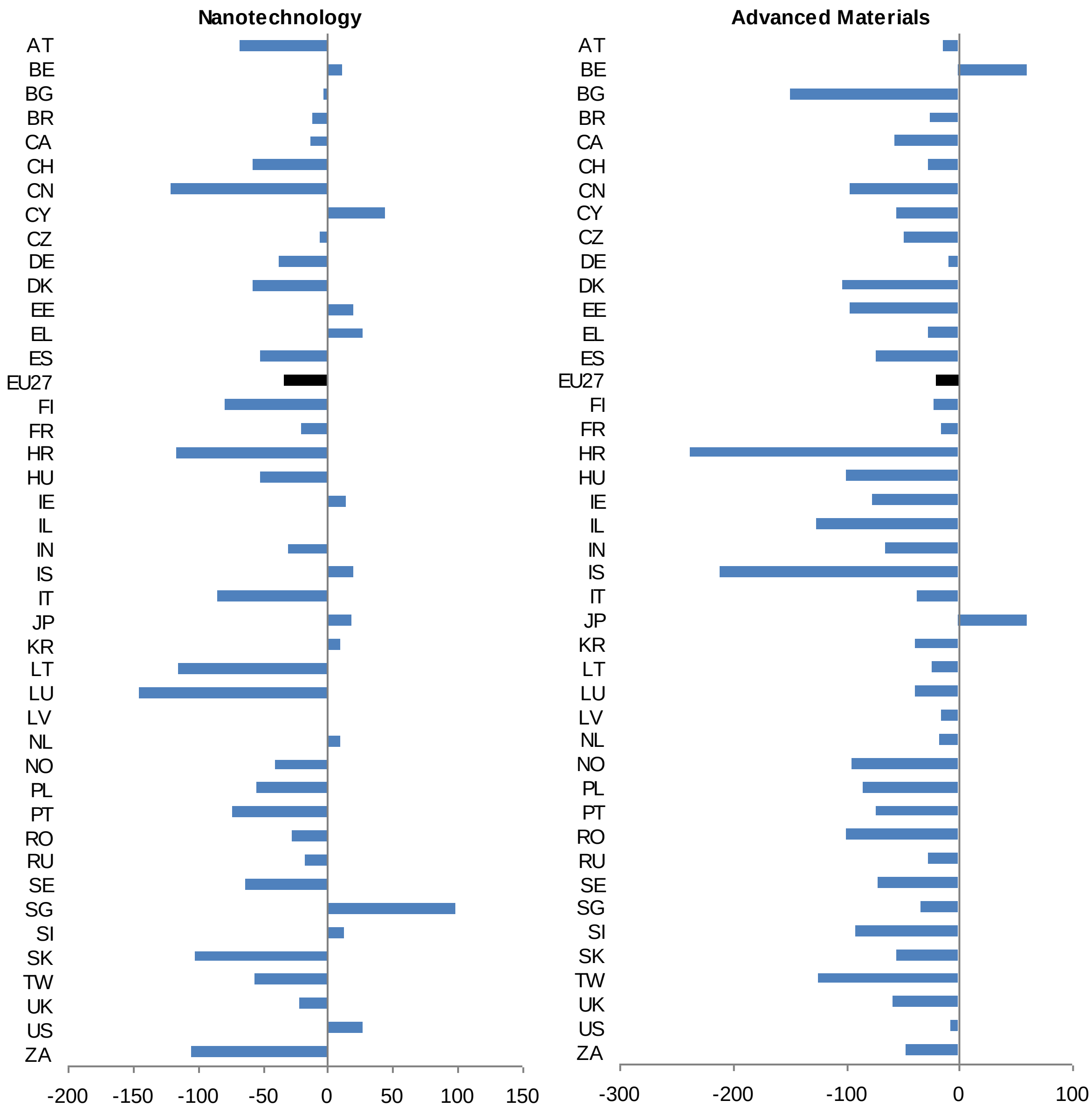

Figure 16: Specialisation of patent applications in nanotechnology and advanced materials, 2000-2009 (value <0 = not specialized, value >0 = specialized)

Source: EPO: Patstat, calculations by ZEW.

The market share indicates the importance of a country in total production of new technological knowledge (as measured through patents) in a specific KET. Figure 17 shows these technology market shares as an average for the 2000-2009 periods. In nanotechnology, the US holds the highest market share, followed by Japan and Germany. The EU27’s market share is 24 percent and exceeds the one of Japan, but is below the US market share. Next to Germany follows South Korea, France, the Netherlands and the UK. In advanced materials, Japan reports the highest market share (32 percent) which is higher than the EU27 market share (28 percent) and that of the US (27 percent). Within Europe, Germany has by far the highest market share, followed by France and the Netherlands. Market shares of South Korea and China are still low.

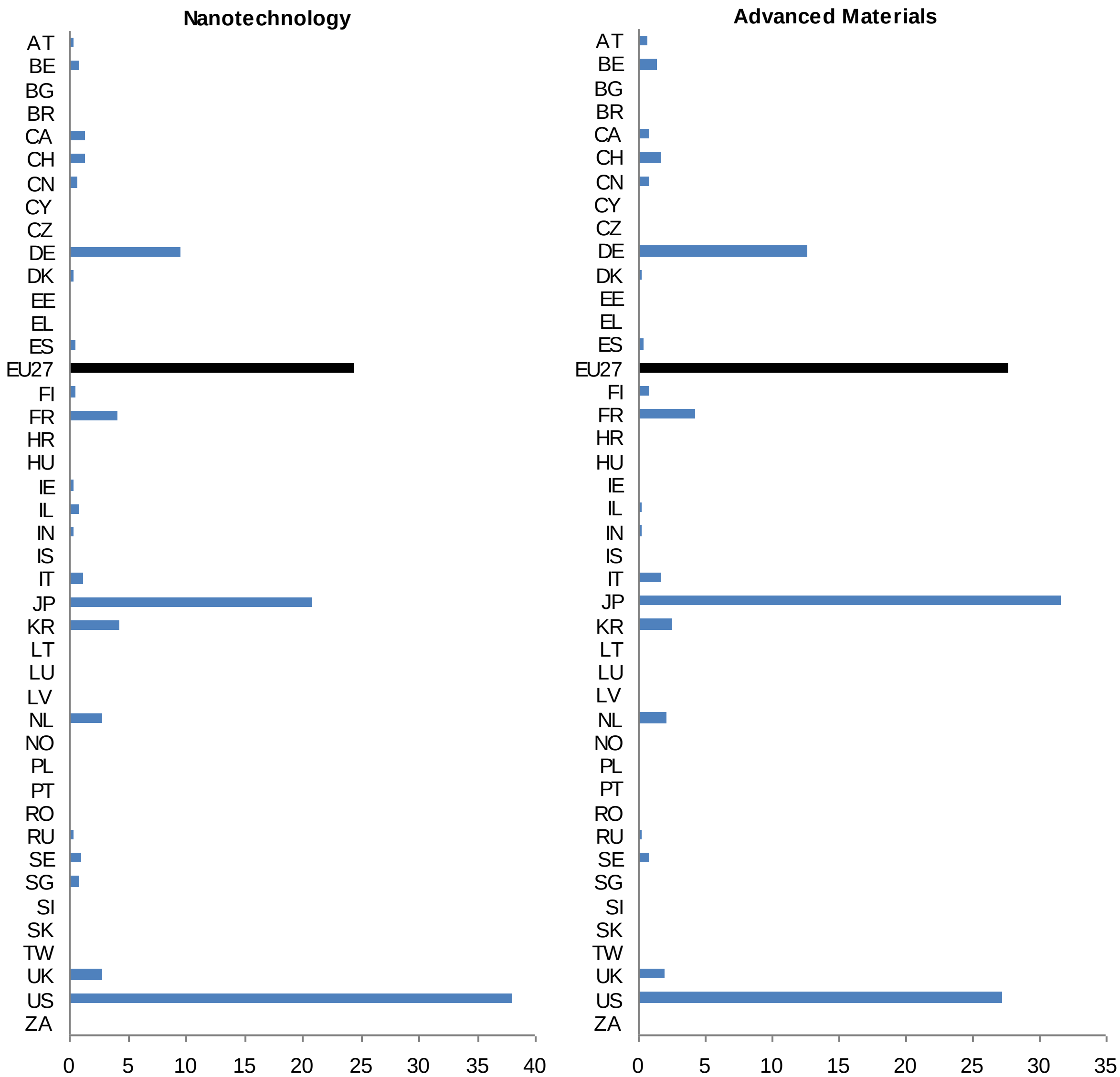

Figure 17: Market share of countries in patent activities in nanotechnology and advanced materials, 2000-2009 (in %)

Source: EPO: Patstat, calculations by ZEW.

The fourth indicator - medium-term dynamics - measures the change in the number of patent applications between two periods, the first half of the 2000s (2000/04) and the second half of this decade (2005/09). In order to avoid extreme values for countries with very few patent applications in KETs, rate of change in the number of patent application between the two periods are weighted by the countries share in total change in patent applications. For this reason, countries with substantial patent activity show the largest positive or negative values. In nanotechnology, South Korea shows the strongest dynamics, followed by Hungary (though at a very low absolute level of patent activity) and Spain (Figure 18). Only few countries report a negative development in nanotechnology patent activity over the past decade, including the US and Denmark. In advanced materials, China shows by far the highest dynamics, followed by South Korea, Japan, Brazil and Spain also report significant positive values. The highest negative values are reported for the US, Germany and the Netherlands. The negative dynamics in Germany and the Netherlands also push the EU27 value downward due to the high significance of both countries for total patent activity in the field of advanced materials within Europe.

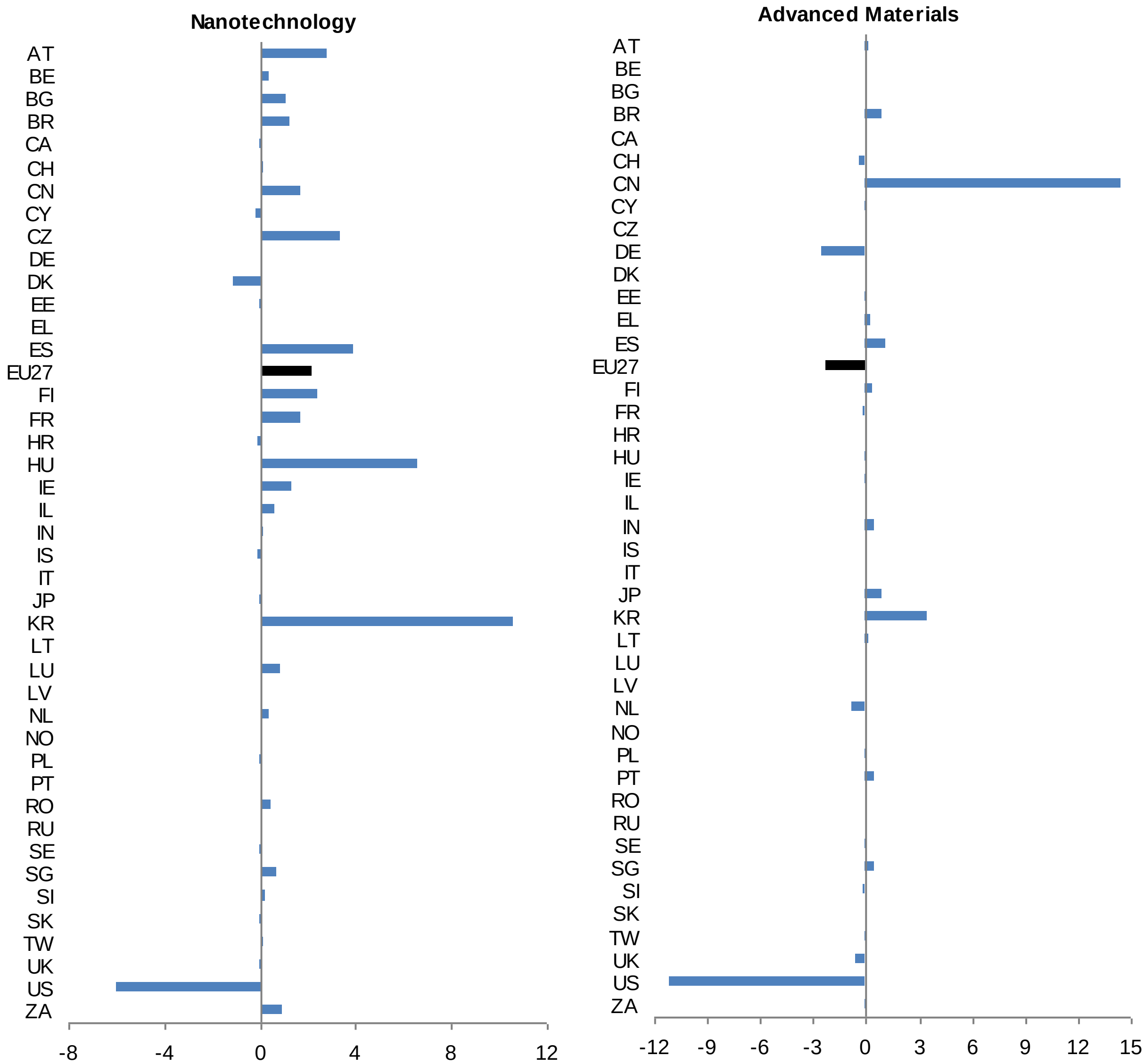

Figure 18: Size-weighted change in patent activities 2000/04 to 2005/09 in nanotechnology and advanced materials (in %)

Source: EPO: Patstat, calculations by ZEW.

4.2.3 Strengths and weaknesses of technology indicators

A main strength of the technology indicators used here is their completeness in terms of country, time and technology coverage. The PATSTAT database includes all countries and captures the entire patent activity. Since patents demand a similar level of technological novelty in all fields of technology, data are highly comparable across fields of technology. When using EPO/PCT applications, comparability across countries and time is also high since the same patent regulation applies to all applicants, and also likely changes in patent regulation affect applicants in the same way, regardless of the country they come from or the field of technology a patent refers to.

With respect to assigning patent applications to KETs, the IPC codes offer very detailed opportunities to link patents to a certain KET. For most of the six KETs, the chosen definitions tend to capture the relevant technologies quite well. Difficulties are encountered for some KETs, however:

- In industrial biotechnology, it is particularly difficult to separate new technological developments in field of enzymes for industrial applications from applications in health and agriculture since the IPC codes do not differ by the type of application. This is particularly true for IPC classes C12M, C12P, C12Q, and C12S. Although patents with co-occurrence of IPC codes in the fields of health and agriculture are excluded, there is still a significant share of patents classified as industrial biotechnology patents which still relate to health or agricultural applications. In addition, some areas of industrial biotechnology such as biopolymers can hardly be identified through IPC codes because these codes include no differentiation by the source of raw materials used.
- In AMT for other KETs, identifying AMT for industrial biotechnology, nanotechnology, photonics, and advanced materials turned out to be somewhat difficult since many manufacturing technologies are not specific to these KETs. For this reason, some of the patents considered as 'AMT for other KETs' patents may in fact relate to production technology used to manufacture other than KETs products (e.g. the IPC codes from IPC sections F and G). Furthermore, separating advanced from less advanced manufacturing technologies is another difficulty.

Furthermore, one should note some general weaknesses of technology indicators which relate to the limitations of patent data as innovation indicators. When looking at patent applications (instead of granted patents), one has to consider that not all patent applications are granted which means that some patent applications do not represent new technological knowledge. In addition, the economic value of individual patents varies a lot which may restrict the accuracy of patent count data as used here. Strategic patenting of companies can result in an inflation of patent applications which does not necessarily represent an expansion in new technological knowledge. Fourthly, not all new technological knowledge is patented which may result in some underrepresentation and may limit comparability across sectors. Despite these shortcomings, patent data are generally viewed as the most reliable technology indicators for international and inter-temporal comparisons.

In general, technology indicators can be regarded as high-quality indicators which are well suited to capture technology developments in KETs. They provide valid and reliable information on the performance of countries in the production of new technological knowledge with commercialisation potentials by country and time for each KET.

4.2.4 Next steps to refine/optimize this approach

Despite the general suitability of patent-based technology indicators, there are still some ways to reduce the amount of imperfection in the measurement:

- First, the varying level of economic value by patent may be tackled by applying value-weighted patent counts. Literature has proposed a series of value indicators for patents, including patent citations, age of the patent, number of litigations, number of claims or number of assigned IPC classes. Most of the proposed value weights have the drawback that they cannot be observed at the time of patent application but only some time, often many years later. As punctuality is crucial for indicators to be used in the KETs Observatory, the most promising patent value indicators refer to information already contained in the patent file at the time of disclosure of a patent application. This information includes the number of claims, the number of assigned IPC classes and the backward citations (citations of other patents in the patent file). When further elaborating technology indicators, one should test the usefulness of this information for calculating value-weighted patent counts.
- Secondly, the definition of KETs through IPC codes can be improved by consulting more experts that has been possible until the current state of the KETs Observatory. This particularly refers to AMT for other KETs. Results from expert workshops or expert assessments can be used to further refine the list of IPC codes used to identify patents related to AMT for other KETs.
- Thirdly, identification of KET-related patents in the field of industrial biotechnology could profit from information on the sector affiliation of applicants. With this information at hand, patents from companies that are exclusively active in the field of pharmaceuticals or agrochemicals (such as crops or pesticides) could be excluded from industrial biotechnology since it is unlikely -though certainly not impossible- that these companies develop technologies for industrial biotechnology. However, at the level of new technologies in biotechnology it is often difficult to determine whether a certain new development will end up in industrial, health or agricultural application.

We do not propose to run further validations based on text searches of KET patents since the large effort needed to do such a text search properly, does not pay off for the limited increase in accuracy that can be gained from this activity.

4.3 Production & demand indicators

4.3.1 Data input and calculation

Production indicators offer information on the relevance of the sectors involved in KETs (e.g. significance and market share). When considered over a certain time period, they provide insight into the potential opportunities for further development of these sectors (as presented by dynamics in production of a country). Assessing the relative importance of KETs components in the total production of a country furthermore could give an indication of the growth potential of a country (as reflected in industry specialization, but also import and export).

Demand indicators provide insight in the level of adoption and its dynamics (i.e. the absorptive capacity) of KETs components by consumers in a country, and subsequently about further domestic growth potential of the relevant sectors. A country's demand for KETs components can be measured by combining production and trade statistics. Domestic demand is equal to domestic production minus exports plus imports.

For the KETs Observatory, the PRODCOM (PRODuction COMmunautaire or Community Production) database and its accompanying classification has been used as a basis to analyse production and demand of KETs components[38]. The PRODCOM data are classified according to product groups described on 8-digit level. In practice, the PRODCOM classification allows for the highest level of fragmentation of products into product groups, because it has the highest number of digits in comparison to other classifications (see Figure 1). It therefore has the potential to provide an optimal basis for the appropriate coverage of the different KETs.

For each of the KETs, we have identified a selection of PRODCOM entries based on the identified KETs components[39] as described in Section 0. In practice, we adopted different approaches for the selection procedure for each of the KETS, depending on for example level of maturity and spread in application of the respective technology.

For industrial biotechnology and nanotechnology, the initial list of PRODCOM entries originated from a keyword search that used the identified components for these specific KETs as an input. For industrial biotechnology, this initial list has been further refined during a workshop that was attended by several experts in industrial biotechnology. Hence, these experts were asked to give their opinion on the selected PRODCOM entries. The outcome was a refined list of PRODCOM codes (see appendix2)[40]. For nanotechnology, the initial list was further refined by means of consultation of internal and external experts (see appendix 2).

For micro- and nanoelectronics, the Commission has requested during the course of the project, to focus on chips with regard to the selection of components and corresponding PRODCOM codes. Hence, the initial list of PRODCOM entries has been revised accordingly (see appendix 2).

For photonics, an initial list of PRODCOM entries was drafted using the taxonomy from SPIE as a basis. During a workshop which was attended by several photonics experts, this list was further refined (see appendix 2)[41].

[38] The 2009 edition has been used.

[39] Initially, the consortium identified components and KETs-based products that are commercially available today and in the near future in the component approach. In a subsequent phase, the consortium decided to focus on the list of components to identify an initial list of companies, PRODCOM and HS codes.

[40] The refined list of PRODCOM entries for industrial biotechnology has not been validated by the experts that attended the industrial biotechnology workshop due to the issues mentioned in section 4.3.3.

[41] The refined list of PRODCOM entries for Photonics has not been validated by the experts that attended the photonics workshop due to the issues mentioned in section 4.3.3.

For advanced materials and advanced manufacturing technologies, the point of departure for the selection of PRODCOM entries was the list of components identified in the previous section (see Figure 8 and Figure 9). This list was subsequently refined using internal and external experts. In refining the list for advanced materials, the choice was made to focus on basic materials, instead of products that use advanced materials (even if AM are a main part of that product) (see appendix 2).

With the help of the underlying data in the PRODCOM database, information on KETs based output has been collected. Figure 19 provides an overview of the different steps taken to calculate the production indicators[42].

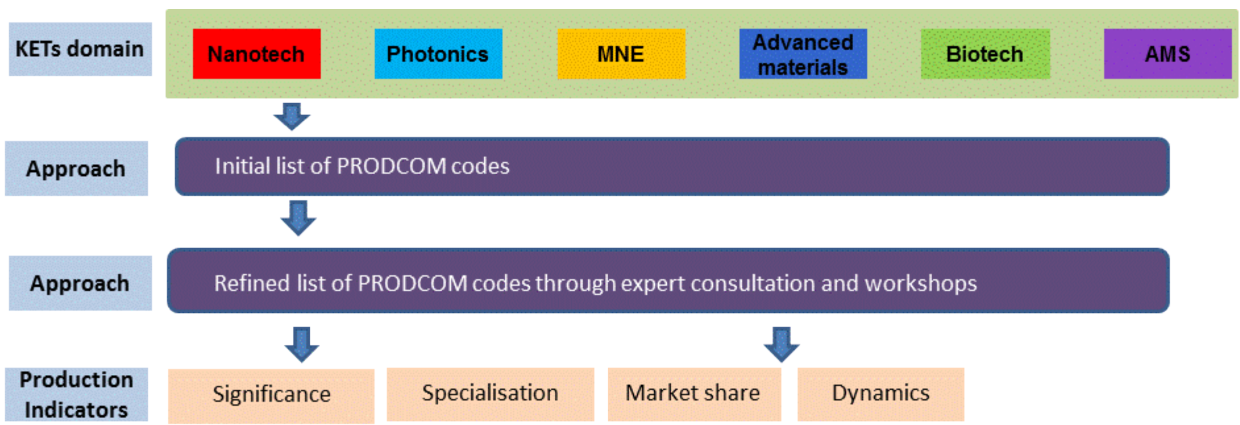

Figure 19: Overview of the different steps taken to calculate the production indicators

The monetary value of the volume of KETs components produced provides us insights in the supply of KETs on product markets. Production indicators can thus be interpreted as supply indicators. The corresponding production indicators that have been calculated are very similar in nature to the technology indicators (with P as the value of the production):

- Significance (SG) measures the share of output in a certain KET over a country's total output.

  Significance (*SG*) of production P of a certain KET *k* in country *i* in year *t*: ${}^{P}SG_{kit} = P_{kti} / P_{it} * 100$

- Specialisation (SP) relates the significance of a certain KET in a specific country to the significance of that KET across all (European) countries and hence indicates whether a country puts relatively more resources in producing this KET than other countries do.

[42] PRODCOM Annual Production Data (value), based on NACE Rev. 2, retrieved from http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/tables_excel. Characteristics of the data set (e.g. revision of the classification) are given in http://epp.eurostat.ec.europa.eu/portal/pls/portal/!PORTAL.wwpob_page.show?_docname=1486253.PDF.

Specialisation (*SP*) of country *i* in the production of a certain KET *k* in year *t* measured by revealed production advantage (i.e. the significance of a certain KET in a country's total production over the significance of that KET in global production): $^{P}SP_{ki} = \ln [(P_{kit} / P_{it}) / ((P_{kt} / P_{t})] * 100$

- Market share (MS) gives the share of production of a certain country in total production of all countries considered.

  Market share (*MS*) of country *i* in production of KET *k* in year *t*: $^{P}MS_{kit} = P_{kit} / P_{kt} * 100$

- Medium-term dynamics (MD) inform about trends in output. The indicators are defined as follows:

  Medium-term dynamics (*MD*) in production of country *i* for each KET *k* between period *p-1* and period *p*: $^{P}MD_{kip,p-1} = (P_{kip} - P_{ki,p-1}) / P_{ki,p-1} * 100$

The demand indicators are constructed in the same way as the production indicators and can be interpreted accordingly. Figure 20 provides an overview of the different steps taken to calculate the demand indicators.

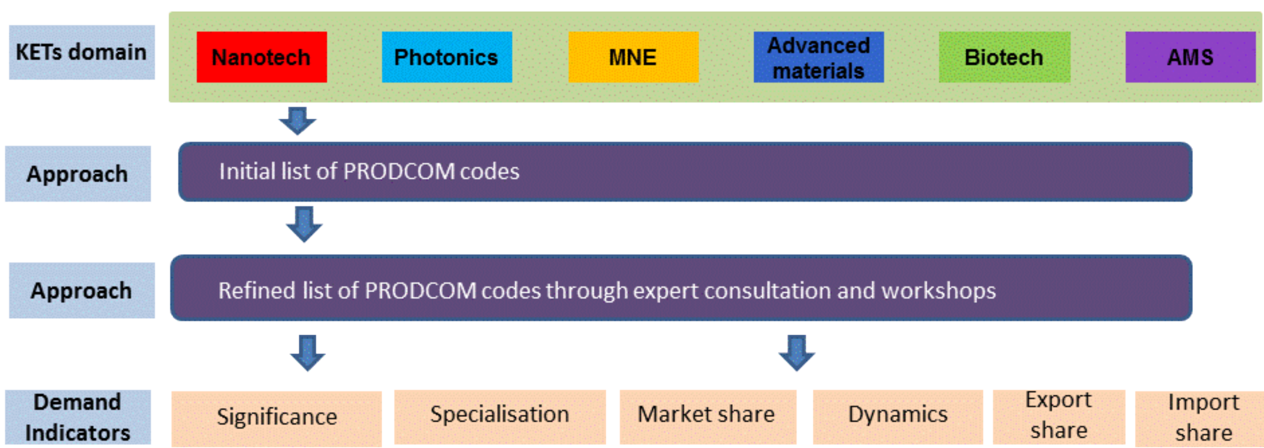

Figure 20: Overview of the different steps taken to calculate the demand indicators

Significance (SG) measures the share of demand for a certain KET in a country's total demand. Specialization (SP) relates the significance of a certain KET in a country's total demand to the significance of that KET in total demand across all countries and hence indicates whether demand in a certain country prefers a specific KET more than demand in other countries does. Market share (MS) gives the share of demand for a specific KET in a certain country in total demand of that KET across all countries considered. Medium-term dynamics (MD) inform about trends in demand. In addition, demand indicators also include two measures on the openness of a country. The export share relates the volume of exports of a specific KET to total production of that KET in the country considered. The export share says how much of a country's production is shipped abroad. The import share relates the volume of imports of a specific KET to total domestic demand for that KET in the country considered. The import share says how much of a country's demand for certain KET is coming from foreign production.

The demand indicators are defined as follows (with demand D being production P minus exports E plus imports I):

- The demand indicators are defined as follows (with demand D being production P minus exports E plus imports I):
- Significance (*SG*) of domestic demand (D) for a certain KET *k* in country *i* in year *t*: $^{D}SG_{kit} = D_{kit} / D_{it} * 100$
- Demand specialisation (*SP*) of country *i* in a certain KET *k* in year *t* measured by revealed demand advantage (i.e. the significance of a certain KET in a country's total demand over the significance of that KET in total European demand): $^{D}SP_{ki} = ln\ [(D_{kit} / D_{it}) / ((D_{kt} / D_{t})] * 100$
- Market share (*MS*) of country *i* in total European demand for each KET *k* in year *t*: $^{D}MS_{kit} = D_{kit} / D_{kt} * 100$
- Medium-term dynamics (*MD*) of demand of country *i* for each KET *k* between period *p-1* and period *p*: $^{D}MD_{kip,p-1} = (D_{kip} - D_{ki,p-1}) / D_{ki,p-1} * 100$
- Export share (*ES*) of country *i* in KET *k* in year *t*: $^{D}ES_{kit} = E_{kit} / P_{kt} * 100$
- Import share (*IS*) of country *i* in KET *k* in year *t*: $^{D}IS_{kit} = I_{kit} / D_{kt} * 100$

4.3.2 Output

The PRODCOM based database of Eurostat offers consolidated information on sold production, exports and imports by country. We focus for the collection of data on the 2005 - 2010 time periods as data for 2011 are not yet complete and/or available. The PRODCOM database covers only EU27 countries. According to the terms of the PRODCOM Regulation, Cyprus, Luxembourg and Malta are exempted from reporting PRODCOM data to Eurostat and zero production is recorded for them for all products[43]. The output of the production and demand indicators can be consulted at the KETs Observatory website[44]. The values of the indicators displayed at the website and in the figures below, are subject to change as they are calculated within the framework of this feasibility study. These values are subsequently not validated and should be handled with caution.

[43] In order to be complete, these countries are included in the tables presenting the relevant indicators in this section.
[44] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

In this section we show the results for the demand and production indicators. Due to limitations of the underlying PRODCOM data (see section 4.3.3) these results do not reflect accurately the actual performance of the KETs related industry, and the demand for KETs in a specific country.[45]

Figure 21 shows the indicator value for significance of production and demand in micro- and nanoelectronics for the average of the 2005-2010 periods. Denmark shows a high value for the significance of production in micro- and nanoelectronics[46]. With regard to the significance of demand in micro- and nanoelectronics, Denmark, Hungary, Germany, Finland, and Italy demonstrate a high score.

[45] Outliers in the performance of certain countries in the figures are mainly caused by limited data availability and coverage of the underlying PRODCOM data. The outliers can subsequently only be explained by the mathematics behind the formulas for specific indicators.
[46] Outliers in the performance of certain countries in the figures are mainly caused by limited data availability and coverage of the underlying PRODCOM data.

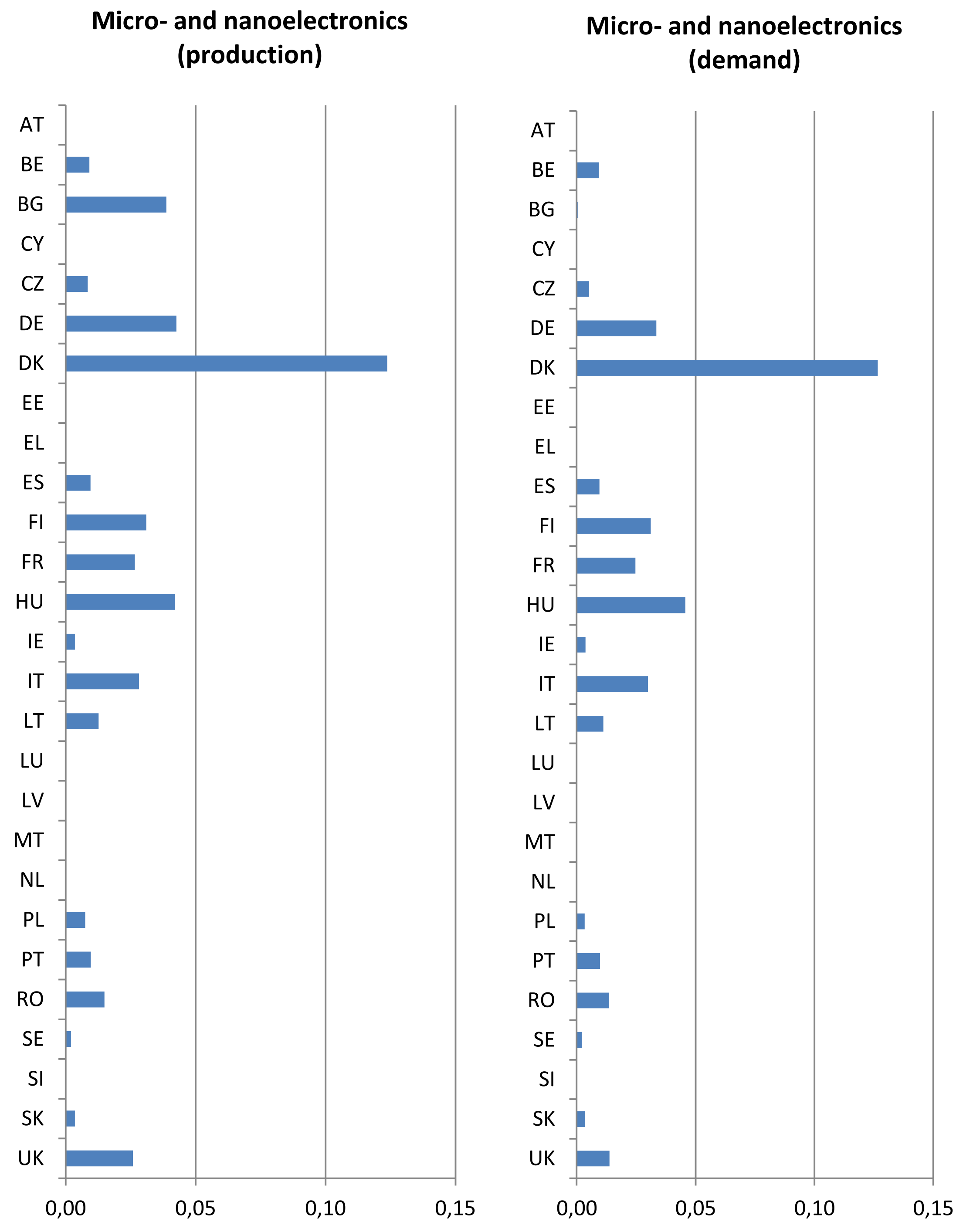

Figure 21: Significance of production and demand in micro- and nanoelectronics, 2005-2010 (in %)[47]

Source: PRODCOM, calculations by TNO.

[47] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

Figure 22 provides an overview of the specialization of production and demand in micro- and nano-electronics. Germany, Denmark, Finland and UK have a high score for specialization in production, while Poland and Ireland demonstrate a low score. With regard to the specialization in demand, Denmark, Germany and Finland show the highest score, followed by Hungary and Italy.

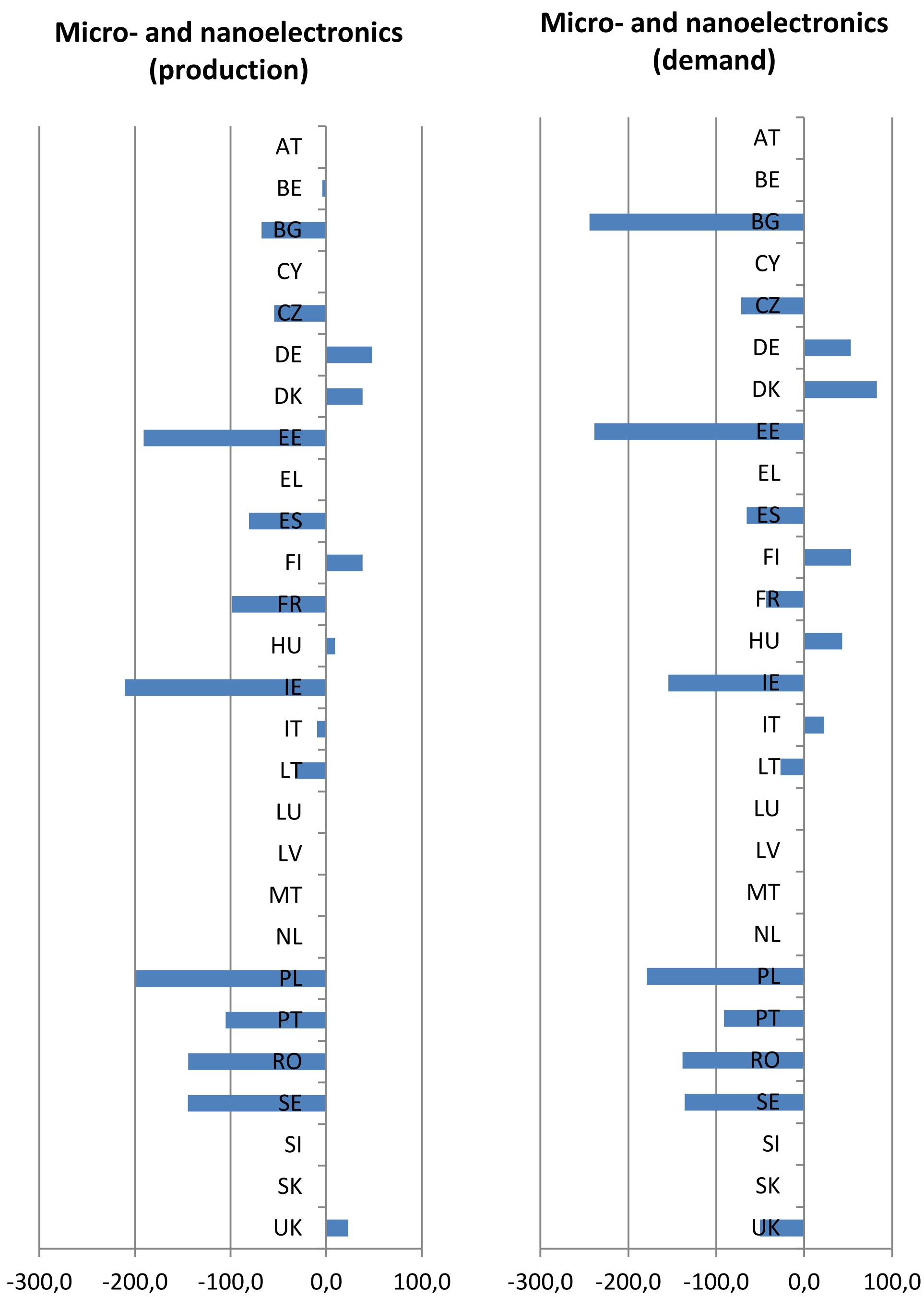

Figure 22: Specialisation of production and demand in micro- and nanoelectronics, 2005-2010 (value <0 = not specialized, value >0 = specialized[48].

Source: PRODCOM, calculations by TNO.

[48] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

Figure 23 provides an overview of the market share in production and demand for micro- and nanoelectronics. Germany reports the highest market share in production (33 percent), followed by UK (22 percent), Italy (12 percent) and Denmark (11 percent). For the market share in demand, the same countries show a high market share in demand although the order is slightly different. Germany has the highest score (33 percent), followed by Italy (17 percent), UK (15 percent) and Denmark (11 percent).

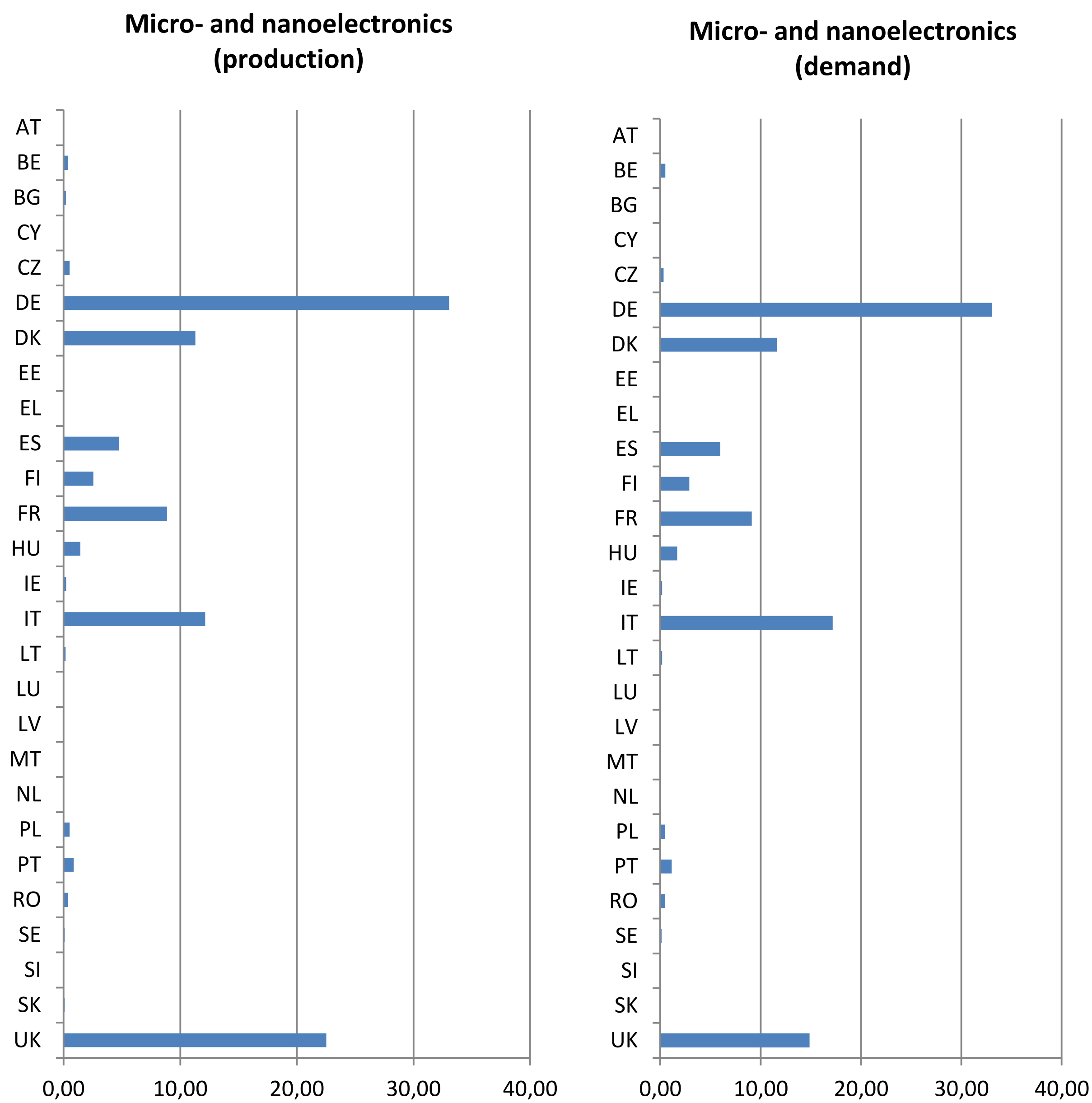

Figure 23: Market share in production and demand in micro- and nanoelectronics, 2005-2010 (in %)[49]

Source: PRODCOM, calculations by TNO.

[49] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

Figure 24 provides an overview of the dynamic indicator for production and demand for micro- and nanoelectronics calculated for the period 2005-07 to 2008-10. The country with the highest value for dynamics in production is Estonia[50]. Other countries that have a high score are Portugal, Spain and UK. In case of dynamics for demand, Portugal has the highest score.

[50] Outliers in the performance of certain countries in the figures are mainly caused by limited data availability and coverage of the underlying PRODCOM data.

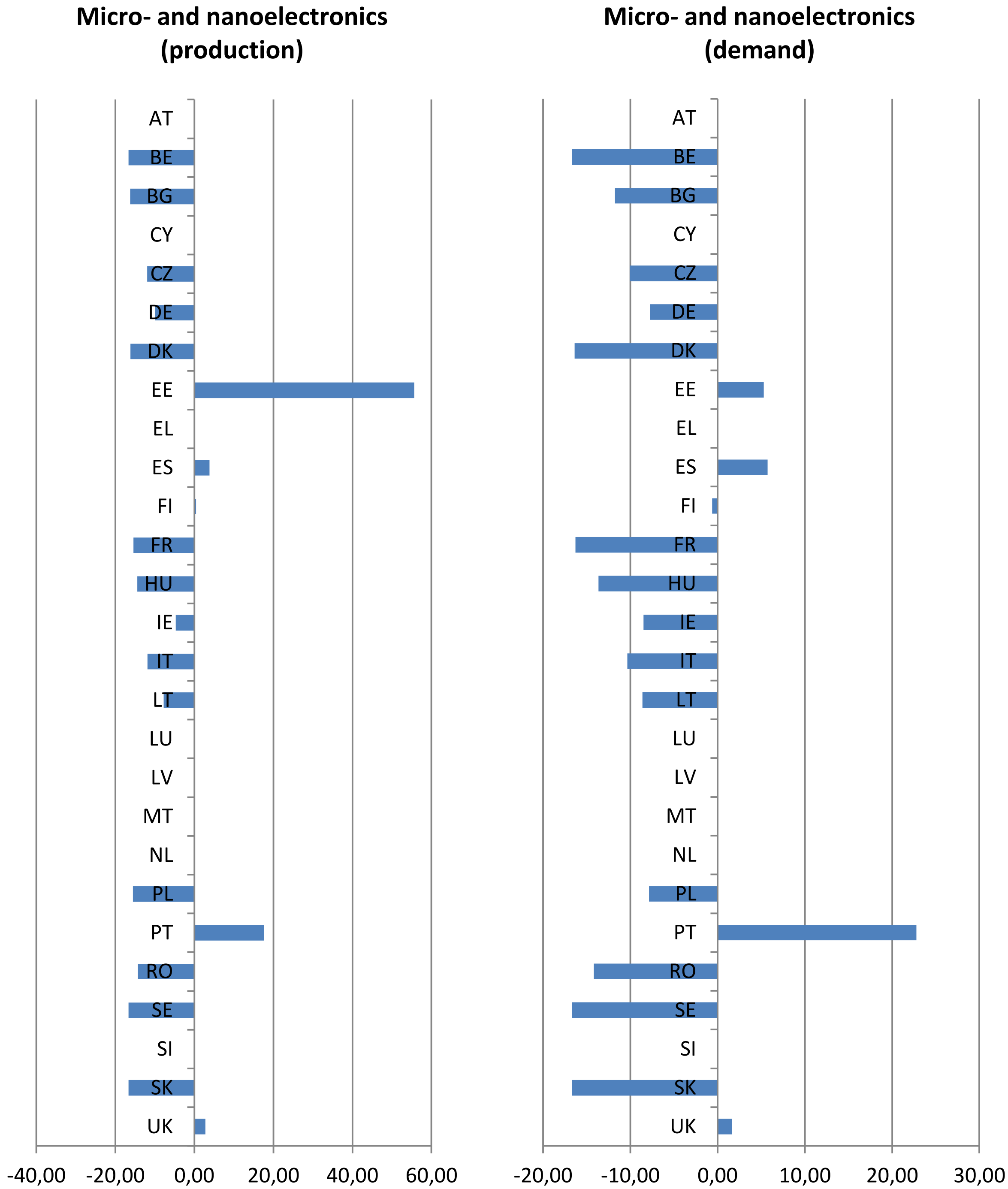

Figure 24: Dynamics in production and demand in micro- and nanoelectronics, 2005-07 to 2008-10 (in %)[51]

Source: PRODCOM, calculations by TNO.

[51] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

The export and import share of a country in total exports for micro- and nanoelectronics is shown in Figure 25. It reflects the relative strengths of countries in the micro- and nanoelectronics industry. Germany demonstrates a high score in both export and import. Also the Netherlands, France, Italy and UK have a high score on export and import.

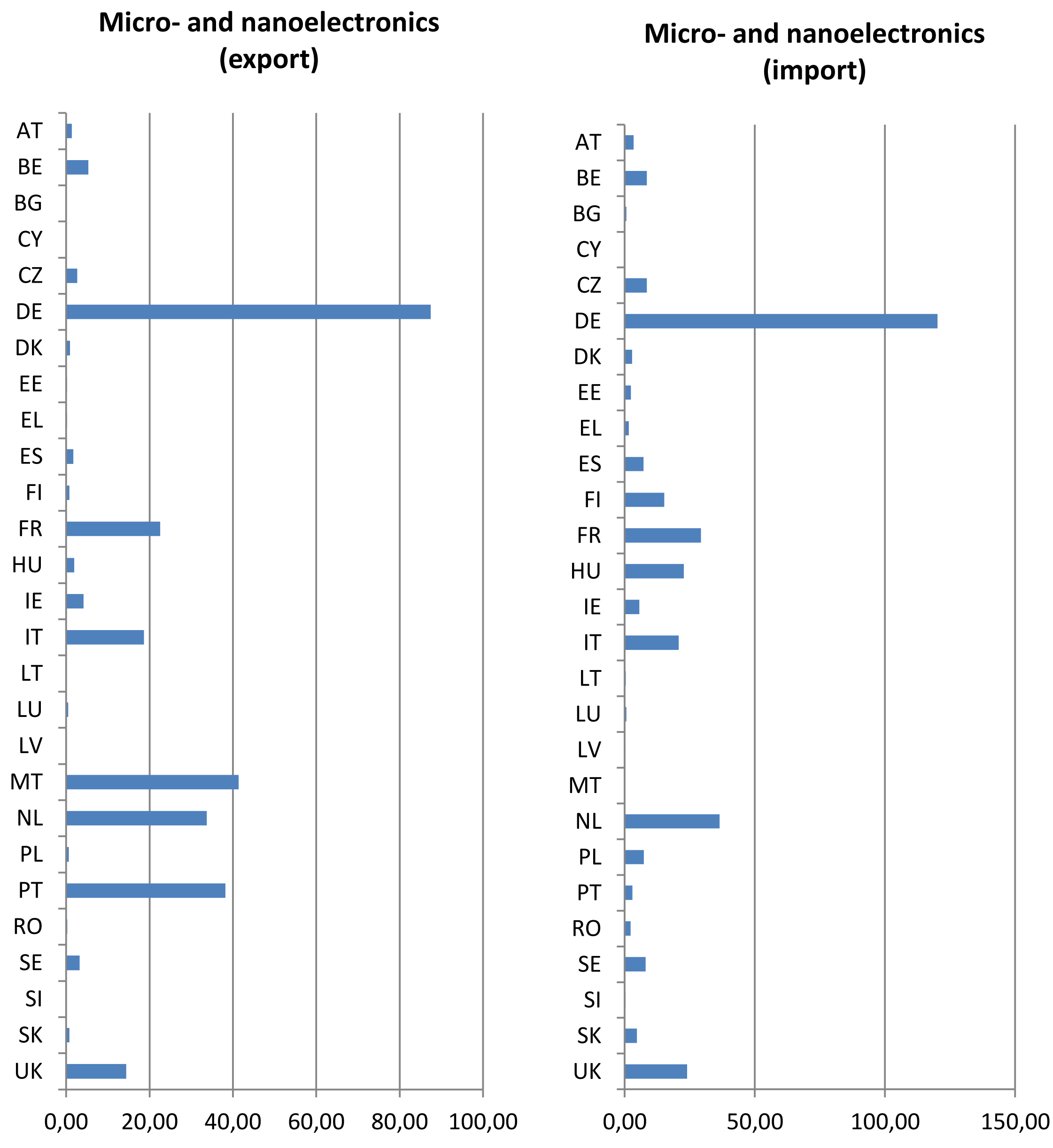

Figure 25: Export and import of a country in micro- and nanoelectronics, 2005-2010 (in %)[52]

Source: PRODCOM, calculations by TNO.

[52] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

4.3.3 Strengths and weaknesses of production and demand indicators

The strengths and weaknesses of the approach for compiling the production and demand indicators are at the one hand defined by the characteristics of the underlying production and trade data, and on the other hand by the accuracy and corresponding KETs level of the selected PRODCOM entries.

The strength of the approach lies in the fact that all output and trade of KETs based products produced is recorded according to or with the help of PRODCOM entries. Moreover, from KETs based product to PRODCOM entry to production (trade) data is a very direct link.

It should be noted that output and trade data have certain generic shortcomings resulting from issues concerning (the methodology) of information gathering:

- Due to different methodologies for the collection of trade and production data, values for exports may be higher than production. Domestic demand can subsequently become negative.
- While trade data records all traded products, production data is often restricted to output data of enterprises with more than 20 employees[53].
- Production statistics in general do not cover well so-called secondary products (i.e. products which are not part of the main economic activity of a production unit). On the other hand, trade data may include some re-exporting of imports that were only marginally processed in the importing and re-exporting country and therefore do not appear in production statistics.
- PRODCOM entries and data do not reflect (potential) impact on the market of cutting edge technological developments. In practice, all existing data are "backward looking" which is the case for all KETs.

These generic shortcomings do not impede general use and adoption of these data (e.g. for economic analysis and research). They also do not change consistency and reproducibility of indicators to be compiled, and subsequently will not influence the acceptance of the resulting figures on production and demand. There are however other important shortcomings associated to the use of PRODCOM data which influence the quality of the indicators as currently calculated, and which limit the adoption and use of the current results.

A first important weakness of the current set of underlying production data is related to the fact that production data are incomplete because of for example confidentiality issues.[54] This implies that production data are not published if output within a certain entry can be easily linked to specific actors.

[53] Few countries provide data for companies with less than 20 employees.

[54] In the data sheets presenting the value of production, this is reported as ":C". In practice, there are also, (but very few) data absent because they could not be collected and are subsequently estimated. Estimated data are shown only on aggregated EU level. On national level they are indicated with ":E" and sometimes (but very rarely) data are both confidential and estimated. On national level, these data are indicated with "CE". Handling (and potential solution, see Section 4.3.4) of these different types of missing values within the framework of this study is the same throughout the report.

Table 11 provides an example of the coverage of PRODCOM based information for a random selection of entries[55]. It shows that import and export are covered well, but that production is not.

Prodcom	FR EXP	FR IMP	FR PROD	NL EXP	NL IMP	NL PROD	DE EXP	DE IMP	DE PROD	IT EXP	IT IMP	IT PROD
20132111	14,182	3,264	50,907	1,021	192	:	7,399	6,448	:	323	2,759	7,585
20132116	1,076	35,873	:	7,424	920	:	2,876	30,209	:	585	23,492	0
20132120	757	1,347	:	118	9	0	644	461	:	1,601	121	0
20132130	93,600	139,214	190,378	137,971	41,851	:	230,929	166,397	430,523	109,184	0	249,267
20132140	1,319	4,444	0	2,370	2,662	0	5,085	16,353	:	12	2,056	0
20132150	1,548	40,345	:	181,430	197,182	0	427,740	643,301	:	113,464	101,557	:
20132180	2,465	16,033	0	19,496	11,002	:	28,229	89,841	52,774	3,703	23,586	0
20132235	0	4,167	0	41	129	:	173	8,767	45,827	0	3,812	0
20132237	15,898	16,726	0	991	4,775	:	74,727	15,332	128,048	2,199	10,172	0
20132260	41	23,470	:	31	1,745	:	19,545	8,151	:	14	2,312	:
20132413	8,968	20,922	26,458	11,463	7,231	:	38,978	4,208	85,779	865	12,551	40,264
20132415	0	2,186	0	11	11	0	686	1,374	:	0	628	0
20132433	4,764	30,026	:	11,243	10,660	:	44,808	15,846	63,465	13,300	2,669	48,164
20132435	48	752	:	0	3,029	0	4,334	491	12,519	0	39	8,232
20132453	0	208	0	546	1,506	:	2,206	2,427	:	21	2,438	0
20132455	7,574	115,561	:	122,449	156,233	:	14,610	85,962	24,098	3,420	57,451	1,404
20132460	7,052	18,993	25,975	8,721	54,370	:	14,743	52,638	58,725	621	20,102	:
20132473	0	29,509	8,508	273	21,386	0	96,090	4,675	78,577	0	7,006	28,512
20132475	0	126,028	:	73,999	40,166	:	400,716	120,812	372,563	27,795	60,155	285
20132477	0	299	:	1	470	0	7,647	2,150	:	0	30	0
20133110	293	16,087	:	10,758	18,803	:	51,340	21,706	109,988	1,755	8,647	91,027
20133130	25,519	60,764	146,331	57,823	37,335	41,496	99,416	70,806	126,957	18,949	32,361	35,139
20133150	6,753	7,210	7,124	1,206	3,278	0	14,870	14,116	:	6,491	7,203	:
20133170	15,352	12,664	:	26,461	15,326	:	23,144	29,506	16,788	1,581	5,977	0
20134310	53,510	40,002	:	30,743	63,775	0	51,696	50,240	233,606	0	58,672	:
20134320	17,178	26,949	45,954	1,875	10,462	0	28,996	13,380	:	0	16,419	29,778
20134340	22,711	28,726	56,834	50,803	85,697	:	23,752	51,200	73,652	9,962	9,268	97,123
20134390	4,021	37,827	:	8,782	31,617	:	144,634	63,029	205,255	27,281	32,944	24,456

Table 11: Coverage of PRODCOM data for a selected sample of PRODCOM codes of advanced materials

[55] Reported production implies a production value of zero or higher. The PRODCOM Regulation stipulates that countries are exempted from reporting PRODCOM data to Eurostat if production on the aggregated NACE level is less than 1% of total production. In that case zero production is recorded. Note that this is the case for Luxembourg, Cyprus and Malta. A value of zero for a specific PRODCOM entry could also result from the fact that firms do not have to report their production in case total production value for the firm involved is less than 1000 EURO; it has less than 20 employees; or the production concerns secondary products.

A second weakness results from the fact that PRODCOM entries are not technology oriented but product based. Therefore, the selection of the relevant codes requires consultation with technology and data experts. Our experience with identification of KETs related entries indicates that the resulting sets differ, depending on the background of these experts. It is therefore important to select the right experts to assess the PRODCOM entries[56]. The variations on the selected entries are caused by the fact that:

- The definition of KETs components is unambiguous with respect to part of the value chain it covers. This implies that a basis for the decision on inclusion or exclusion of a certain product / PRODCOM code, it is not clear.
- The definitions of the KETs itself (as for example formulated by the respective High Level Expert Groups) are not (mutually) exclusive. Again this implies that a basis for the decision on inclusion or exclusion of a certain product / PRODCOM code is not clear.
- Technology experts have not adopted KETs as a way to classify technologies. It is subsequently not straightforward to classify products according to KETs; for example in the area of Photonics, there is a big gap between technology and application. PRODCOM entries are not entirely KETs related. As a result, selection of appropriate codes is not straightforward (as became clear during the validation workshops). This may change in the future as the PRODCOM list (i.e. the classification system) is revised every year[57].

A third weakness related to the linking of PRODCOM codes to the selected components. Some PRODCOM entries can be assigned for 100% to a specific KET, while other PRODCOM entries only cover 5% of a particular KET. In theory, the current production data would subsequently represents an overestimation. Furthermore, the current selections of PRODCOM entries for the different KETs contain overlaps, as some entries cover more than one technology field. This implies a certain degree of double-counting in total KETs related production and demand indicators.

Because of these weaknesses, the set of production and demand indicators is currently inconsistent. Hence, adoption and use of the resulting indicators is not yet desired. The next section however provides suggestions on how to improve this approach, such that it ultimately leads to a set of data which is correct, and reflects production and demand characteristics of the industry involved in KETs.

4.3.4 Next steps to refine/optimize this approach

Although the current use of the compiled indicators is not feasible, a consistent set of data could be produced in the following consecutive steps are undertaken. These steps are quite challenging, especially step 4 namely the absence of data points due to confidentiality of information on PRODCOM entry level.

1. Redefine definitions for KETs components as well as the individual KETs, such that a clear and unambiguous inclusion or exclusion of PRODCOM entries is possible.
    - ➔ Basis for this redefinition would be a consultation of technology experts, and a validation by policy makers.

[56] See also chapter 7 for more detailed information on the selection of experts
[57] See http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/prom_esms.htm

2. Based on the definitions from step 1, consistent (and limited) sets of PRODCOM entries should be identified for the different KETs, such that they are generally accepted. An example within the framework of this project would be the selection of the codes for MNE[58].
   - ➔ Basis for the selection of PRODCOM entries would be a consultation of classification experts.
3. In order to reduce noise level created by the inclusion of non KETs related products within a PRODCOM entry, and by the allocation of certain entries to more than one KET, classification experts should be asked to specify the relevant KETs related share for a code[59]. Note that this KETs related share of an entry changes in time, and that there are issues concerning backward looking / data from the past evaluated in present time.
   - ➔ Basis for such an assessment would again be a consultation of classification experts.

4. The absence of data points due to confidentiality of information on PRODCOM entry level could be addressed by aggregating data on a higher level[60]. National Statistics Offices should therefore be urged via Eurostat, to represent the output and trade data on KETs level[61].
   - ➔ Data provided at the level of the individual KETs might overcome some of the confidentiality issues. Hence, more production and demand data will become available.
5. An issue not easily addressed is the fact that PRODCOM data cover only EU Member States, and as a consequence, production and demand indicators are only calculated for the EU27 countries. In practice, OECD members, and also some other countries do collect production data[62], but the PRODCOM classification is only used by EU countries. The non-EU countries use different classifications (the US for example has adopted a classification based on sectors but not on products). Collecting production and demand indicators for non-EU Member States will subsequently not be straightforward due to the lack of comparability of data because of different classifications used for compiling data.
   - ➔ It is possible to collect data on production and demand for non-EU Member States but this is likely to take quite some resources.

[58] In the past a similar approach has been adopted for the creation of data on ICT by the OECD and Eurostat.

[59] This also holds for data on national level that is not available because they are estimated, or confidential and estimated (see footnote 51).

[60] The use of aggregated output and trade data on NACE or CPA level is inadequate to increase the quality of the indicators as they merely sum up over the respective PRODCOM entries, thereby including missing values. It would furthermore also increase the level of noise by including additional non KETs related PRODCOM entries. It was suggested by some experts to retrieve data on KETs by mapping the KET share of NACE entries. The consortium has decided not to pursue this approach as a it is unlikely that the KET based value for an indicator matches that KETs based share within a NACE code (e.g., if the KETs based level of a NACE based entry is say x %, BERD for example is most likely not equal to x % of the level of business expenditure on R&D for that NACE code).

[61]This has for example been done in the Netherlands by the CBS (National Statistics Office) and Agentschap NL for the Top sectors. Per sector, relevant companies were selected (based on clear definition for each of the sectors), and aggregated data were compiled (BERD, production, etc.) based on micro-data (see http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2012/10/16/monitor-topsectoren.html).

[62] For a complete overview of countries covered, and the way they present their production data, see http://stats.oecd.org/mei/default.asp?lang=e&subject=1.

4.4 Trade indicators

4.4.1 Data input and calculation

International trade is a useful performance indicator as it indicates whether the technology produced in a certain country can be commercialised in other countries as well. Export success of technology is often regarded as a higher level of performance compared to domestic sales since exporters have to overcome certain liabilities of foreignness, such as a lack of reputation, higher transaction costs and costs to adjust technology to specific location requirements. New technology that is successfully commercialised on international markets may thus contain a particular innovative superiority or a price advantage which both can contribute to overcoming the barriers of entering foreign markets. However, international trade is also affected by other factors than price and quality of products, such as exchange rates, tariff and non-tariff barriers to trade (such as regulations that discriminate foreign over domestic products), transport costs and the macroeconomic environment.

International trade analysis has come up with a number of trade indicators to assess a country's performance. Figure 26 provides an overview of the different steps taken to calculate the trade indicators.

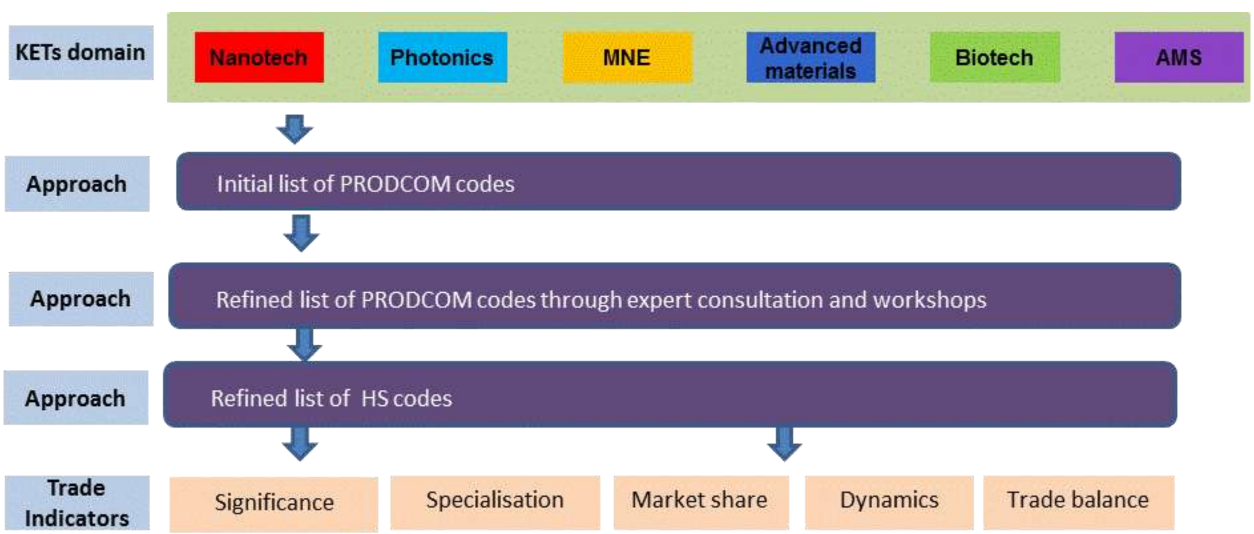

Figure 26: Overview of the different steps taken to calculate the trade indicators

We use five indicators: the indicators on significance, market share and dynamics all relate to export activities and are defined and to be interpreted similarly to the respective indicators used for technology and production. With respect to the market share indicator, one should note that the total volume of exports (and therefore a country's share in total exports) can be biased when compared to the respective results for technology and production because of country size and trade area effects. First, large countries tend to export less of their total production than small countries because of the larger size of the domestic market which is more likely to absorb a larger fraction of production than for a small country. This is particularly true for highly specialised products such as KETs components which are characterised by a concentration of production on a rather small number of facilities while potential users are often spread all over the world. In such a situation, it is very likely that a small country hosting a production facility for a KETs component will export almost all since the country's share in global demand for this product will be small. For a large country, it is more likely that domestic clients represent a significant share of global demand, resulting in a larger fraction of production that is consumed domestically. Secondly, if an integrated trade area consists of many independent countries (which are the unit of observation in trade statistics) the sum of export volumes of all these countries will be much higher than for a trade area of same size that consists only of one or a few large countries. This situation is obvious when comparing export volumes of EU member states and the USA as export volumes of EU member states primarily consist of exports to other EU member states while exports of the USA only covers sales to two other countries of its trading area (NAFTA). Market shares of European countries in total exports will thus be overrated compared to market shares for production and technology.

Two further trade indicators - trade balance and specialisation - relate exports and imports. The trade balance informs whether a country is a net exporter or importer for a certain KET. As specialisation indicator we use the standard revealed comparative advantage measure which indicates whether the trade position in a certain KET area (i.e. exports over imports) is better or worth than for all products traded by this country.

The trade indicators are similarly constructed as the technology and production indicators, though some deviations occur owing to the specific nature of trade as an interaction rather than an output activity. **Significance** (SG) measures the share of a country's exports in a certain KET over the country's total export and tells how important that KET is for a country's export activity.

- Significance (*SG*) of a certain KET *k* in total exports (*E*) of country *i* in year *t*: $^{E}SG_{kit} = E_{kit} / E_{it} * 100$

Specialisation (SP) is measured by a standard indicator in trade analysis, the so-called revealed comparative advantage. This indicator relates the ratio of exports to imports in a certain country over the same ratio for all countries considered. If this ratio is higher in a certain country than in the average, it shows that the country is able to yield higher exports than imports compared to other countries for the respective KET (even in case imports exceed exports). If a country is able to export more than to import -compared to a peer group of countries- than this country is likely to have a comparative advantage and is specialised on the export of this KET.

- Specialisation (*SP*) of country *i* on trade in a certain KET *k* in year *t* measured by revealed comparative advantage (i.e. a country's export to import relation for a certain KET over export to import relation in the country's total trade): $^{E}SP_{ki} = \ln [(E_{kit} / I_{kit}) / (E_{it} / I_{it})] * 100$

Market share (MS) gives the share of exports from a certain country in total exports of all countries considered and tells how much a country contributes to the total exports of the considered group of countries.

- Market share (*MS*) of country *i* in total[63] exports for each KET *k* in year *t*: $^{E}MS_{kit} = E_{kit} / E_{kt} * 100$

Medium-term dynamics (MD) inform about trends in exports.

- Medium-term dynamics (*MD*) of exports of country *i* for each KET *k* between period *p-1* and period *(with p-1 being 2005-07 and p being 2008-10) p*: $^{E}MD_{kip,p-1} = (E_{kip} - E_{ki,p-1}) / E_{ki,p-1} * 100$

Finally, the **trade balance** (TB) relates the difference between exports and imports to the total trade volume (exports plus imports). A positive value shows that the country exports more than it imports in a certain KET area which indicates some type of competitive advantage.

- Trade Balance (*TB*) of country *i* in a certain KET *k* in year *t*, i.e. the difference between exports and imports (*I*) over the sum of exports and imports: $^{E}TB_{kit} = (E_{kit} - I_{ikt}) / (E_{kit} + I_{kit}) * 100$

A further trade indicator which has been used regularly in trade analysis is the unit value. This indicator gives the price of one unit of a traded product, whereby the unit being measured either in weight units (tonnes) or pieces. It can inform about the quality of traded products since products of a higher quality will have a higher price per unit that low-quality products. The main shortcoming of this approach is, however, that it assumes identical products to be compared, which is rarely the case, even if one applies the most disaggregated level or product classification. Since it is the purpose of classifications to classify distinct products into groups with common, but not identical features, differences in unit values will not only represent quality differences but also differences in the types of products traded by countries within a certain product category. In addition, data on the weight of traded products or the number traded pieces of a product tend to be incomplete and complicates comparative analysis. For both the conceptual and the data reason, no unit value based indicators are used in the KETs Observatory.

Trade data are taken from the UN Comtrade (United Nations Commodity Trade Statistics) database which is produced under the International Merchandise Trade Statistics by the International Merchandise Trade Statistics Section of the United Nations Statistics Division. Trade in KET products is identified by using a list-based approach that relies on the results of the production and demand indicators. Taking the conversion tables between PRODCOM/CPA codes and KETs (see Appendix 2), 6-digit CPA codes (which are the first 6 digits of the 8-digit PRODCOM codes) are transferred to the HS classification used in trade data (Harmonized Commodity Description and Coding System, managed by the World Customs Organisation) (see Appendix 8).For data from 2007 onwards CPA codes were linked to 6-digit HS2007 codes, using the official conversion table between CPA and HS2007. For data from 2002 to 2006, the HS2007 codes were linked to HS2002 using the official conversion table between

[63] 'Total' refers to the sum of the 42 countries considered (EU-27 plus USA, Japan, Korea, China, Canada, Switzerland, Croatia, Bosnia and Herzegovina, Israel, Iceland, Montenegro, Norway, Russia, Serbia, Macedonia). Trade data for Taiwan are not available.

HS2007 and HS2002 since data previous to the year 2007 are only available for the HS2002 classification system. For all 6-digit CPA codes identified, an unambiguous link to HS codes could be established.

We refrained from linking 8-digit PRODCOM codes to HS2007 since in many cases it would have been impossible to establish an unambiguous link as PRODCOM uses a more detailed classification than HS. We could have linked PDOCOM to the more detailed CN (Combined Nomenclature) system which is used in European trade statistics. However, data by CN are available for European countries only and not for third countries, which would substantially restrict the analytical scope of trade analysis.

4.4.2 Output

The trade indicators provide almost complete data on trade performance by KETs for all EU countries and all third countries for each year of the period covered (2002 to 2010). However, no data for Taiwan and no data for Kosovo are available in UN Comtrade. Trade data are measured in monetary values of exports and imports in US dollar. Currencies are converted to US dollar using current exchange rates.

The output of the trade indicators can be consulted at the KETs Observatory website (https://webgate.ec.europa.eu/ketsobservatory/[64]). In order to illustrate the output, the results for each indicator are presented for two KETs, Photonics and Advanced Manufacturing Technologies (AMT). The values of the indicators displayed at the website and in the figures below, are subject to change as they are calculated within the framework of this feasibility study. These values are subsequently not validated and should be handled with caution.

The significance indicator reports the share of products related to the fields of photonics and AMT for KETs, respectively, in total exports of manufactured goods of a country. Figure 27 shows that photonics products account for less than 10 percent of total exports in most countries, except for Malta (45 percent), South Korea (20 percent), Hungary (17 percent) and Finland (12 percent). The extremely high share for Malta reflects the fact that this country has a limited portfolio of export products resulting from the small size of its manufacturing sector, and that photonics is one of the few major goods export industries of the country. For the EU27, 5 per cent of total exports are in the field of photonics. A similar share of total EU27 exports, 4 per cent, is with products in the field of AMT for KETs. High shares in total exports of this KET are reported for Japan, Switzerland, Italy, Germany, the US and Denmark.

[64] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

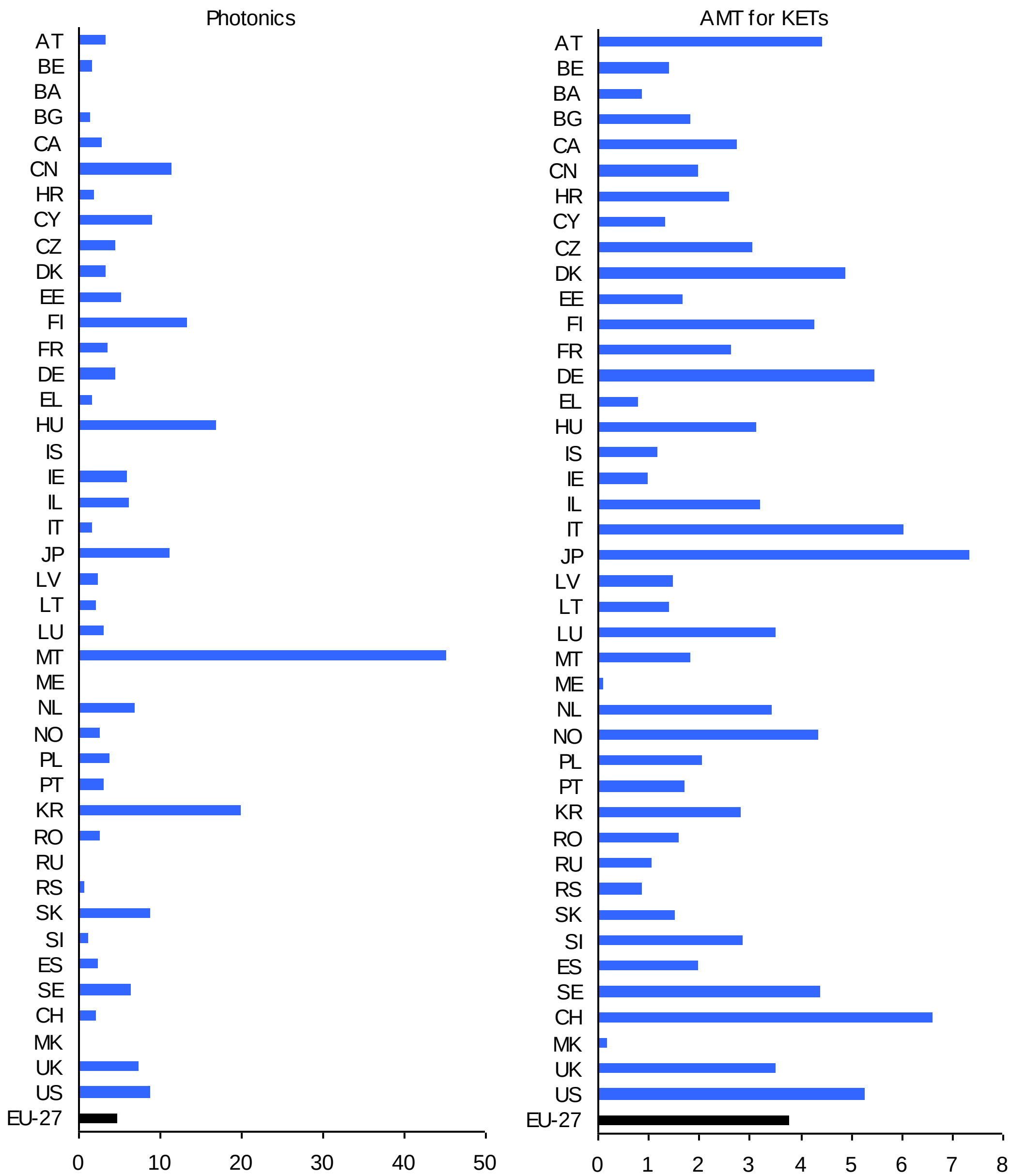

Figure 27: Significance of products related to photonics and AMT for KETs in total exports, 2002-2010 (in %)[65]

Source: UN: Comtrade, calculations by NIW.

[65] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

A standard trade indicator is the revealed comparative advantage (RCA) indicator. It is a specialisation index and relates a countries export to import ratio for a certain product category to the export/import ratio for the country's total trade. A positive value indicates that the respective product category shows a better export-to-import performance than the country as a whole, which is linked to comparative advantages in the production and trade of this product category in the country considered. Figure 28 shows that the RCA for photonics related products is negative for most countries. A positive specialisation is reported for Malta, Cyprus, Finland, Hungary, Korea, Japan, Sweden, the US and Slovakia. The EU27 as a whole is not specialised in photonics exports. Countries which have no or only very small photonics exports show a highly negative RCA. In AMT for KETs, the RCA is more dispersed between positive and negative values. Italy reports the highest positive value, followed by Switzerland, Japan, the US, Germany and Denmark. The EU27 is positively specialised on this KET. High negative specialisation is reported for some small countries, but also for China, Korea and Russia. This result indicates that these countries focus their exports on other products than AMT for KETs.

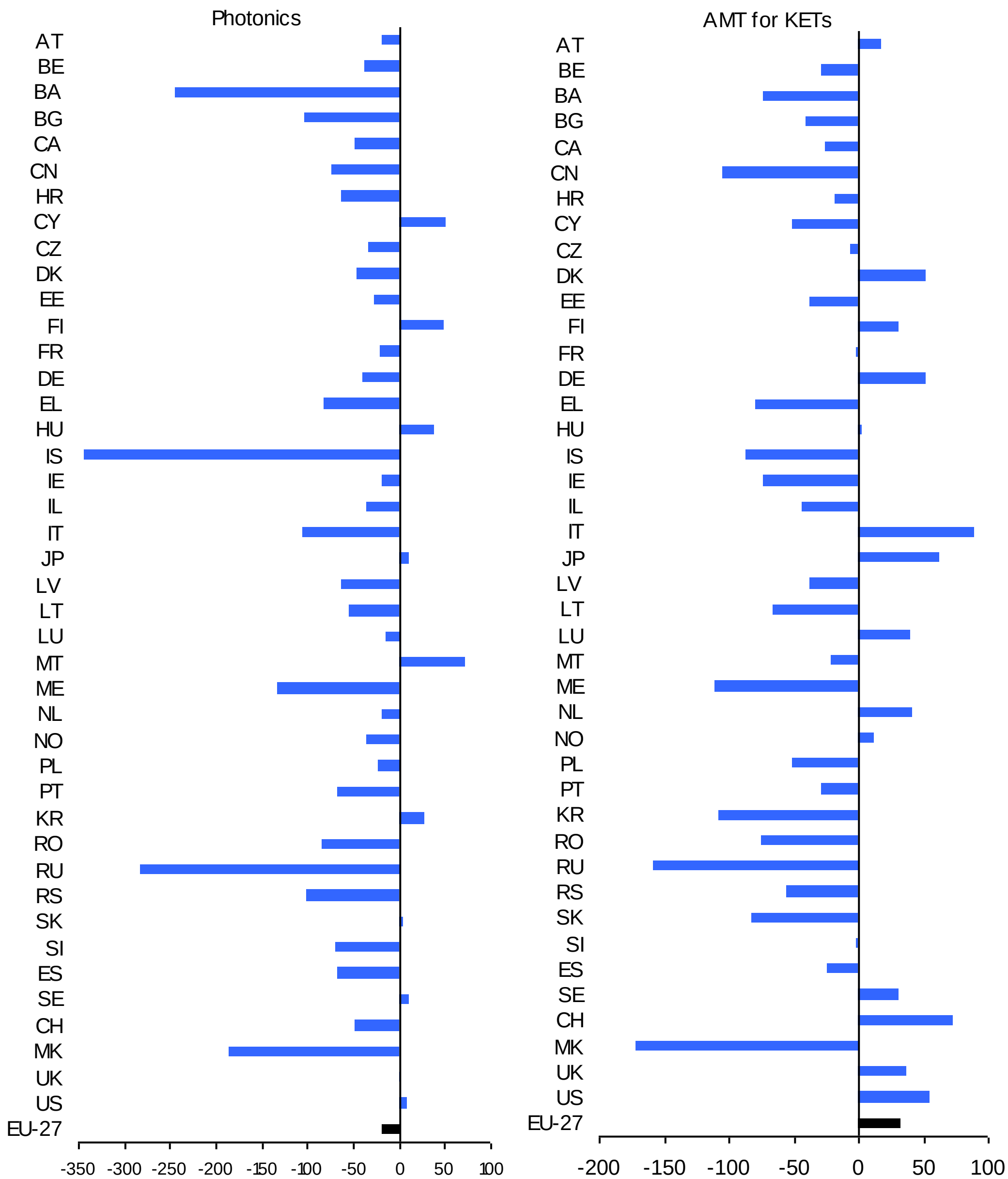

Figure 28: Trade specialisation index (RCA) for products related to photonics and AMT for KETs, 2002-2010 (value <0 = not specialized, value >0 = specialized)[66]

Source: UN Comtrade, calculations by NIW.

[66] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

The market share in total exports of a certain KET indicates the importance of a country in international trade for a specific KET. International trade is defined as all exports from one country to any other country and includes intra-EU trade for EU member states. Total trade of EU27 is the sum of all exports of all 27 EU member states and includes trade among member states. For this reason, EU27 figures are not comparable to figures for non-EU countries such as the USA or Japan[67]. Figure 29 shows that China, Japan, the US, South Korea and Germany have the highest market shares for photonics related products while the largest export countries for products in the field of AMT for KETs are Germany, the US, Japan, Italy and China. Large countries tend to have higher market shares than small countries which basically reflect the larger production capacities in larger countries.

[67] Calculating market share data for EU-27 excluding intra-EU trade is of course possible, but requires a greater effort in data analysis which was not possible within the scope of this feasibility study.

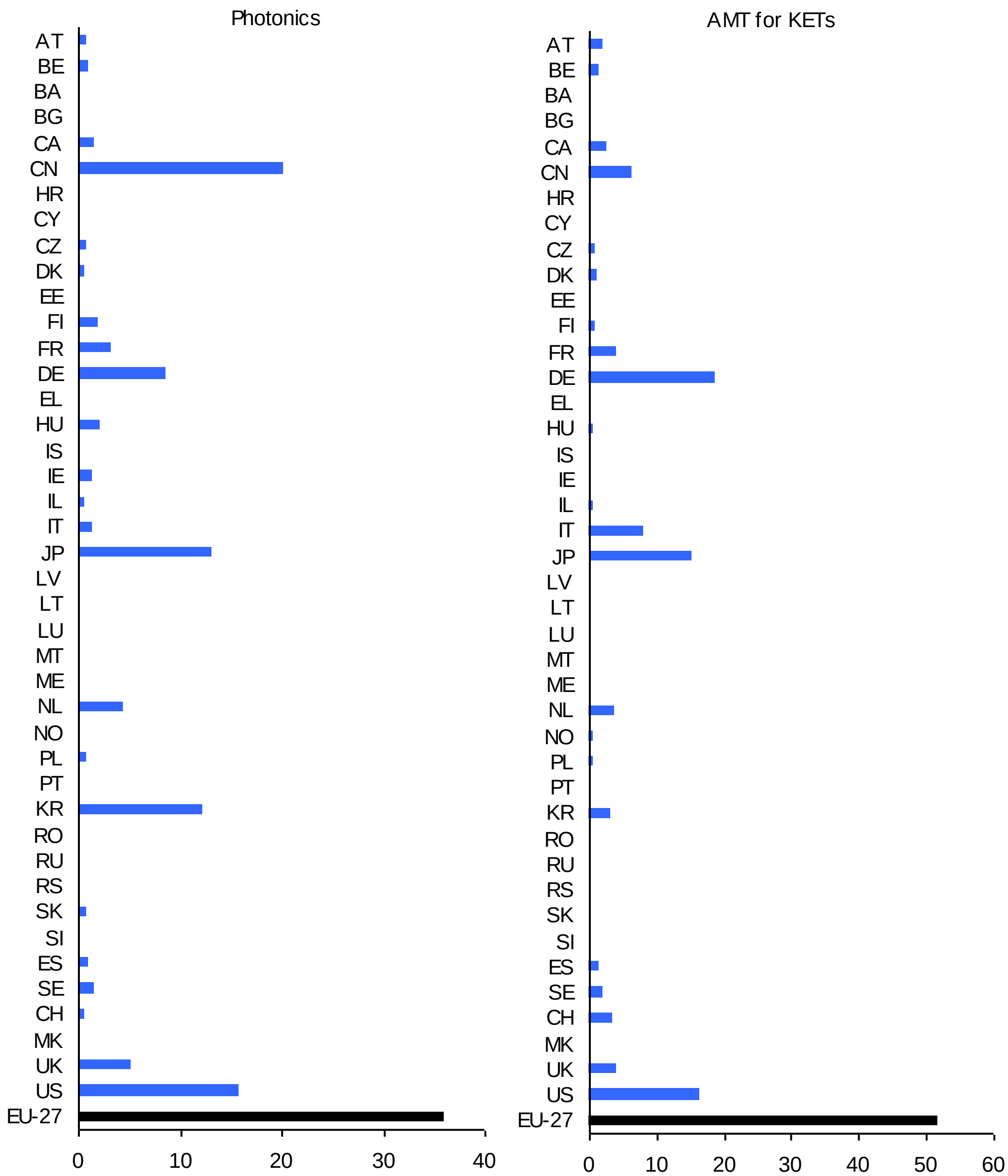

Figure 29: Market share in total exports of products related to photonics and AMT for KETs, 2002-2010 (in %)[68]

Source: UN: Comtrade, calculations by NIW.

[68] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

The fourth indicator measures the dynamics in exports of KET-related products. In order to avoid too high impacts from business cycle fluctuations, we look at medium-term dynamics which measure the change in nominal export volumes between 2005-2007 and 2008-2010. Nevertheless, this indicator can show very high values for countries which had almost no exports in the first period and entered in the export business within a certain KET during the second period. In the field of photonics related products, this is the case for Romania, Israel, Serbia and Latvia which all show growth rates of more than 200 per cent (Figure 30). In order to avoid high growth rates, one could use size-weighted growth rates as has been done for technology indicators, though this would devaluate the actual export dynamics in small countries and makes the interpretation of the results more complex. We therefore decided not to apply size-weighted growth rates for export dynamics.

Large countries tend to report rather small rates of change. In the EU27 countries, trade in photonics related products slightly decreased between the two periods. For AMT for KETs, a different picture emerges since most countries could increase their exports between the two periods. Again, countries with a very small total export activity in this KET sometimes report very high values, such as Bosnia and Herzegovina and Montenegro. Among the large countries, China increased their exports at the highest pace. In the EU27, exports increased by 14 percent between the two periods, which is clearly a higher rate than in the US and Japan.

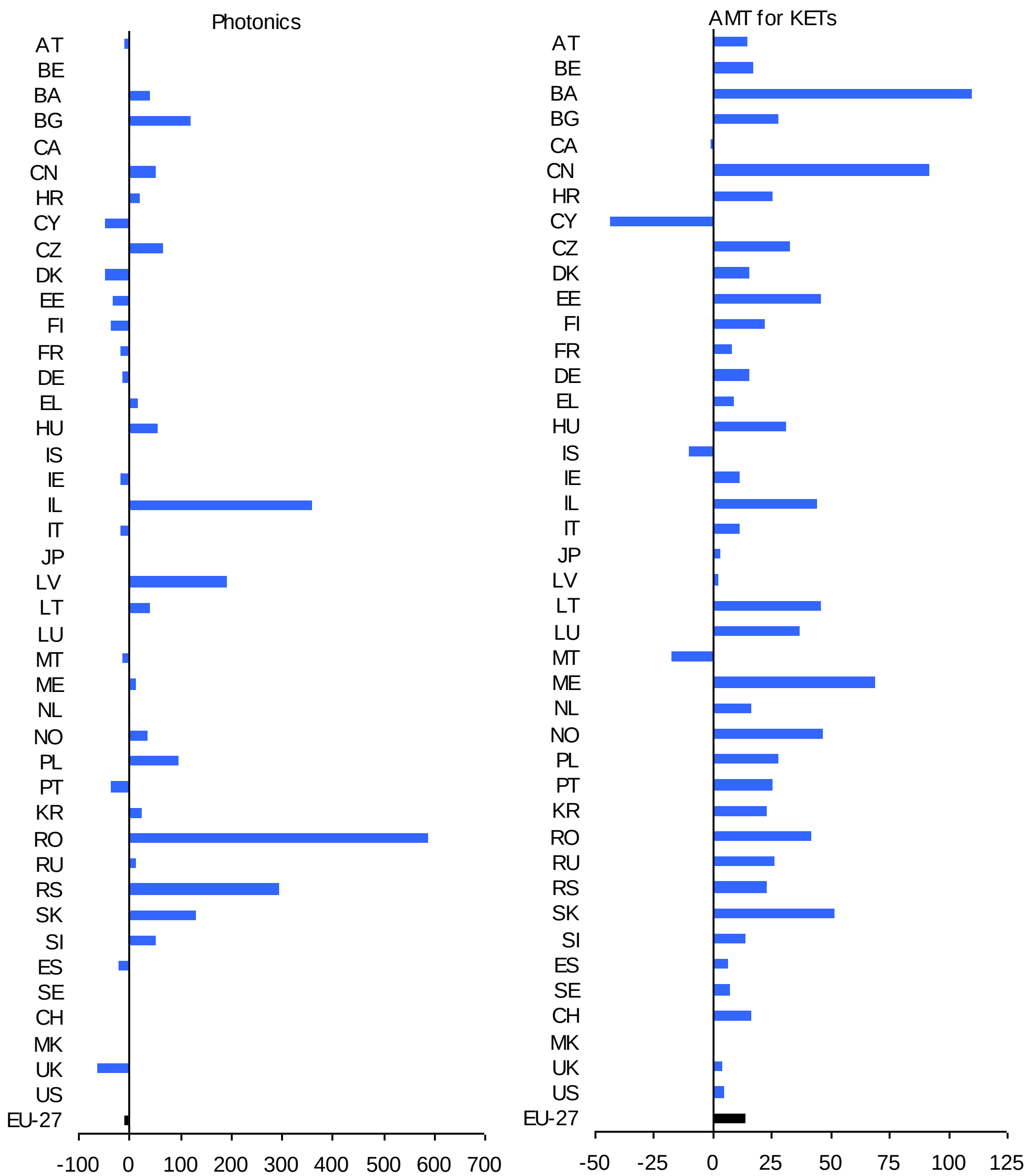

Figure 30: Medium-term change in exports of products related to photonics and AMT for KETs, 2005-07 to 2008-10 (in %)[69]

Source: UN Comtrade, calculations by NIW.

[69] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

The final trade indicator reports the trade balance for a certain KET. The trade balance shows whether a country exports more than it imports in a certain product category. Higher exports than imports -i.e. a positive trade balance- indicate some competitive advantage of this country. In order to control for the total volume of trade, the trade balance is related to the sum of exports and imports in the respective product category for the country in consideration. Figure 31 depicts the trade balance indicator for photonics and AMT for KETs. Only a few countries report a positive trade balance for photonics, including Finland, South Korea, Japan, Hungary, Ireland, Sweden and Malta. Some countries show a negative trade balance of almost 100 per cent since these countries do not have any significant export activity in photonics. The EU27 in total has a slightly negative trade balance in this KET. The situation is different with AMT for KETs. Here, the EU27 shows a positive balance of trade which is driven by export surplus in Italy, Germany, Finland, the Netherlands, Sweden and Denmark. In addition, Japan and Switzerland also report a clearly positive trade balance.

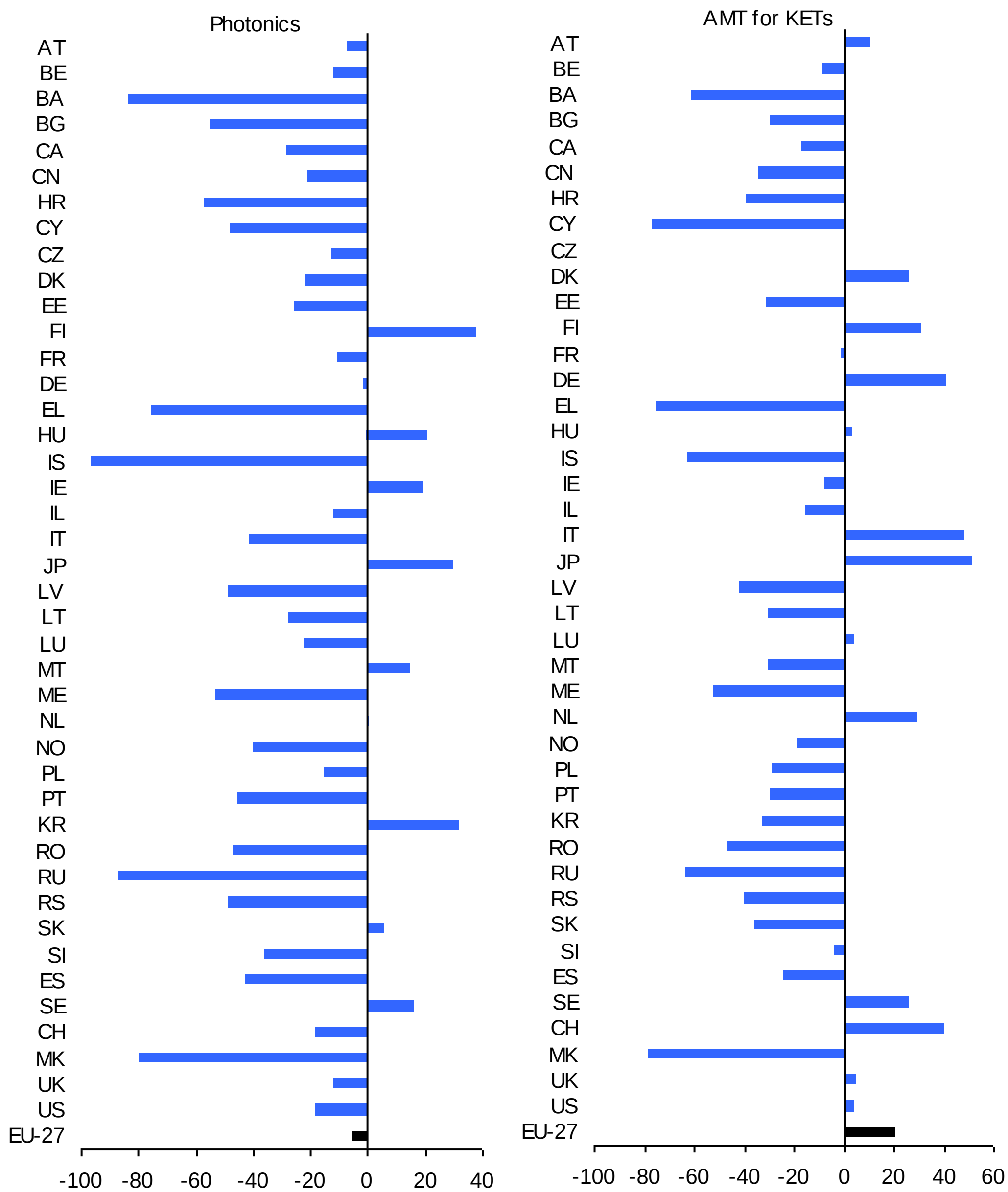

Figure 31: Trade balance for products related to photonics and AMT for KETs, 2002-2010 (in %)[70]

Source: UN Comtrade, calculations by NIW.

[70] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

4.4.3 Strengths and weaknesses of trade indicators

Trade indicators are generally of high quality and high international comparability owing to the high and long-established standards in international trade statistics.

With respect to using trade data to assess performance in KETs, the main limitation refers to the difficulties in identifying KET-based products in product classifications. Since the product classifications used for production and trade statistics rest on the same concepts and use very similar coding systems, the same shortcomings as described in the chapter on production and demand indicators also apply for trade indicators.

With regard to trade indicators, the disclaimer refers to the need for further expert assessment of the PRODCOM/HS codes used to identify each KET, but not on the data quality which is very good.

4.4.4 Next steps to refine/optimize this approach

In order to remove the limitations with regards to identifying KET-based products in product classification, the accuracy of trade indicators for KETs would directly profit from any efforts and progress made in the field of production and demand indicators.

Since linking PRODCOM/CPA to HS is straightforward as far as the six KETs are concerned, there is no room for refinement or optimization in this area.

4.5 Business indicators

4.5.1 Data input and calculation

The input for the calculation of the business indicators are the lists of companies. The initial list of companies is an output of the technology diffusion approach and the component approach. In the technology diffusion approach, a list of organisations has been compiled that appear among the 15 largest applicants of KETs patents based on EPO/PCT patent applications in the period 2000 to 2010[71]. The companies which are among the top-15 patent applicants in the respective KETs area are a first input for the initial list of companies. In the component approach, the list of components developed for each KET, has served as a basis to identify companies that are active in developing and/or producing these components. The initial identification has been done based on existing literature, web searches and expert's knowledge. The number of experts that were consulted in this initial phase was limited. The initial list of companies is a compilation of the list of companies identified through the technology diffusion approach and the component approach.

[71] In the scope of this feasibility study

The companies identified through the component approach included most of the companies identified through the technology diffusion approach. The major players were identified through both approaches[72]. The advantage of the component approach is that also companies that do not patent can be identified and it allows including SMEs in the list.

In a subsequent phase, additional experts have been consulted to further refine the initial list of companies. **The consortium decided to focus the selection of companies on companies that are active in the development and production of KETs components since components tend to be less volatile compared to final products.** In the feasibility study, the list of components is therefore used as a point of departure to identify companies. The aim of the refined lists of companies is to come to a representative list of companies, not to come to an exhaustive list. A representative list of companies is a list of companies that is representative for measuring and monitoring the deployment of a particular KET. This list should include both large players and small & medium sized firms. According to the Consortium, it makes more sense to follow a selected group of companies to monitor the deployment of KETs.

For industrial biotechnology and photonics, a workshop has been organized that was attended by several experts in the respective KET. The goal of the workshop was to validate the initial list of companies. Hence, the goal of the feasibility study was explained and the approach towards selecting the companies. The initial list was discussed with the experts; some companies were removed, while other companies were added to the list. The objective of the workshop was to identify a representative list of companies that are active in the development and production of KETs components. During the workshop, the experts assessed to the best of their knowledge the initial list of companies. The outcome of the workshop is a refined list of companies which cannot be considered as the final list of companies[73]. The reason is that the experts were asked to take the components as given; seen the limited scope of the workshop, there was no opportunity to elaborate the list of components. Moreover, the input received is limited to the knowledge of the experts that were present e.g. the experts in the workshop on industrial biotechnology agreed that in-depth knowledge on Asian companies was lacking. In addition, there was no access to the internet during the workshop so no additional searches could take place. The refined list of companies also has a bias towards larger companies as these companies tend to be better known compared to SMEs (see appendix 3).

For nanotechnology, advanced materials, and advanced manufacturing technologies, we received input from the Commission's internal experts from sectorial units of DG CONNECT and DG RTD and several external experts. This input has been taken into account to revise the initial list of companies. As this input was requested and received on an ad-hoc basis, the list is a refined list of companies that cannot be considered as the final list of companies for these respective KETs (see appendix 3). Further expert validation is necessary to produce a final representative list of companies.

For micro-and nanoelectronics, the initial list of companies was compiled based on the output of the technology diffusion and component approach. When discussing this initial list with internal experts of

[72] See Table 4 for an overview of the organizations with the highest number of patent applications in KETs
[73] The refined list of companies for industrial biotechnology and photonics needs to be further enhanced to come to a final list of companies that can be validated.

the Commission, we were asked to revise this list of companies by taking the worldwide revenue ranking of the Top 25 semiconductors suppliers in 2011[74] and the Top 14 semiconductor foundries[75] as a point of departure. Hence, the approach to come to the refined list of companies for micro- and nanoelectronics differs from the other five KETs as it does not take the list of components as a point of departure to identify companies (see appendix 3).

The refined lists of companies serve as input to extract data from Amadeus. Amadeus is a database of comparable financial information for approximately 19.3 million public and private companies (at micro level) in 43 countries in Europe (Albania, Austria, Belarus, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Rep. of Macedonia, Malta, Rep. of Moldova, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom). The refined lists of companies contain companies headquartered in Europe, US and Asia. As Amadeus only provides data for 43 countries in Europe, only data for companies having their headquarters in these countries, could be extracted. This implies that the lists of companies that has been used to calculate the business indicators, are the refined lists reduced to EU-headquartered companies.

Amadeus contains financial information for public and private companies based on annual accounts. Some data like operating revenue is well covered, while other data contains a lot of missing values e.g. R&D expenses. Initially, several dimensions of business indicators were examined including employment, productivity, profitability, R&D &Technology and location. After checking the data availability, operating revenue and employment were selected to calculate the business indicators on significance, specialisation, and market share and business capacity dynamics[76]. In order to complement the R&D data, our lists of companies was cross-checked with the 2011 EU Industrial R&D Investment Scoreboard. Additional data was found but in general, the coverage (about 40%) was not sufficient to guarantee reliable results. Productivity is based on added value and number of employees. With regard to the variable “added value”, a lot of data is missing. Therefore, this indicator was not retained.

The input for the calculation of the indicators is the companies that are comprised in the refined lists of companies that were compiled for each KET and have their headquarters in Europe. These lists contain small, medium and large companies. Especially for large companies, often not all activities of these companies can be linked to a particular KET. Therefore, it is important to assign a certain weight to these companies that reflect the extent of their KETs related activities. This cannot be easily done using secondary data. The Consortium proxies the weight of companies by calculating the number of patent applications 2000-2010 in a particular KET to the total number of patent applications of that company.

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[74] http://en.wikipedia.org/wiki/Semiconductor_sales_leaders_by_year

[75] http://en.wikipedia.org/wiki/Foundry_model#cite_note-0

[76] If access is obtained to Orbis in the future KETs Observatory, the sample size will be larger and the data coverage will be extended. An increase in data availability will allow including additional business indicators such as productivity and R&D expenses.

We presented the weights to the experts at the workshop of industrial biotechnology and photonics. To their opinion, some weights assigned to companies did not reflect a correct situation. Therefore, it was decided that it was a better option to assess the companies and assign a weight by the experts. It was agreed that following categories would be used:

<=5 limited activity

<=10 small activity

<=25 partial activity

<=50 50/50 activity

<=100 dominant activity

For the experts, it was relatively easy to identify companies that had 50% to 100% of their activities in a particular KET. It was more difficult to assign the weights of 5% or 10 % as this often comprised large multinationals with a diversity of activities. Hence, the importance of the decision to focus on identifying a representative list of companies that is involved in the development and production of components comes into the picture as this formed the basis to assign the weight to multinational companies. In order to reduce the risk for error, it is important to have a balanced team of experts. This implies that the experts have a broad knowledge of the particular KETs industry, not only covering European based companies, but also US or Asian based companies. Ideally, the experts are not affiliated to one particular company, but rather are representatives of cluster organizations or technology associations that represent a broad group of small, medium and large companies.

For nanotechnology, micro-and nanoelectronics, advanced materials, and advanced manufacturing technologies; no weights have been assigned. In the scope of the feasibility study, it was not possible to organize a workshop for these KETs. In order to assign weights, it is necessary to have a group of experts around the table that agree on the weights. As no workshops could be organized for these KETs, no weights have been assigned.

To calculate the business indicators, we opted to work with consolidated data (at corporate level). During the expert workshops it seemed to be easier to assign weights to the company as a whole. Hence, there is no need to look to the different subsidiaries and/or daughter companies when using this system of weights. For several multinational companies, it is often quite complex to examine the different subsidiaries to look for KETs related activities. For example for large companies like Siemens, BASF, Samsung, General Electric, it is very difficult to assign KETs related activities to one specific subsidiary. An extensive search in annual reports and on the website can eventually give an idea of what kind of activities take place in the different subsidiaries, but this approach is not feasible when companies are reluctant to provide this sort of information publicly. Therefore applying weights to the companies allow working with data at the corporate level.

For micro-and nanoelectronics, a different approach has been followed. The refined list of companies only contained three companies with European headquarters. For the companies with headquarters in the US or Asia, we planned to select the European headquarters. It seemed however that most of these non-European companies do not have a 'formal' headquarter in Europe. For most companies, we could identify a limited number of European (sales) subsidiaries. However large companies like Sony and Samsung, have several European subsidiaries. Selecting all subsidiaries would contradict the approach 'i.e. based on the European headquarter, we followed for the other KETs. Therefore we decided to retain only the largest European subsidiary in case there was more than one subsidiary of which none was indicated as formal headquarter. Figure 32 provides an overview of the different steps taken to calculate the business indicators.

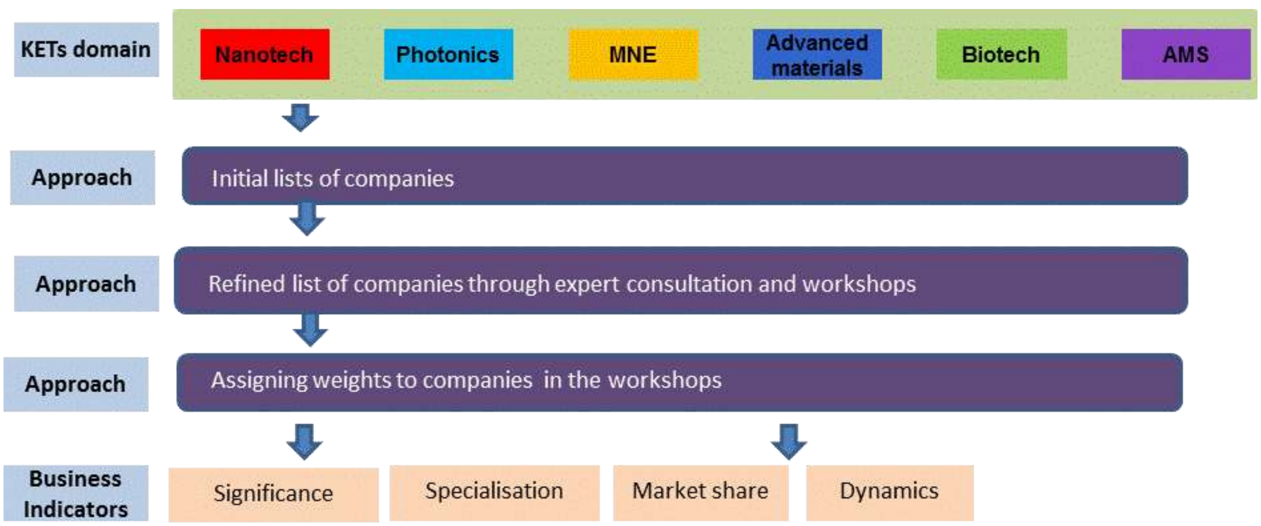


Figure 32: Overview of the different steps take to calculate the business indicators

The **significance** (SG) of a certain KET k in employment or operating revenue (Bx) of country i in year t is calculated as follows: $^{Bx}SG_{kit} = Bx_{kit} / Bx_{it} * 100$. This indicator is defined by the total employment or operating revenue in a certain KET (nominator) divided by total employment or operating revenue in all manufacturing industries (denominator). High values indicate that the country dedicates a substantial share of its resources into the respective KET. This indicator is calculated for each country separately, once for employment and once for operating revenue.

The **specialisation** (SBx) of country i on a particular business indicator in a certain KET k in year t is measured by the revealed comparative advantage (i.e. the significance of a certain KET in a country's employment r operating revenue over the significance of that KET in global particular business indicator). The formula is: $^{Bx}SP_{ki} = ln\ [(Bx_{kit} / I_{kit}) / ((Bx_{it} / I_{it})] * 100$. This indicator relates the significance of employment or operating revenue of a certain KET in the country considered to the average significance of that KET in all (European) countries. The indicator thus tells whether a country puts more or less focus on this KET (by employment or operating revenue) than other countries do. As the indicator relates two shares, it can be subject to extreme values, particularly if the average significance of a KET is very low but a few countries invest quite a lot in developing new technical knowledge in that KET. In order to trim extreme values, we take the natural logarithm (ln) of the relation of the two shares.

The **market share** (MS) of country i in employment or operating revenue for each KET k in year t is calculated as follows: ${}^{Bx}MS_{kit} = Bx_{kit} / Bx_{kt} * 100$. The market share of a country in total employment or operating revenue in a certain KET area indicates the relevance of that country in the respective KET. This indicator, in contrast to the previous indicators, is strongly influenced by the size of a country as larger countries are more likely to have more employment and operating revenue than small countries. The indicator is measured by dividing the total employment or operating revenue of a certain country (nominator) by the total employment or operating revenue in the respective KET area in the EU27.

Finally, the B**usiness Capacity Dynamics** (BxD) of country i for each KET k between year t and the previous year t-1 is calculated as follows: ${}^{Bx}MD_{kit,t-1} = (Bx_{kit} - Bx_{ki,t-1}) / Bx_{ki,t-1} * 100$ *(t-1 represents 2005-2007 and t 2008-2010)*. The dynamics of employment or operating revenue shows whether a country is on an upward or downward trend.

4.5.2 Output

The output of the business indicators can be consulted at the KETs Observatory website (https://webgate.ec.europa.eu/ketsobservatory/[77]). In order to illustrate the output, several graphs will be displayed and discussed in the paragraphs below. The business indicators on significance, specialisation, and market share and business capacity dynamics are based on operating revenue and employment. For each indicator, the results for two KETs will be discussed. The values of the indicators displayed at the website and in the figures below, are subject to change as they are calculated within the framework of this feasibility study. These values are subsequently not validated and should be handled with caution.

Figure 33 shows the significance in operating revenue and employment in industrial biotechnology. Significance is expressed as a percentage. A high value for a certain KET indicates that firms headquartered in that country devote much of their resources to this particular KET.

In terms of operating revenue and employment, Austria shows a high share. Other strong performers are Denmark, Germany, the Netherlands and Switzerland. High values indicate that the country dedicates a substantial share of its resources into the respective KET. Figure 33 displays all countries for which data is available[78].

[77] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

[78]This implies that countries that have a value of zero are displayed, while countries for which no data is available are not shown.

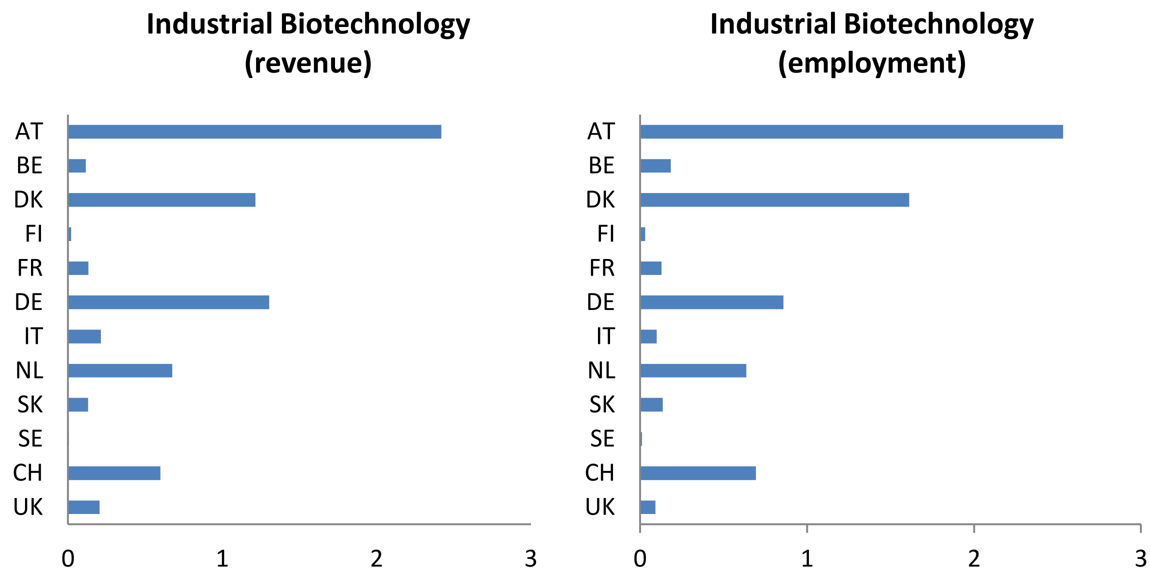


Figure 33: Significance of operating revenue and employment in industrial biotechnology, 2005-2010 (in %)[79]

Source: Amadeus, calculations by IDEA Consult.

The **specialisation** indicator relates the significance of employment or operating revenue of a certain KET in the country considered to the average significance of that KET in all (European) countries. The indicator thus tells whether a country puts more or less focus on this KET (by employment or operating revenue) than other countries does. Figure 34 gives an overview of the specialisation of operating revenue and employment in industrial biotechnology. Positive values are reported for Austria and Denmark for both operating revenue and employment, while Germany and the Netherlands show a positive value for operating revenue but a slightly negative value for employment. Countries that show a low specialisation value are Sweden and Finland.

[79] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

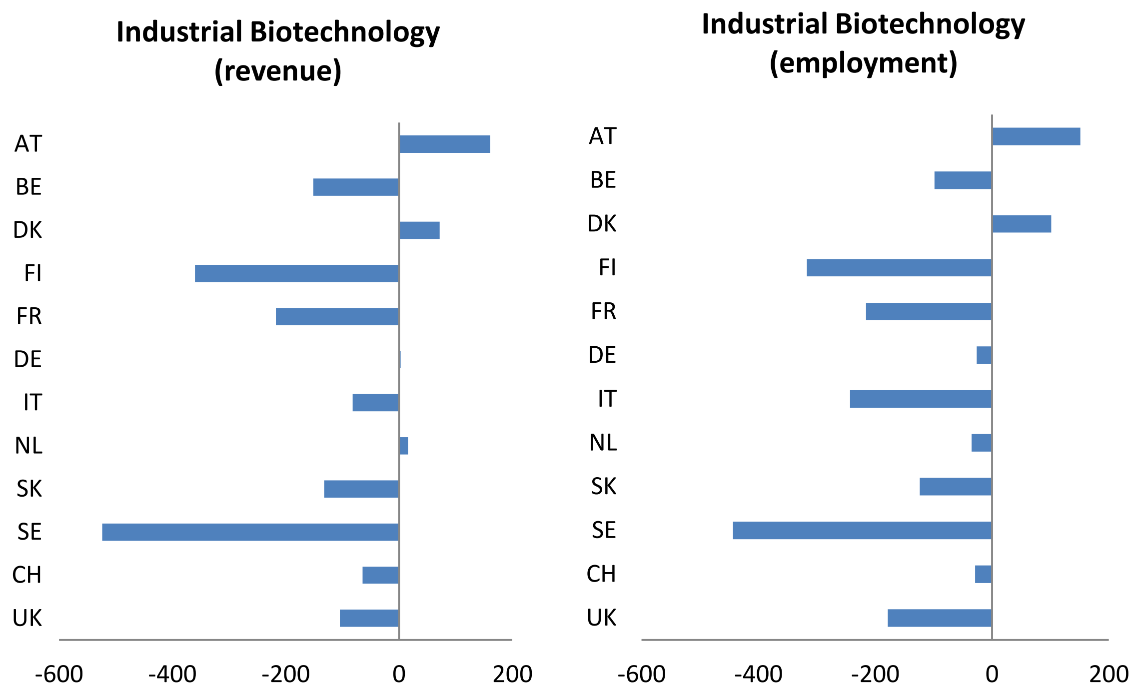


Figure 34: Specialisation of operating revenue and employment in industrial biotechnology, 2005-2010 (value <0 = not specialized, value >0 = specialized)[80]

Source: Amadeus, calculations by IDEA Consult.

The market share of a country in total employment or operating revenue in a certain KET area indicates the relevance of that country in the respective KET. The market share in operating revenues is highest in Germany (38 percent) In addition; also the Netherlands and Italy are important players (Figure 35). Germany is a key player concerning the market share in employment of industrial biotechnology (37 percent). Also Denmark demonstrates a high market share, followed by the Netherlands, Austria, Italy, UK, and Switzerland. It must be noted that this indicator, in contrast to the previous indicators, is strongly influenced by the size of a country as larger countries are more likely to have more employment and operating revenue than small countries. Figure 35 displays all countries for which data is available[81].

[80] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

[81]This implies that countries for which no data is available are not shown.

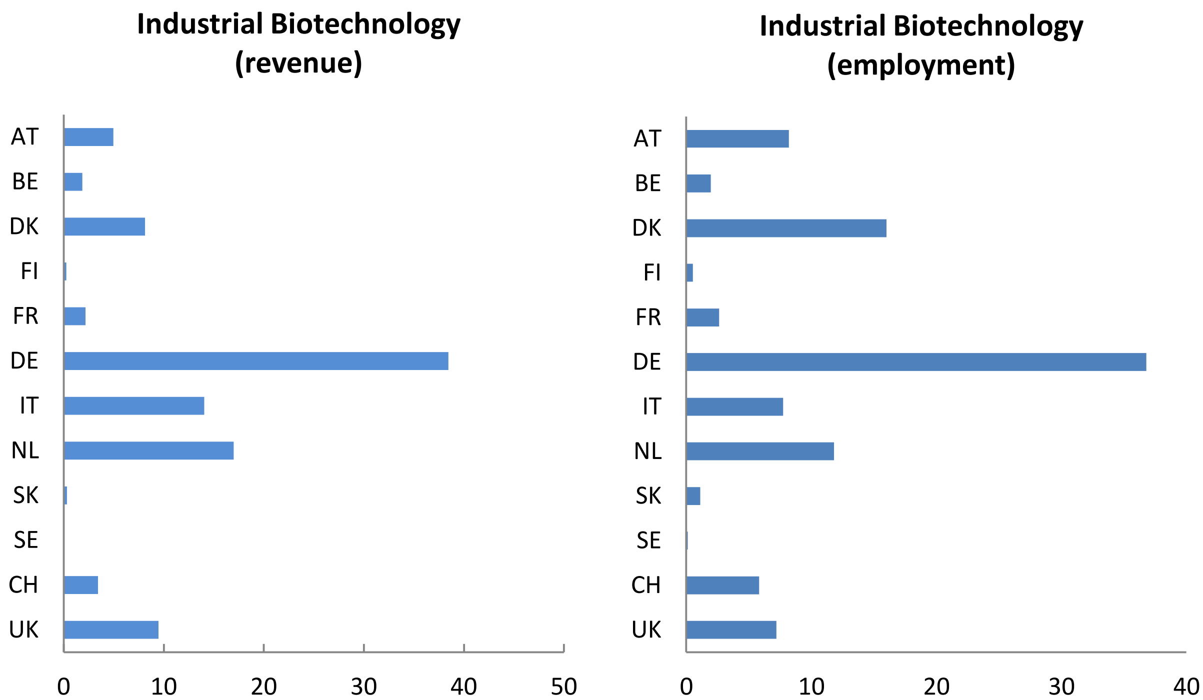
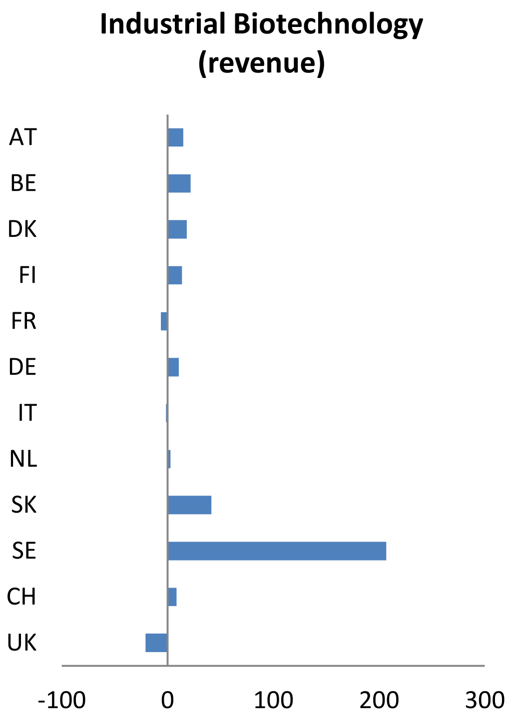


Figure 35: Market share of countries in operating revenues and employment in industrial biotechnology, 2005-2010 (in %)[82]

Source: Amadeus, calculations by IDEA Consult.

The indicator Business Capacity Dynamics refers to the evolution of total operating revenue and employment of a KET over time. This indicator has been calculated between two periods, 2005-2007 versus 2008-2010 (Figure 36). Most countries have operating revenue dynamic which is positive, while several countries demonstrate a negative dynamic in employment in industrial biotechnology. Sweden demonstrates a high value for both operating revenue and employment dynamics. This is due to the fact that in our sample, only two companies have their headquarters in Sweden and one of these firms, a small firm, has grown substantially over the past years. This illustrates again the issue with small absolute numbers per KET in smaller countries, which can lead to very high rates of change, while the change in absolute numbers is rather low.

[82] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.



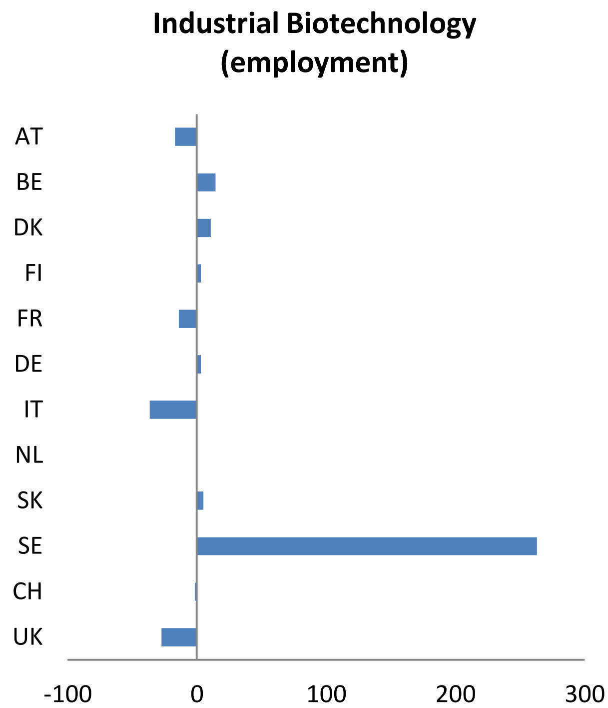


Figure 36: Business capacity dynamics for operating revenue & employment 2005-07 to 2008-10 in industrial biotechnology (in %)[83]

Source: Amadeus, calculations by IDEA Consult.

4.5.3 Strengths and weaknesses of business indicators

The major strength of the business indicators is the fact that company data is highly reliable as it is based on annual accounts. Once a final, validated list of companies is available for each KET, accurate data on the business indicators can be provided. Moreover, data on company level allows shedding insight in the relevance of SMEs per KET and per country. For example, Table 12 demonstrates that companies that have a high share in photonics show a higher average profit margin and growth rate compared to companies with a smaller share. Companies with a high share of KETs activities tend to be small, fast growing companies with high profitability. By using experts to identify companies, small, medium-sized and large companies are included in the sample of companies that is used to calculate the business indicators. The use of experts allows including emerging and promising companies.

[83] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

Photonics	Average profit margin (nr comp)	Average growth rate (nr comp)	Average employment
Share KET in activity < 50%	2.98 (29)	0.32 (28)	39528
Share KET in activity≥ 50%	9.91 (25)	1.10 (21)	3583

Table 12: Division of the companies by the share of KETs related activities in their total activity[84]

Source: Amadeus, calculations by IDEA Consult.

Several weaknesses can be identified. A first major weakness is the input for the calculation of the business indicators. Within the resources reserved for the feasibility study, it was not possible to come up with final validated lists of companies for the six KETs. This implies that the output of the business indicators will be subject to change once the final lists of companies will be available.

A second weakness is the data coverage by Amadeus. In Amadeus, the data availability is typically better for large companies compared to small companies. Small companies tend to be less represented in Amadeus as there are thresholds per country to submit an annual account at the national public body and also because of threshold before companies are included in Amadeus. Especially young and small companies tend to be poorly covered.

A third weakness is related to the assignment of weights to companies. As the best way to assign weight to companies proved to be experts' views, this process is due to subjectivity. In allocating weights, a broad knowledge of the particular KETs industry by the experts is important. In case the experts are familiar with the activities of several companies in a particular KET, they can assign similar weights to companies with similar KETs related activities.

Figure 37 and Figure 38 show the influence of applying the weights. There are some fundamental changes in the market share in operating revenue for industrial biotechnology, while the effect of applying the weights in more limited in the case of photonics. The influence of the weights is seen best in case several multinational large companies are part of the refined list of companies for a particular KET. For example, in case of industrial biotechnology, BASF, Bayer and Evonik are part of the list. These companies have a weight of respectively 5%, 10% and 10%. When applying the weights, the market share in operating revenue of Germany reduces significantly (see Figure 37).

[84] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

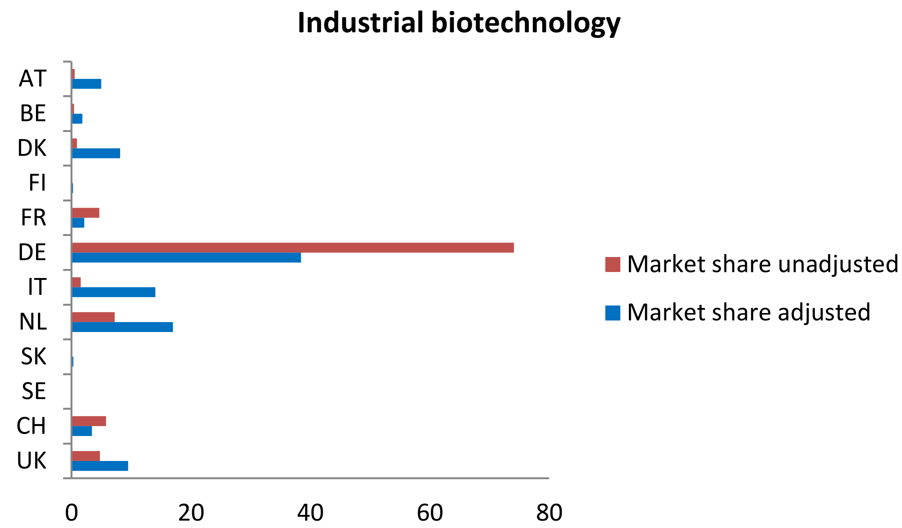


Figure 37: Influence of weights on market share in operating revenues for industrial biotechnology[85]

Source: Amadeus, calculations by IDEA Consult.

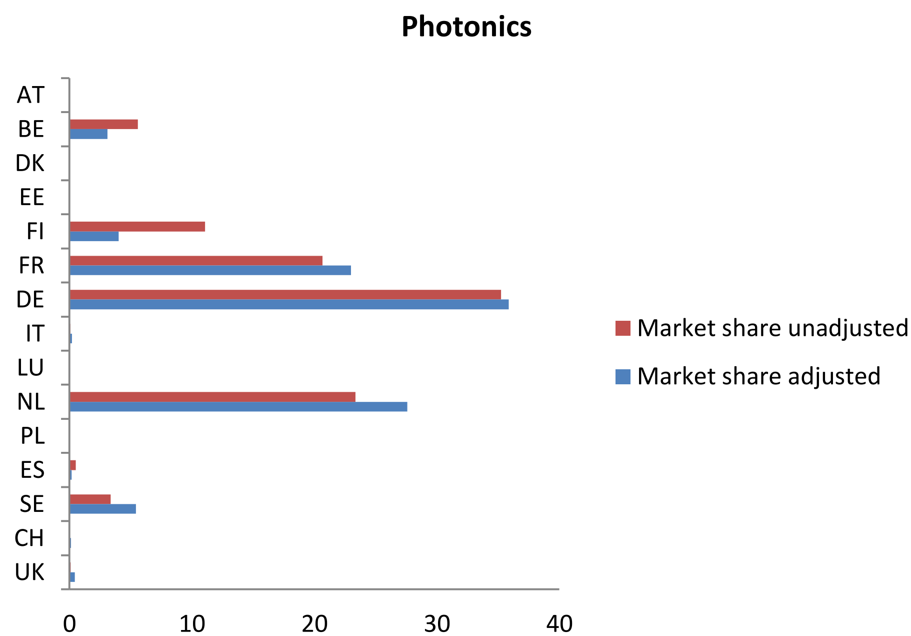


Figure 38: Influence of weights on market share in operating revenues for photonics[86]

Source: Amadeus, calculations by IDEA Consult.

[85] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

[86] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

A fourth weakness is related to the actual calculation of the business indicators. As the Consortium only has access to Amadeus, only data from companies that have their headquarters in Europe could be included to calculate the business indicators. This implies that for most refined lists of companies, an average the calculation of the business indicators is based on only 1/3 of the companies. Table 13 gives an overview of the number of companies that have been included in the calculations versus the total number of companies included in the refined lists.

	Number of companies included for the calculation of the business indicators	**Total number of companies in the refined lists**
Industrial biotechnology	46	113
Nanotechnology	161	224
Micro- and nanoelectronics	25	25
Photonics	69	100
Advanced materials	54	138
Advanced manufacturing technologies	61	97

Table 13: Overview of number of companies included in the calculations versus the total number of companies

As for some KETs, only a limited number of companies could be included to calculate the business indicators, this implies that for some smaller European countries, the results are often based on one or two companies.

A fifth weakness is related to the fact that in our approach, companies are assigned to a country according to the location of their headquarters. Some companies have their production sites at the same location as their headquarters, while other companies choose to locate their headquarters in a particular country due to fiscal reasons. For example, EADS has its headquarters in the Netherlands. While it has many activities in other European countries like Germany and France, the revenues and employment figures of EADS are attributed to the Netherlands.

The business indicators presented in this report and displayed at the website of the KETs Observatory represent an overestimation. More information is needed on the actual KETs-activities of the companies to come to a more nuanced view. For example, the indicator business capacity dynamics in operating revenue should be interpreted with caution as not all growth of (multinational) companies can be attributed to specific KETs-activities.

4.5.4 Next steps to refine/optimize this approach

The initial list of companies is an output of the technology diffusion approach and the component approach. These lists have been further refined to a variety of approaches e.g. experts workshops, expert consultations, international rankings. This results in the calculation of preliminary business indicators. In a next step, it is necessary to compile final lists of companies for all six KETs.

A first step to take is to agree on the lists of components that have been identified for all six KETs[87]. To reach this agreement, it is essential to set up a workshop of technical experts that have expertise in a respective KET. These technical experts need to agree on the definition of a particular KET. Once the definition is set and the boundaries are clear, the components can be identified. In this feasibility study, we have been able to identify most relevant components for each KET using background material and expert views. A workshop of technical experts that validate the definition of each KET and its components is necessary to finalize this step.

In this feasibility study, we have aimed to develop a methodology that monitors the deployment of innovation in the respective KETs areas. As components may form the basis of future end-products which are not yet on the market today and are less volatile compared to final products, we use the list of components as a point of departure to identify companies. Therefore, once the final list of components for all KETs is validated, a group of industry experts can start to identify relevant companies.

In our view, it does not make sense to compile an exhaustive list of companies. Rather we think it makes more sense to compile a representative list of companies. As the goal is to monitor the deployment of KETs, it is sufficient to monitor a representative list[88] of companies in order to detect new trends and evolutions. The group of experts needed to compile final lists of companies ideally consists out of industry experts who have a broad knowledge of the particular KETs industry. For example, experts from cluster organizations or European technology platforms often have an in-depth knowledge of the actors that play an important role in the development and production of particular technologies and innovations. It is also important to include industry experts that have thorough knowledge on US and Asian companies as a representative list of companies needs to cover the entire world, and not just Europe.

In setting up this workshop, it is important that the invited experts are well chosen based on their experience and that they are well prepared when entering the workshop. The participation of experts who reside outside Europe should be considered. This preparation entails having a detailed look at the final list of components and the refined lists of companies that are currently available in order to get familiar with the setting and selection process. For example, it is important that experts acquire information on the companies they are not familiar with, that they consult existing studies to identify additional companies that might for example be raising stars. Extensive communication between the experts and the consultants in charge of organising the workshop will be required in order to come to a

[87] Initially, the consortium identified components and KETs-based products that are commercially available today and in the near future in the component approach. In a subsequent phase, the consortium decided to focus on the list of components.

[88] Experts will need to define what a representative list entails for each KET

final list of companies that is representative for a particular KET. Several iterations will be necessary to derive to the final list of companies.

In the feasibility study, the Consortium only had access to Amadeus. As a consequence, only data from companies that have their headquarters in Europe could be taken into account to calculate the business indicators. Orbis, another database of Bureau Van Dijk, contains comprehensive information on companies worldwide. Hence, in order to calculate the business indicators for all companies included in the final list of companies, it is necessary to obtain access to Orbis. Orbis has not been used in this feasibility study as the Consortium did not have access to Orbis, but only to Amadeus[89]. As Amadeus and Orbis tend to inadequately cover young and small companies, an option is to survey these companies to get a better insight in their KETs-related activities.

In calculating the indicators, it is important to make a difference between small, medium and large companies. Especially large multinational companies often have a variety of activities of which not all are KETs-related. Therefore, it is essential to assign weights to companies to capture the correct extent of their KETs-related activities. During the workshops that were organised in the feasibility study, the experts proposed to distinguish five categories in assigning weights. It will be necessary to validate these categories with the group of industry experts. In addition, weights will have to be assigned to the final list of companies. The preliminary weights obtained in this study for photonics and industrial biotechnology can be used as a point of departure, but should definitely not be regarded as the final choice of weights. In order to make the allocation of weights more objective, the industry experts ideally are familiar with the activities of multiple companies in a particular KET.

In this feasibility project, companies are assigned to a country according to the location of their headquarters. As some companies opt to locate their headquarters in a particular country for fiscal reasons, it may imply that the production facilities are located in another country. Moreover, in recent years, several production activities have been outsourced to other companies and/or other countries. An extensive search in annual reports and the company's website can provide insight in the activities that are taking place in the different subsidiaries, however, this depends upon the availability of information the company releases. For the companies that do not disclose this information publicly, a dedicated survey is the only option to obtain this information.

The data obtained for the indicator significance currently entails an overestimation. This is caused by the fact that we do not have information on how much of the firms' activities are actually KET-related. Assigning weights to companies is important in this regard.

Countries that do have companies that are active in a particular KET but for which no company specific data could be found, are currently not displayed and treated in a similar way as countries that do not have KETs-active companies in their country. If more information is available, a more nuanced view will be obtained.

[89] Access to Orbis can be obtained by paying a license fee to Bureau van Dijk or through the systems of credits in case the organization has access to Amadeus. The actual costs needs to be negotiated with Bureau van Dijk and depends upon the number of users, the type of client, the selected modules, etc.

4.6 KETs deployment indicator – a summary indicator

4.6.1 Input and calculation

The indicators that have been discussed in the previous sections offer extensive information on the state of KETs deployment in different countries. In order to calculate the KETs deployment indicators, a methodology was applied that is widely used for building a summary index out of a number of individual indicators (see, for example, the summary index of the Innovation Union Scoreboard[90]).

For producing a summary indicator, the following steps are performed:

a) Selecting relevant, unidirectional and unique indicators; this means that indicators measure that type of performance that should be measured by the summary indicator, that a higher indicator value indicates higher performance, and that they do not measure performance aspects already measured by other indicators;

b) Transforming the original values of each selected indicator to a common scale, including outlier control and treatment of highly skewed indicators;

c) Weighting each selected indicator by a value that represents the significance of the indicator for total performance;

d) Adding the weighted transformed indicator values to a summary index.

Selecting relevant, unidirectional and unique indicators has been a main objective of the indicator framework presented above. Transformation is done by relating a country's value for a certain indicator (averaged over the period under consideration) to a reference value. The reference value represents the unweighted average of indicator values for a reference group *r* of countries. This reference group should include countries that are regarded as leading in the development and deployment of KETs and represent both large and medium-sized to small countries. We choose the USA, Japan, Germany, Korea, the Netherlands, Sweden, Switzerland and Finland as reference group. The choice of reference countries is not critical for the results achieved, however, but is simple used for easing the interpretation of the summary index.

The transformed indicator values are then multiplied with a weight w and summed up to yield the deployment indicator DI. Finding appropriate weights for each indicator n is anything but straightforward. We choose to use equal weighting by unity except for indicators on significance and specialisation, which are receive a weight of 0.5 since both indicators are more closely related to each other and tend to represent similar performance aspects.

[90] See http://ec.europa.eu/enterprise/policies/innovation/facts-figures-analysis/innovation-scoreboard/index_en.htm.

To calculate the KETs deployment indicators, following formulas have been used (significance (SG), specialisation (SP), market share (MS), export share (ES), import share (IS), trade balance (TB)):

- KETs technology deployment indicator:
  - ${}^{T}DI_{ki} = 0.5({}^{T}SG_{kit} / {}^{T}SG_{ref}) + 0.5\ ({}^{T}SP_{ki} / {}^{T}SP_{ref}) + ({}^{T}MS_{kit} / {}^{T}MS_{ref})$

- KETs production deployment indicator:
  - ${}^{P}DI_{ki} = 0.5({}^{P}SG_{kit} / {}^{P}SG_{ref}) + 0.5\ ({}^{P}SP_{ki} / {}^{P}SP_{ref}) + ({}^{P}MS_{kit} / {}^{P}MS_{ref})$
- KETs demand deployment indicator:
  - ${}^{D}DI_{ki} = 0.5({}^{D}SG_{kit} / {}^{D}SG_{ref}) + 0.5\ ({}^{D}SP_{ki} / {}^{D}SP_{ref}) + ({}^{D}MS_{kit} / {}^{D}MS_{ref}) + ({}^{D}ES_{kit} / {}^{D}ES_{ref}) + ({}^{D}IS_{kit} / {}^{D}IS_{ref})$
- KETs trade deployment indicator:
  - ${}^{E}DI_{ki} = 0.5({}^{E}SG_{kit} / {}^{E}SG_{ref}) + 0.5\ ({}^{E}SP_{ki} / {}^{E}SP_{ref}) + ({}^{E}MS_{kit} / {}^{E}MS_{ref}) + ({}^{E}TB_{kit} / {}^{E}TB_{ref})$
- KETs business deployment indicator:
  - ${}^{Bx}DI_{ki} = 0.5({}^{Bx}SG_{kit} / {}^{Bx}SG_{ref}) + 0.5\ ({}^{Bx}SP_{ki} / {}^{Bx}SP_{ref}) + ({}^{Bx}MS_{kit} / {}^{Bx}MS_{ref})$

4.6.2 Output

Given the large number of combinations between KETs and deployment indicators, we will not give an exhaustive discussion of each result. Instead we demonstrate for each type of deployment indicator (technology, production, demand, trade, business) the result for one KET to illustrate the concept and the main results of the composite indicators. The values of the indicators displayed at the website[91] and in the figures below, are subject to change as they are calculated within the framework of this feasibility study. These values are subsequently not validated and should be handled with caution.

Figure 39 shows the technology deployment indicator for nanotechnology. At world level the US emerges as a key player, followed by Japan. In Europe, Germany and Bulgaria perform well. Also Singapore is quite active in this KET.

[91] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

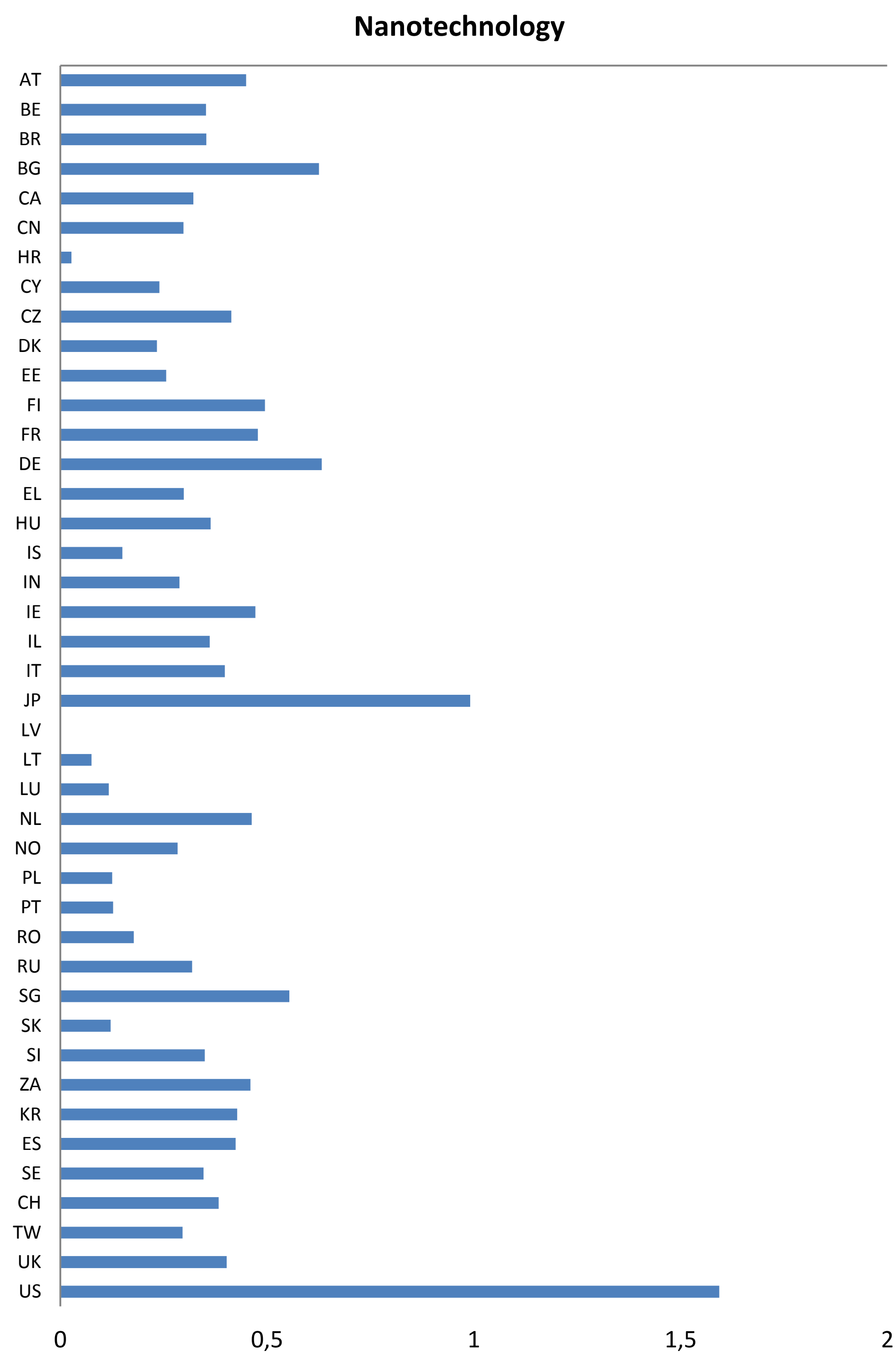


Figure 39: The technology deployment indicator for nanotechnology, 2000-2009[92]

Source: EPO: Patstat, calculations by ZEW.

[92] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

Turning to production, we see in Figure 40 that for micro-and nanoelectronics, Denmark, Germany and UK have a high score, followed by Italy and France.

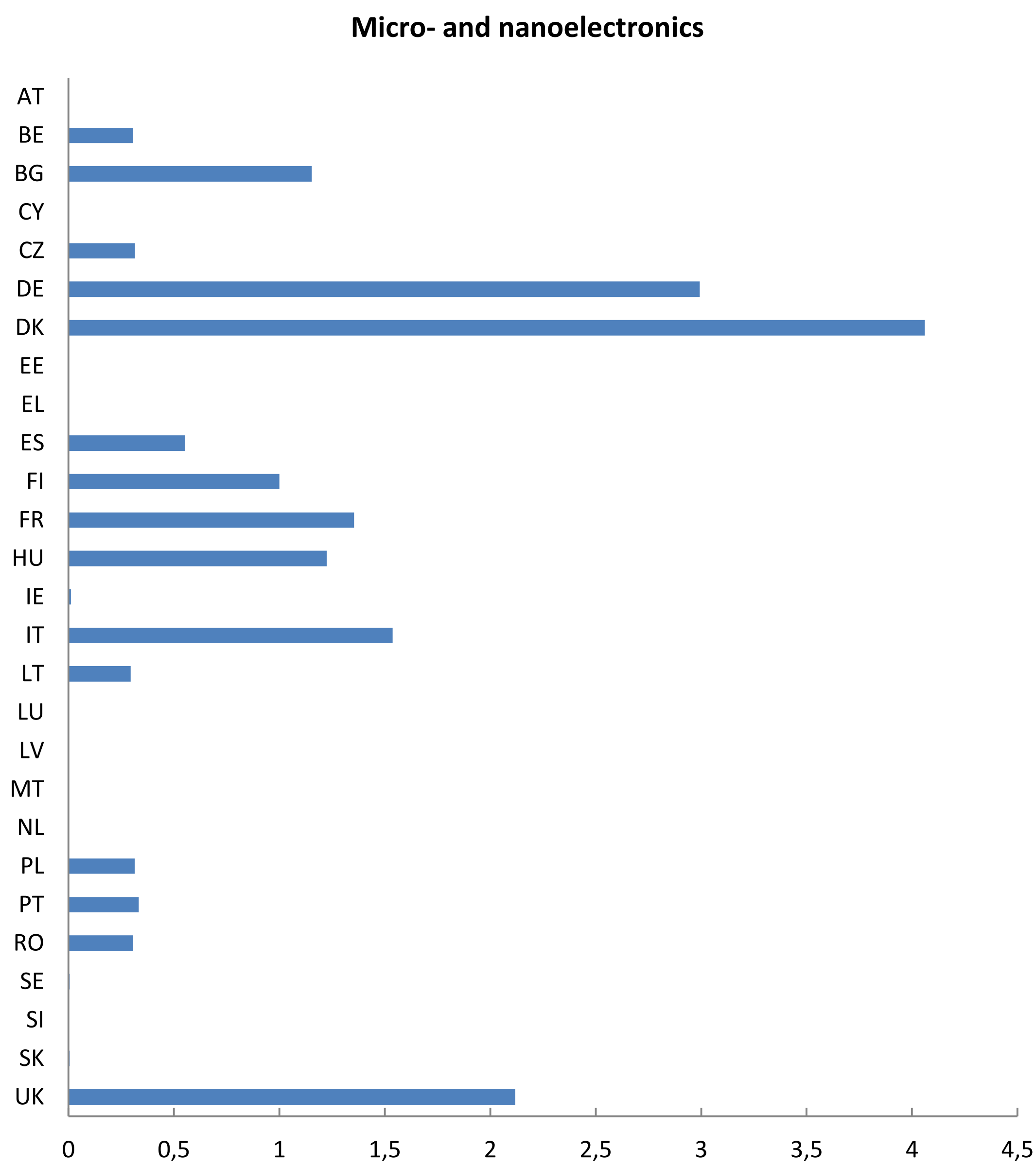


Figure 40: The production deployment indicator for micro-and nanoelectronics, 2005-2010[93]

Source: PRODCOM, calculations by TNO.

[93] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

Looking at the demand composite indicator for micro-and nanoelectronics (Figure 41), Denmark and Germany have the highest scores. Also Italy scores well.

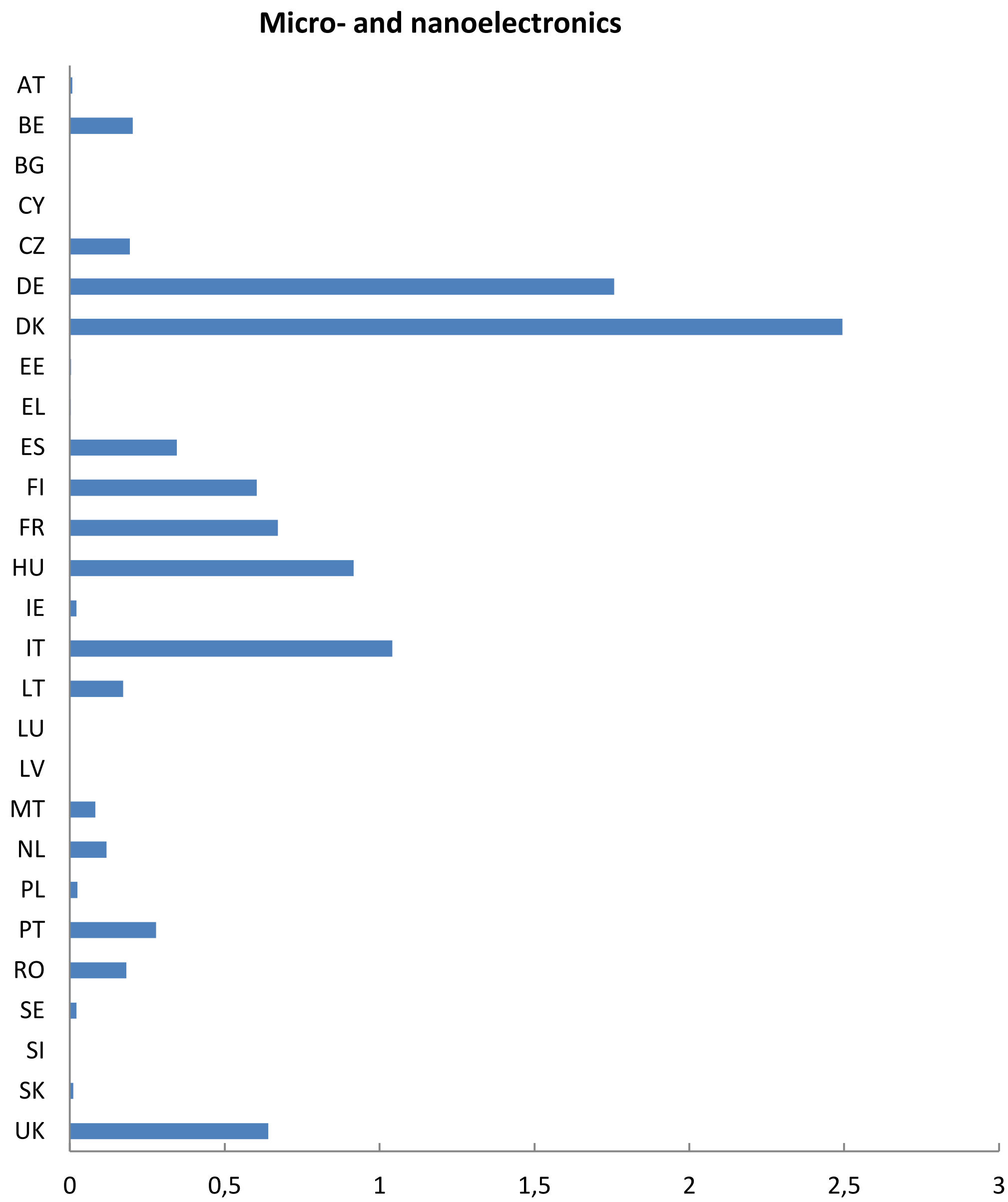


Figure 41: The demand deployment indicator for micro-and nanoelectronics, 2005-2010[94]

Source: PRODCOM, calculations by TNO.

[94] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

In Figure 42 the trade deployment indicator is displayed for advanced manufacturing technologies. We note that trade is dominated by some of the largest manufacturing countries (Germany, Japan, US). Also Italy, Switzerland and the Netherlands score well.

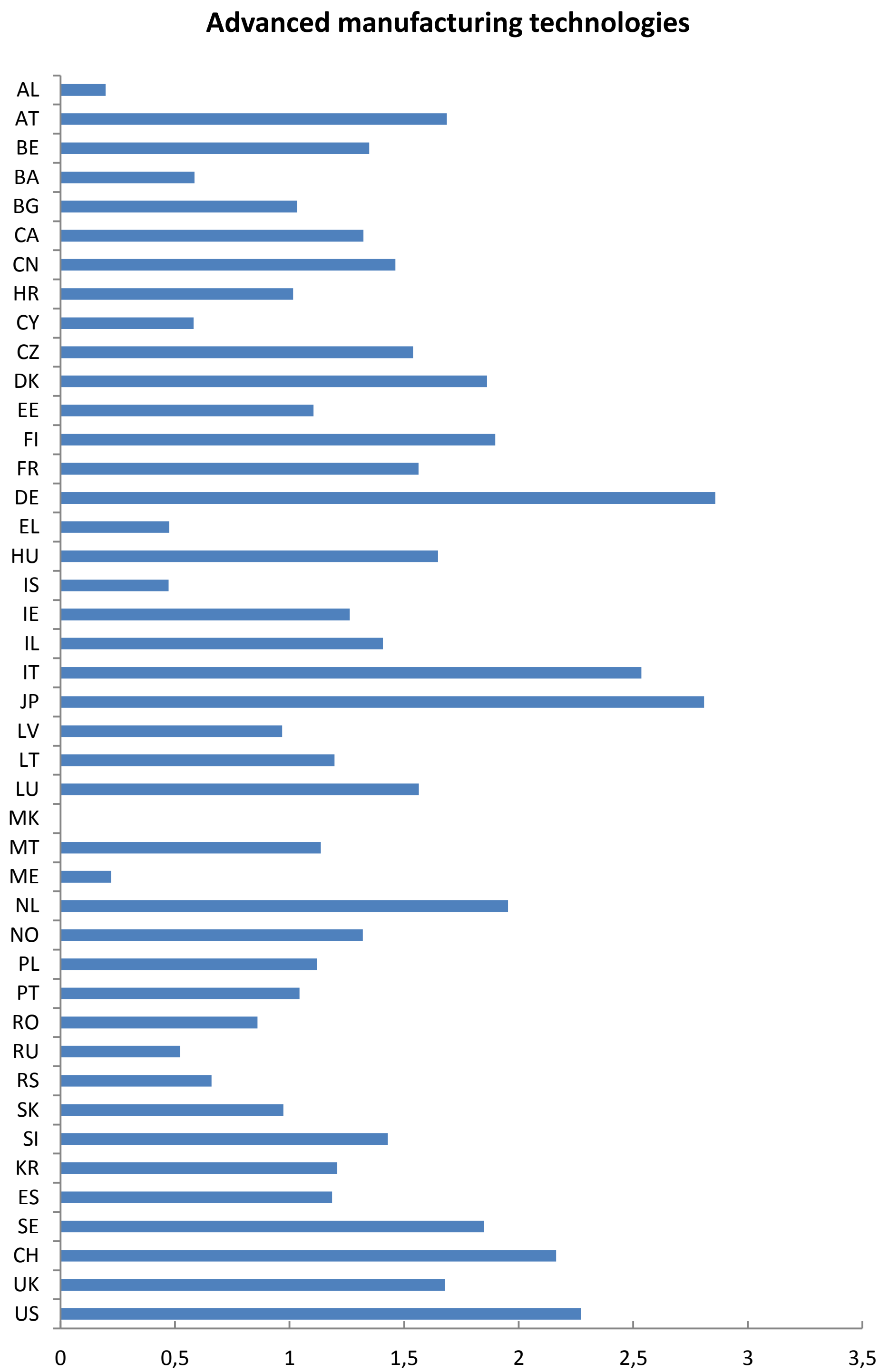


Figure 42: The trade deployment indicator for advanced manufacturing technologies, 2002-2010[95]

Source: UN Comtrade, calculations by NIW.

[95] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

Finally, for the composite business indicator, Figure 43 shows that Austria, Denmark, Germany and the Netherlands demonstrate a high score.

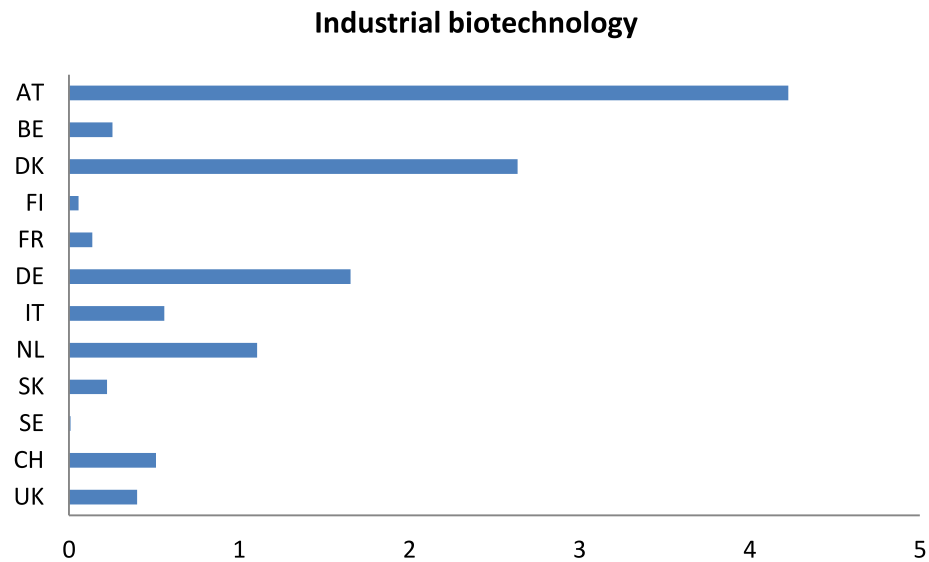


Figure 43: The business deployment indicator for industrial biotechnology, 2005-2010[96]

Source: Amadeus, calculations by IDEA Consult.

4.6.3 Strengths and weaknesses of deployment indicators

The main limitations to the deployment indicators relate to the difficulties identified for each individual indicator as these indicators are used a direct input to calculate the deployment indicators.

4.6.4 Next steps to refine/optimize this approach

The accuracy of the deployment indicators is dependent upon the accuracy of the individual indicators that are used to calculate the respective deployment indicator. Hence, an improvement in the input for the calculation of the individual indicators will result in an improvement of the respective deployment indicator.

[96] The values of the indicators are subject to change as they are calculated within the framework of a feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies. These values are subsequently not validated and should be handled with caution.

4.7 Conclusion

Figure 44 provides a summary of the different steps taken to calculate the different KETs indicators. The output of the technology diffusion approach and component approach has been further refined through expert validation and has provided the input for the calculation of the KETs indicators.

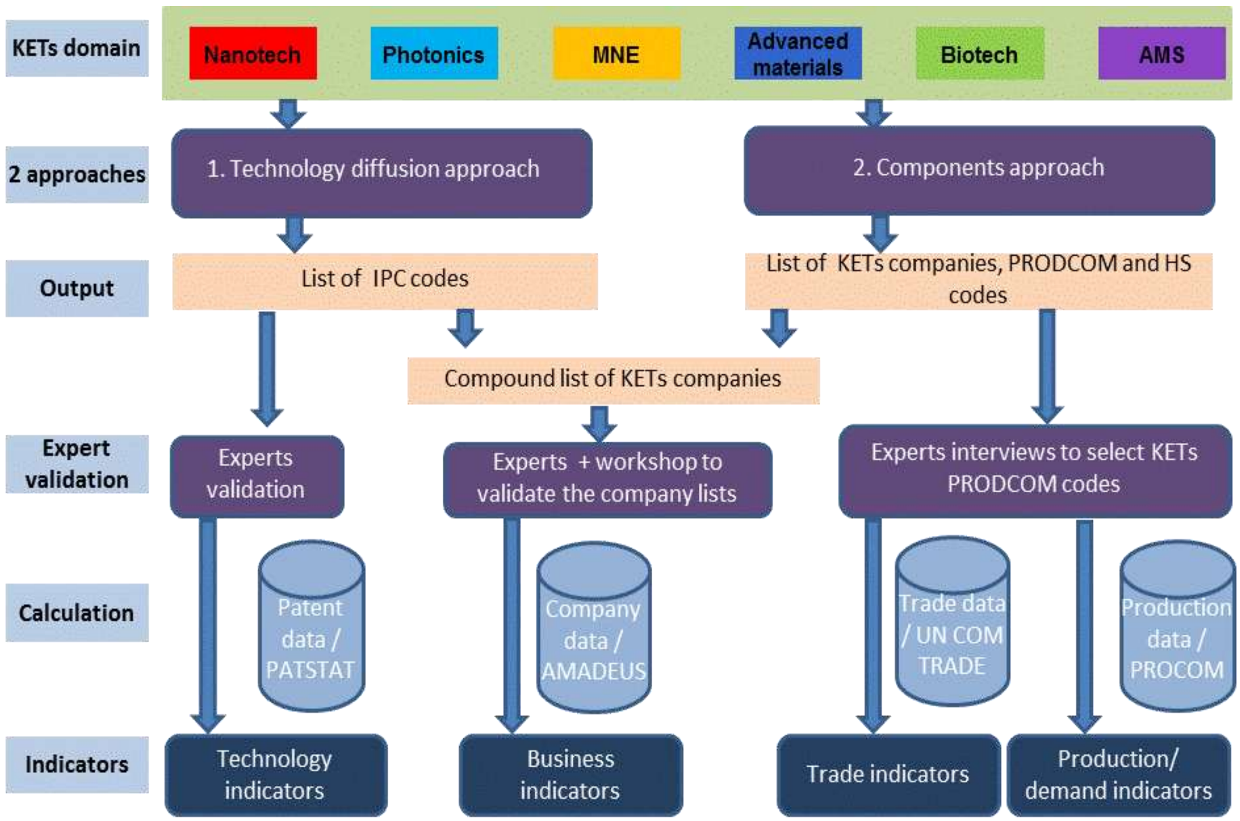


Figure 44: Summary of the different steps taken to calculate the KETs indicators

Table 14 provides an overview of the availability of data that has been gathered in the scope of this feasibility study to calculate the various indicators. The country coverage is dependent upon the countries that are covered in the respective databases. For example, to calculate the business indicators, the database Amadeus has been used. Therefore, only data for Europe is available.

	Country coverage	Year
Technology indicators	EU-28 (including Croatia) and US, Japan, South Korea, China, Taiwan, Canada, Switzerland, Brazil, Norway, India, South Africa, Russia, Israel, Iceland and Singapore	2000-2009
Production indicators	EU27	2005-2010
Demand indicators	EU27	2005-2010
Trade indicators	EU-28 (including Croatia and US, Japan, Korea, China, Canada, Switzerland, Bosnia and Herzegovina, Israel, Iceland, Montenegro, Norway, Russia, Serbia, Macedonia	2002-2010
Business indicators	EU27, Norway, Switzerland	2005-2010

Table 14: Overview of the availability of data

5 Monitoring of EU and extra-EU policies on KETs deployment

5.1 Policy profiles

Policy profiles of all EU27 countries and several non-EU27 countries (China, India, Israel, Japan, South-Korea, Switzerland, and United States) have been compiled in this study. The policy profiles can be a source of inspiration for policy makers that are considering formulating policy measures to stimulate the deployment of KETs.

The policy profiles contain information on national policies with regard to the deployment of KETs. The profiles attempt to be comprehensive, although it might be possible that there exist additional measures with regard to the deployment of KETs that have not been added in the profile. The information is based on desk research of available databases and literature. In the selection of policy measures, following key words were used to identify relevant policy measures with regard to the deployment of KETs:

- Commercial exploitation, commercial development, pre-competitive development, experimental development
- Business model, value chain, industrial roadmap
- Co-funding of public and private sector, public-private partnerships, public procurement
- Prototypes, proof-of-concept, industrial applications, demonstration projects, large test facilities, test environments, joint labs, development of plants

For some countries, it was difficult to find policy measures that particularly target KETs. In that case, more general policy measures were examined and attention was devoted toward the technological areas they target.

For the selected countries, a policy profile per country is available. Each policy profile contains a section on general background, fiches on several selected policy measures and a section on other calls or interesting information. Figure 45 gives an overview of the topics that are comprised in the fiches of the selected policy measures.

Name of policy measure	
Implementing body	○
Targeted KETs	○
General description	○
Date of implementation	○
Target group(s)	○
Overall budget	○

Impact	○
Information sources	○

Figure 45: Structure of the policy measure description

An average policy profile is about 10 pages long. Therefore, we have opted not to include the policy profiles in the report but in appendix 4. All policy profiles are also uploaded on the website https://webgate.ec.europa.eu/ketsobservatory/policyprofiles[97]. The last update of all policy profiles is 12 November 2012.

5.2 Next steps to refine/optimize this approach

It would be very interesting to add regional measures to the current policy profiles. As there was a focus on national policy measures, no regional policy measures have been included in the policy profiles. This is not to say that regional policy measures are not important as they may have a relevant impact. However, in order to include policy measures at a regional level, additional efforts are necessary. For example, covering policy measures at regional level in Germany implies that the effort of data collection is multiplied by 16 times, as each Federal State runs a portfolio of policy measures. In this feasibility study, no sufficient resources were available to cover the regional level.

It would also be good to verify the policy profiles by national policy experts. In the feasibility study, the policy profiles are based on desk research of available databases and literature, no additional verification by experts has taken place. Therefore, the precision of the policy profiles is dependent upon the correctness of information available at national policy websites, websites such as ERAWATCH, national policy reports. Some websites and reports are up-to-date while others have a delay of a few months to a few years. Therefore, it might happen that some policy measures do not exist anymore or has changed names recently and that this has not been captured in the policy profiles. We therefore suggest organizing a workshop with national and regional policy experts from EU27 countries and the 7 non-EU27 countries to verify and validate the policy profiles. In order to make sure that the policy profiles are not outdated, it would be good to update the policy profiles once a year.

The policy profile mentions the overall budget available for the selected policy measure. In case the measure directly targets KETs deployment, the budget available for KETs deployment in a particular country concerning a particular measure, can be assigned. Several policy measures however have a broader scope which makes it more difficult to identify the budget available for KETs deployment. The national and regional policy expert workshop could focus on identifying the relevant KETs deployment budget. This would allow monitoring the available budget for KETs deployment.

[97] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

6 The KETs Observatory website

6.1 Structure of the KETs Observatory website

KETs Observatory is an online monitoring platform that aims to provide a single access point to information and analysis of KETs deployment and KETs related policies in Europe and competing economies.

The homepage is set up as a starting point in order to get quick access to all relevant information on the website. At the moment, all available information is structured around 9 buttons or themes, but the number of buttons can easily been increased or decreased (modular system). The 9 buttons are all supported by an intuitive icon so that the users already get an impression of what is behind the buttons (Figure 46).

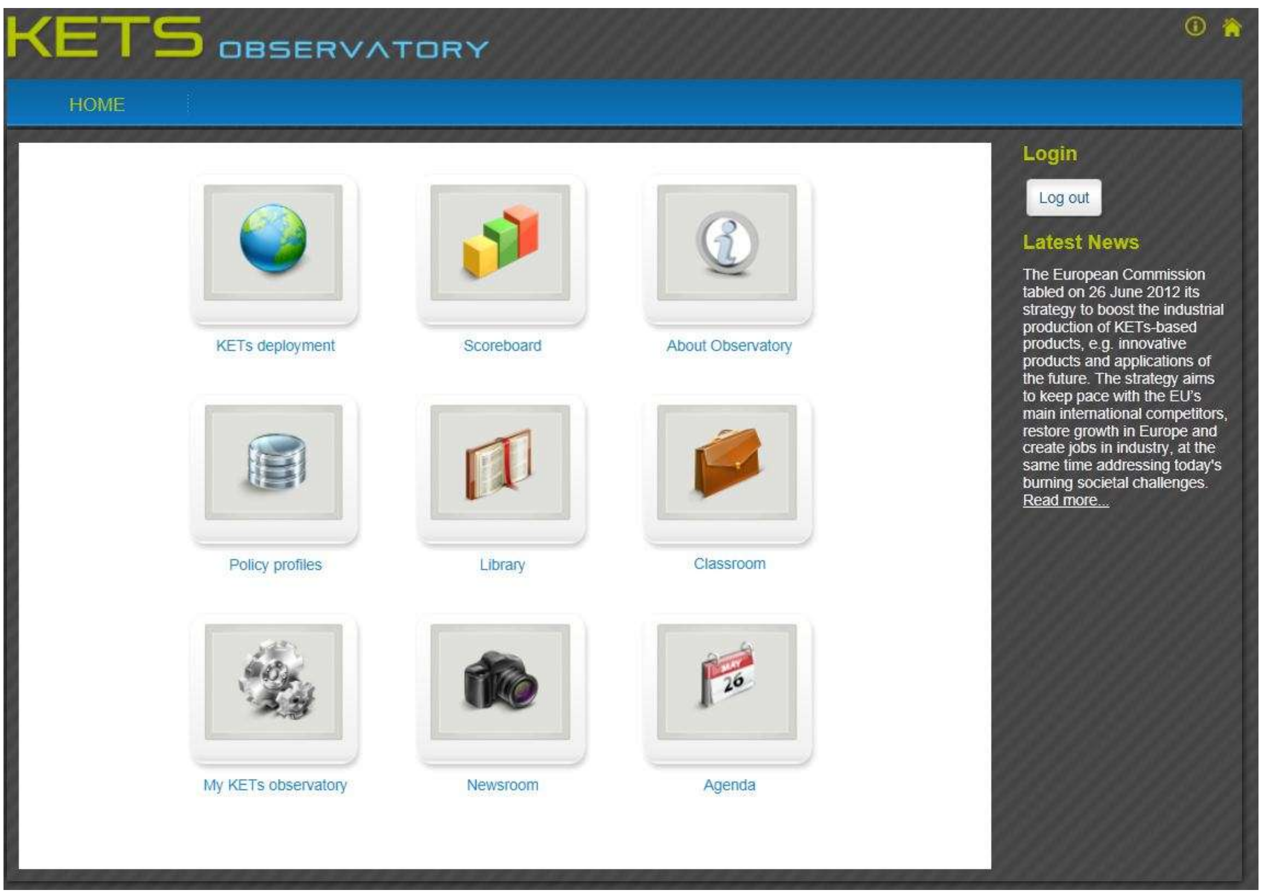


Figure 46: KETs Observatory homepage

6.1.1 KETs deployment

This section provides an interactive overview of all available indicator values plotted on a worldwide map (google maps). Indicators can be displayed by a making a selection of KETS, indicators and countries in the right-hand side banner (Figure 47).

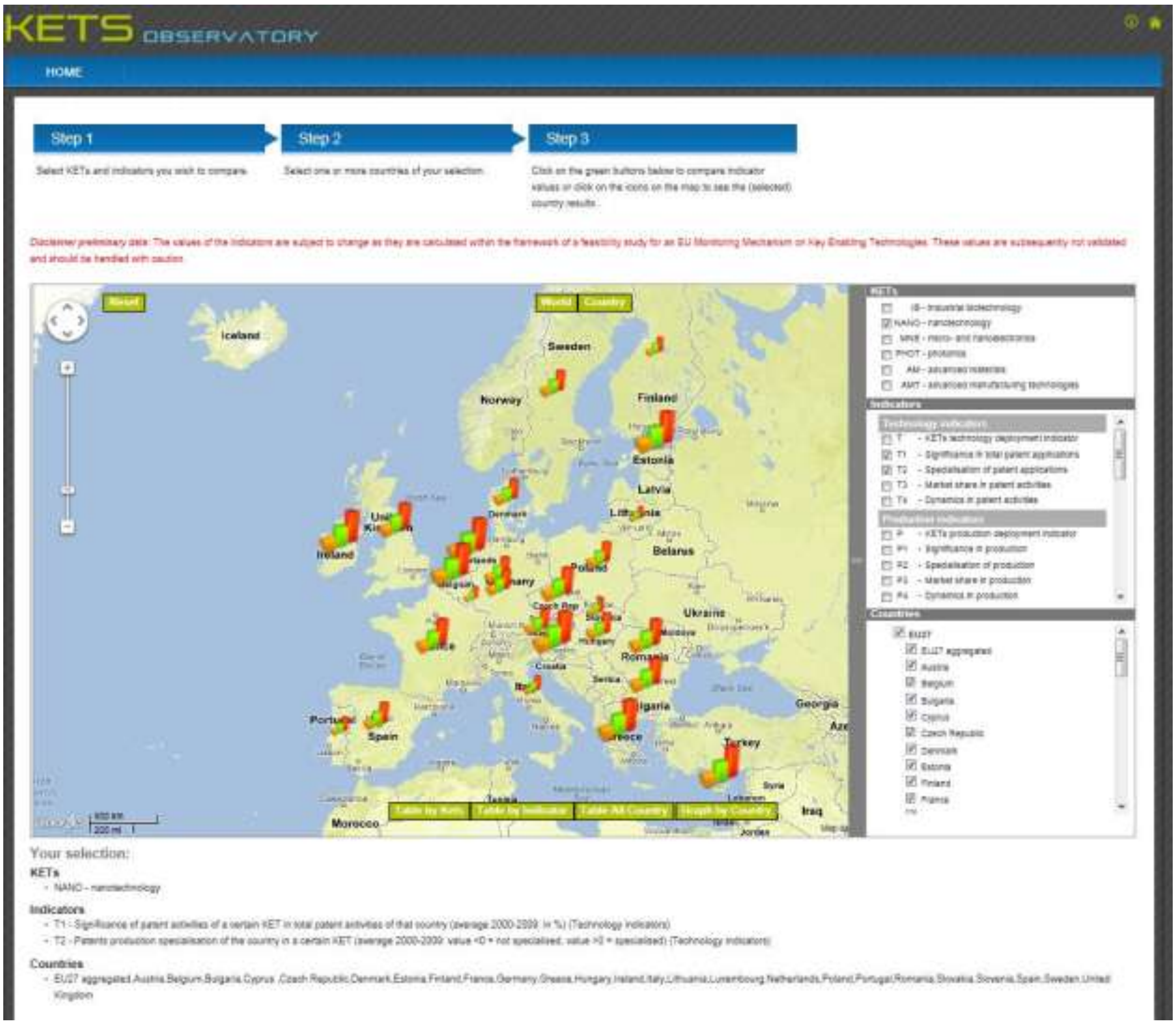


Figure 47: Map demonstrating KETs deployment

As a result of the selection, the indicators values are plotted on a map by a value dependent graph icon (only relevant if one indicator for one KET is selected). The selection is also displayed under the map in order to provide a legend for the abbreviations that are used in the graphs and tables. The legend mentions the KETs, indicators and countries that have been selected. Under the heading 'indicators', a comprehensible explanation is given of each of the selected indicators. The reset button allows clearing the selected KETs, indicators and countries.

There are 5 ways to display the detailed values:

a. Variables for 1 country: all selected variables for 1 country can be displayed (in a graph) by clicking on the graph icon of the selected country on the map. As a result the graphs pop up in banner at the left hand side. In total, variables for six countries can be displayed at a time.
b. Table per KETs: a pivot table is constructed based on the selection of KETs and indicators. The countries are displayed as rows and the KETS and indicators are displayed as columns. In this view, indicators are first structured by KETs and afterwards by indicator.
c. Table per indicator: a pivot table is constructed based on the selection of indicators and KETs. The countries are again displayed as rows and the indicators and KETS are displayed as columns. In this view, indicators are first structured by indicator and afterwards by KETs.
d. Table all country: when selecting a country, a table is created that displays all indicator values for all indicators and all KETs.
e. Graph per country: all variable values are displayed in a graph per KET. In this view it is easy to compare the scores of different countries and indicators per KET. Multiple countries and indicators can be displayed in 1 graph per KET.

The tables can be exported to excel. They can be printed using the print function of excel. The website also contains a EU27 indicator for technology, trade and business indicators. EU27 indicators are not available for production and demand indicators as missing values for several countries prevent the calculation of EU27 totals. The EU27 aggregated value allows for a comparison with other countries such as the US, China, Japan and South-Korea.

6.1.2 KETs scoreboard

Under this section it will become possible to download pdf documents that provide a (static) overview of rankings of indicators values. This section is not yet operational as the indicator values are preliminary and not yet validated. Hence, the values of the indicators are subject to change and should be handled with caution. The excel sheet that is provided to the Commission allows to create rankings according to countries per KET, KETs per country, and scores and rankings of each of the available indicators.

There will be 3 ranking available:

1. PDFs with the scores of each of the countries per KET.
2. PDFs with the scores of each of the KETs per country.
3. PDF for each country with the scores and rankings of each of the composite indicators

6.1.3 About the Observatory

Under this section a concise overview is given of the context of the KETs Observatory. The consortium partners responsible for the execution of the feasibility study are mentioned and a link to their respective website is foreseen. Also the contact details of the project responsible can be found in this section.

6.1.4 KETs policy profiles

Policy profiles of all EU27 countries and several non-EU27 countries (China, India, Israel, Japan, Korea, Switzerland, and United States) have been compiled in this study. The policy profiles contain information on national policies with regard to the deployment of KETs. For the selected countries, a policy profile per country is available. Each policy profile contains a section on general background, fiches on several selected policy measures and a section on other calls or interesting information.

6.1.5 KETs library

This page contains a concise overview of several KETs related studies & policy documents, both from the European Commission as from national governments or private institutes. Once the library contains a good and representative overview of KETs related studies & policy documents, it will be possible to search for relevant documents based on key words. All documents can be sorted by year and/or country. It will also be possible to contribute to the library by adding own documents, that will be published after validation by the KETs Observatory management unit. Thanks to the 'My KETs Observatory' subscription system, users can be notified when relevant documents are available.

6.1.6 KETs classroom

The Classroom can offer educational material (like videos and presentation) which gives an introduction to KETs related topics.

6.1.7 My KETs Observatory

In this section it will be possible to create a detailed profile. Based on this profile it will become possible to subscribe to alerts, newsletters, posted news, agenda. Depending on choices made, registered users will receive all information or only relevant information.

6.1.8 Newsroom

The newsroom will contain KETs related news that is shared among website visitors. The most recent news item will be published also on the homepage in the right hand side banner. Currently, the KETs newsletter is posted here. The KETs newsletter is also added as appendix 5.

6.1.9 KETs agenda

In this section, information about events (such as conferences, seminars and workshops) can be posted by the KETs Observatory management unit or by the European Commission services. It is also possible to contribute to the agenda by adding own events, that will be published after validation by the KETs Observatory management unit. Thanks to the choices made in the 'My KETs Observatory' subscription system, users can be notified when relevant events will take place.

6.2 Content of the KETs Observatory website

Currently the t_0-data is uploaded in the KETs Observatory website for the selected indicators. Table 15 provides an overview of the year that is available on the website. For example, for technology indicators, the values for the indicators on significance, specialisation and market share refer to the average for the 2000 to 2009 period while the values for the indicator dynamics represent the change in patent activity between 2000-2004 and 2005-2009. All indicators values displayed on the KETs Observatory website should be handled with caution as these values have not been validated yet and hence are subject to change.

	Indicator	**Year available on website**
Technology indicators	Significance	Average for the 2000-2009 period
	Specialisation	Average for the 2000-2009 period
	Market share	Average for the 2000-2009 period
	Dynamics	Size-weighted change between 2000-2004 and 2005-2009
Production indicators	Significance	Average for the 2005-2010 period
	Specialisation	Average for the 2005-2010 period
	Market share	Average for the 2005-2010 period
	Dynamics	Change between 2005-2007 and 2008-2010
Demand indicators	Significance	Average for the 2005-2010 period
	Specialisation	Average for the 2005-2010 period
	Market share	Average for the 2005-2010 period
	Dynamics	Change between 2005-2007 and 2008-2010
	Export share	Average for the 2005-2010 period
	Import share	Average for the 2005-2010 period
Trade indicators	Significance	Average for the 2002-2010 period
	Specialisation	Average for the 2002-2010 period
	Market share	Average for the 2002-2010 period
	Dynamics	Change between 2005-2007 and 2008-

	Indicator	Year available on website
		2010
	Trade balance	Average for the 2002-2010 period
Business indicators	Significance	Average for the 2005-2010 period
	Specialisation	Average for the 2005-2010 period
	Market share	Average for the 2005-2010 period
	Dynamics	Change between 2005-2007 and 2008-2010

Table 15: Overview of year that is available on the website for the different indicators

On the website, only indicators at country level are included at this stage of the KETs Observatory. It is however possible to also include data at regional or supranational level as the database behind the website is constructed in an appropriate way to do so. For example, technology and business indicators can be calculated at regional level.

All data can be uploaded on the KETs Observatory website using the backend. More information can be found in the KETs Observatory manual and technical document. The excel sheet that is provided to the Commission contains all data for the years that have been considered in this feasibility study.

6.3 Next steps

At this stage (feasibility study) only the most relevant webpages were developed in order to demonstrate the feasibility of the KETs Observatory. Once the KETs Observatory is planned to be fully operational, the following modules or dimension still have to be developed:

- In 'KETs Observatory Mapping': indicators for more than one year, regional and supranational dimension
- In KETs scoreboard: the different PDFs have to be created based on validated indicator values and they will need to be uploaded in the backend.
- In My KETs Observatory, KETs agenda, Newsroom: the content pages have to be developed based on existing modules and add-ins.

Besides these buttons, it is possible to add other buttons and content pages depending on new activities that will be taken up by the KETs Observatory management unit.

7 Towards a Future Permanent KETs Observatory

7.1 Introduction

During this feasibility study the focus of the undertaken activities lied mainly on conceptual and methodological aspects. The question of measuring the 'deployment' of KETs has proven to be a challenge; a challenge that needed the development of a whole set of new methodological approaches (as discussed and illustrated in the previous chapters). The feasibility study has shown that the developed methods work in practice and lead to interesting and relevant insights. Having said this, however, the feasibility results also clearly point towards the need for further optimization. This optimization should be the single and first priority of the future permanent KETs Observatory.

The KETs Observatory should be built on the conceptual frameworks designed during the feasibility study. The approaches that need to be applied will be the same, but the rigor and scope of application will have to be more intense. The feasibility analysis has clearly shown the need for substantial expert validation, as there are no standards set and as the approaches applied are innovative in nature.

Besides the methodological up-scaling, which is a necessity, there are also a number of options as to what exactly the KETs Observatory will do. These options depend largely on the needs of the stakeholders and the financial means made available for the KETs Observatory. First, we will discuss the methodological up-scaling as this is the backbone of the permanent KETs Observatory. Secondly, we will expand on the future activities of the KETs Observatory and the way these can be organized.

7.2 Methodological up-scaling

7.2.1 Current situation

As it has been illustrated in the previous chapters, at the heart of the KETs Observatory is a methodological framework that needs to be further upscaled and intensified in order to increase the reliability and validity of the data and indicators that are periodically produced, and to increase the scope of coverage. More specifically, the previous chapters have illustrated that there are issues with regard to:

- Unclear definitions of 'components', mainly in light of the differing characteristics of each of the KETs.
- Lack of specific technology, classification and industry insights. Expert validation is essential as it will add 'insider' knowledge with respect to characteristics of the specific KETs, and the classification schemes to be used (e.g. PRODCOM).
- Limited scope / coverage dealt with during the pilot phase (e.g. not all countries could be included in the pilot phase due to the geographical limitation inherent to the databases used).

Table 16 provides a summary of the quality 'assessment' (built on the opinions of the experts and the assessment of the consortium) of each of the developed indicators (Green= minor optimization potential; orange= substantial optimization potential; red= major optimization potential). The issues mentioned here are also discussed in the respective methodological sections presented before.

	Industrial biotechnology	Nanotechnology	Micro- and nanoelectronics	Photonics	Advanced materials	Advanced manufacturing technologies
Technology indicators						
Production indicators						
Demand indicators						
Trade indicators						
Business indicators						

Table 16: Optimization potential of the developed indicators

The technology indicators are the most reliable and thus have a minor future optimization potential. Only for industrial biotechnology and advanced manufacturing, some additional efforts are needed. For industrial biotechnology, it is difficult to exclude red and green biotechnology from industrial biotechnology in the area of enzymes. In addition, some areas of industrial biotechnology such as biopolymers can hardly be identified through IPC codes because these codes include no differentiation by the source of raw materials used. For advanced manufacturing technologies (AMT), identifying AMT for industrial biotechnology, nanotechnology, photonics, and advanced materials turned out to be difficult since many manufacturing technologies are not specific to these KETs. Expertise of technology experts may help to revise the selected IPC codes in this regard.

The production and demand indicators have a major optimization potential. This is largely due to the coverage of the particular KET in terms of PRODCOM entries. Production and demand data tend to be incomplete for some countries, often due to confidentiality issues e.g. production data are not published if output within a certain entry can be easily linked to specific companies. Another difficulty relates to the fact that PRODCOM entries are not technology based but product based. It is therefore important to consult classification experts to refine the selected PRODCOM entries. The production and demand indicators for industrial biotechnology have a slightly better optimization potential as the list of PRODCOM entries has been refined during a workshop. Also for micro-and nanotechnology, the optimization potential is better as a specific focus on chips has been applied.

Most trade indicators have a major optimization potential. This is largely due to the issues related to the selection of relevant PRODCOM entries as trade data is of high quality and high international comparability. As the linking of PRODCOM to HS is straightforward, there is no additional need for optimization in this area.

Most business indicators show a major optimization potential as well. In this feasibility study, it has not been possible to develop final validated list of companies. Once these lists become available, the values of the business indicators will change. Further optimization routes in a nutshell are the assignment of weights to all companies for all KETs, the allocation of data to the production sites of the company instead of its headquarters, and the inclusion of data for non-European countries. For industrial biotechnology and photonics, the optimization potential is substantial instead of major thanks to the experts' opinions that have been gathered during and after the workshops that have been organized.

The general conclusion is that the presented data and indicators can be improved significantly if different experts can be engaged to validate the required input (basis) to calculate the indicators. **Improvements can be made to all indicators, however further validation will have to make clear if all identified weaknesses can be solved and/or if additional issues arise.**

7.2.2 Routes for optimization

Several routes for optimization can subsequently be formulated. These routes will increase the effectiveness and reliability of the indicator framework. The developed methods themselves are as such not questioned, on the contrary. They have proven their value. Expert involvement is nevertheless needed in view of the tremendous complexity of KETs and their deployment potential. The suggested routes should be run in parallel as they address specific aspects.

7.2.2.1 Route 1: Setup panels of technology experts

The feasibility study has clearly shown the need for expert involvement in the definition and identification of KETs components, as the basis for the identification of companies producing these components and as input for the identification of PRODCOM entries. Technology experts can not only help identifying current components, but can also provide their vision on future components. Also for the technology diffusion approach, a solid list of IPC codes is necessary; the technology experts can also help to setup/validate this list as well. Technology experts are experts with an extensive technological knowledge on a particular KET or multiple KETs.

The current list of components per KET, forms a strong starting point, but will have to be further expanded and validated. The two validation sessions (for industrial biotechnology and photonics) carried out during the feasibility study, showed that this is indeed necessary. At the start of the permanent KETs Observatory, we envisage a major effort in establishing what we would like to refer to as a "representative list" of key components per KET. Also the list of IPC classes will have to be confirmed. In subsequent years, the tasks of these experts will be to maintain and update the representative list. It is important, in view of the differences per KET, to group experts around specific KETs. Concerning the number of experts per panel, ideally one would group 6-8 experts per panel in order to have sufficient variety in expertise.

In summary, the technology expert groups would be tasked with:

- Providing a clear definition of “components” for each KET;
- Validation and expansion of the current list of identified components per technology;
- Validation and expansion of the current list of used IPC codes per technology;
- Annual monitoring and updating in view of future developments.

7.2.2.2 Route 2: Setup panels of classification experts

The permanent KETs Observatory needs to be able to address classification experts, and mainly experts in PRODCOM/HS classes. As the developed approaches are based on linking components to existing trade and production data through PRODCOM/HS codes, it is important to be sure that the selected codes indeed represent trade and production of the relevant components and nothing else. The experts would be asked to identify relevant PRODCOM/HS codes and indicate the degree to which underlying data are indeed attributable to the components concerned (by providing a weight)[98]. This would then make it possible to calculate trade and production indicators with a higher level of accuracy.

Linking PRODCOM to HS is straightforward as far as the six KETs are concerned. Therefore, classification experts need to have a thorough knowledge of the PRODCOM entries and the way the PRODCOM data is compiled. This expertise can be found at EUROSTAT and in several national statistical offices.

In summary, the classification expert groups would be tasked with:

- Validation and expansion of the currently identified set of PRODCOM/HS codes per KET;
- Development of weighting factors, that need to be applied in order to calculate PRODCOM/HS based statistics;
- Development of a “representative list” of PRODCOM/HS codes together with associated weights, that can be used for the calculation of trade and production statistics and indicators;
- Annual monitoring and updating in view of future developments.

7.2.2.3 Route 3: Setup panels of industry experts

The correct identification of companies that are involved in the deployment of KETs is essential towards the production of reliable business indicators. The composition of representative lists of companies for all KETs is essential in this regard. The permanent KETs Observatory should have access to a panel of industry experts. These experts will be tasked with the expansion and validation of the current list of identified companies. During the first year, this will be a major effort; in subsequent years, it is expected that periodic updating will suffice. Once the list of companies is stable and of high quality, the approach as illustrated in the previous chapters will be applied in order to calculate high-quality business statistics and indicators of KETs active companies.

[98] Assigning weights could happen in a similar way as has been applied to assign weights to companies, see section 4.5.1

Industry experts are experts that have a broad knowledge of a particular KETs industry combined with an in-depth knowledge of the actors that play an important role in the development and production of particular KETs. This expertise can be found in large cluster organizations, European technology platforms and similar types of initiatives. It is important to select industry experts that are not bound to a particular company or to particular industry interests in order to allow for an objective opinion with regard to the compilation of the final list of companies and the assignment of weights.

To summarize, the panel of industry experts would be tasked with:

- Validation and expansion of the current list of identified companies active in the deployment of KETs;
- Development of weighting factors, that need to be applied in order to account for the right share of KETs deployment intensity of the companies concerned;
- Development of a "representative list" of companies involved in the deployment of KETs, a fixed sample of companies that will be followed over time;
- Annual monitoring and updating in view of future developments.

7.2.2.4 Route 4: Development of a dedicated survey

The feasibility study has clearly proven that even with extensive expert involvement there will always be information gaps than can only be filled by approaching the companies directly. This is in particular valid for the identification of the location of production facilities of particular companies. Currently, the data sources for the calculation of business indicators (e.g. Amadeus) are based on the location of the headquarters. However, some companies have their headquarters in a particular country due to fiscal reasons, while they do not have any production facility in that country. A second information gap that can be addressed by a dedicated survey is to collect data on SMEs. The Amadeus database tends not to cover SMEs well. A dedicated survey might offer a way to collect information on SMEs that are comprised in the final list of companies but for which no data is available in Amadeus. This type of information will be difficult to obtain, but with the right incentives in place and guaranteeing anonymity, companies might be inclined to cooperate. In order to enhance collaboration, it might be good to supplement a web-based survey with a follow-up by telephone. In addition, the industry experts might invite the members of their organization to fill in the web-based survey. A recommendation letter of the European Commission is also helpful to enhance participation. Synergies can of course be explored with existing surveys, like the periodic CIS survey.

7.2.2.5 Resulting optimization potential

The suggested routes should be run in parallel as all routes enhance the value of the input to calculate the indicators. Table 17 gives an overview of the optimization efforts that are still needed and the experts that are required to realize this.

	Needed optimization effort	Experts needed
Technology indicators	Limited	• Technology experts
Production indicators	Huge	• Technology experts • Classification experts
Demand indicators	Huge	• Technology experts • Classification experts
Trade indicators	Minor	• Technology experts • Classification experts
Business indicators	Major	• Technology experts • Industry experts • Dedicated survey

Table 17: Resulting optimization potential of the developed indicators

To enhance the technology indicators, a limited effort is necessary to turn all technology indicators for all six KETs in green. Only technology experts are required to optimize this approach.

For the production and demand indicators, a huge effort is required to optimize this approach and make the indicators reliable. This is largely due to the coverage of the particular KET in terms of PRODCOM classification codes entries. Production and demand data tend to be incomplete due to confidentiality issues e.g. production data are not published if output within a certain entry can be easily linked to specific actors. This can be partly solved by convincing national statistical offices to provide data on an aggregate basis for the six KETs. This is a challenging and time consuming task. In addition, technology experts are needed to define KETs components so that a clear selection of PRODCOM entries is possible. Next, the expertise of classification experts is required to select relevant PRODCOM entries and to assign weights to these entries with regard to the six KETs.

The trade indicators have a minor optimization potential as there is only a need to select relevant PRODCOM codes. Once the relevant PRODCOM codes are selected, they can be linked to HS codes and trade data can be gathered. The coverage of trade data is of high quality and high international comparability. The issues with the PRODCOM data and assigning weights are not applicable for the trade indicators. Technology experts are needed to define KETs components while classification experts are essential to select the relevant PRODCOM entries.

For the business indicators, a major effort is required to enhance the optimization potential. Technology experts are needed to define KETs components as they serve as a basis to compile a list of companies. Industry experts are essential to identify companies and to assign weights to these companies. A dedicated survey allows collecting information on the production sites and SMEs that are not covered in Amadeus.

7.3 Future activities of the permanent KETs Observatory

The activity portfolio of the permanent KETs Observatory should be triggered by the needs of its main users: the primary target group, being policy makers on EU and national/regional levels (European Commission and national governments dealing with innovation/industrial policy), and the secondary target group, being industry and industry related organizations and RTDI institutions.

7.3.1 Identified 'needs'

At the start of the feasibility study, a number of exploratory interviews were carried out in order to identify the needs of various stakeholders (see Table 18). Although the number of interviews was far from representative, it did provide insight into several important aspects. Below we summarize the identified needs and vision aspects in relation to the permanent KETs Observatory.

Interviewee	Organisation
Cohen Stuart	Dutch Polymer Institute
Dariusz Drewniak	Ministry of Science and Higher Education, Poland
Egbert-Jan Sol	TNO
Gabriel Crean	CEA
Gilbert Declercq	IMEC
Goran Linqvist	Clsuterobservatory
Harald Gruber	EIB
Jean-Frédéric CLERC	CEA Grenoble
Johan Van Helleputte	IMEC
Laurentino Lavezzi	French government
Leena Sarvaranta	VTT
Marc Morrison	ObservatoryNano
Markus Müller-Neumann	BASF
Mark van Spall	ASML
Martin Meier	Volkswagen Group
Nelly Kernevez	Soitec
Nikos Pantalos	European Commission, responsible for ClusterObservatory
Patrick BERNARD	SAFT
Patrick de Jager	ASML
Ron Van Baden	Philips
Shiva Dustdar	EIB
Thomas Zadrozny	Nanofutures

Table 18: List of interviewees

The KETs Observatory should…

- Be exclusively open to EU-based actors;
- Provide 'objective' and 'timely' information;
- Mobilize an active European KETs community that is strongly networked;
- Provide economical not technical data (although some also plead for R&D type of data);
- Mobilize a network of (national) experts that 'feed' information into the KETs Observatory;
- Provide KETs based data and not sectorial data;
- Provide tailored 'fact-sheets' summarizing quantitative and qualitative information;
- Make use of professionally developed and produced data and indicators;
- Develop and maintain a database of companies being key (e.g. 'integrator' companies) and thus active at the forefront of KETs-deployment;
- Be easily accessible and searchable.

Part of these needs is almost automatically taken into account under the methodological up-scaling, which is as argued a necessity for improving data and indicator reliability. Other needs will also be covered by the activities of the KETs Observatory. More details are provided below.

7.3.2 Future activities

On the basis of the above mentioned needs, the KETs Observatory shall carry out 4 types of activities: 1) methodological activities, 2) data collection activities, 3) analytical /study activities, and 4) outreach activities. Table 19 presents an overview of the main activities foreseen at this point in time.

Type	Description
METH	Setup and management of pools of technology, industry and classification experts ✓ *Concerns: selection of experts, contacting, contractual arrangements, organization of meetings, animation of meetings, processing of results, contact point in case of questions, etc.*
METH	Refinement of list of IPC codes ✓ *Concerns: refinement of the list of IPC codes for industrial biotechnology and advanced manufacturing technologies*
METH	Development (& updating) of a representative list of KETs components ✓ *Concerns: literature screening, selection and analysis key components per KET, comparison to feasibility study, description of characteristics, expert interaction, validation & refinement, etc.*
METH	Development (& updating) of a representative list of relevant PRODCOM codes per KET ✓ *Concerns: literature screening, selection and analysis PRODCOM/HS classes, comparison to feasibility study, description of characteristics, expert interaction, allocation of 'weights', validation & refinement, etc.*
DAT	Identification (& updating) of a representative list of EU deployment companies per KET *Concerns: literature screening, comparison to feasibility study, description of characteristics, analysis of production location versus HQ location, integration versus disintegration, expert interaction, allocation of 'weights', validation & refinement, etc.*

Type	Description
DAT	Identification (& updating) of a representative list of non-EU deployment companies per KET ✓ *Concerns: literature screening, comparison to feasibility study, description of characteristics, analysis of production location versus HQ location, integration versus disintegration, expert interaction, allocation of 'weights', validation & refinement, etc.*
DAT	Annual survey setup and implementation ✓ *Concerns: interaction with Eurostat, setup of questionnaire, expert validation, survey development, piloting, follow-up etc.*
DAT	Inventory (& updating) of national and/or regional KETs deployment policy support measures ✓ *Concerns: selection of experts, contacting, contractual arrangements, organization briefing books, briefing of experts, facilitation of inputting, follow-up, etc.*
IND	Indicator development and calculation of KETs Deployment Scoreboard (on the basis of indicator framework developed during feasibility study) ✓ *Concerns: data retrieval and cleaning, analysis, calculation of indicator framework as developed during feasibility study, expert validation, integration into database, website etc.*
ANA	Development of factsheets on KETs deployment ✓ *Concerns: definition of objectives and scope, specific data retrieval and cleaning, analysis, validation, reporting etc.*
ANA	Development of focused policy briefs on KETs relevant issues ✓ *Concerns: definition of objectives and scope, specific data retrieval and cleaning, analysis, validation, reporting, presentation etc.*
ANA	Development of an annual report on EU's position with respect to KETs deployment and major trends therein ✓ *Concerns: definition of objectives and scope, specific data retrieval and cleaning, analysis, validation, reporting, presentation etc.*
ANA	Treatment of ad-hoc (study or analytical) request made by the European Commission ✓ *Concerns: definition of objectives and scope, specific data retrieval and cleaning, analysis, validation, reporting, presentation etc.*
OUTR	Production and distribution of a KETs deployment newsletter ✓ *Concerns: definition of objectives and scope, specific data retrieval and cleaning, analysis, validation, drafting, advice from editorial committee/advisory board, lay-out, distribution etc.*
OUTR	Networking events (workshops, conferences, etc.) ✓ *Concerns: definition of objectives and scope, specific data retrieval and cleaning, programme design, invitation of experts, travel arrangements, facilitation during event, summary, distribution of key findings, etc.*
OUTR	Development (& update) of tutoring material on KETs ✓ *Concerns: definition of objectives and scope, preparation and development of material, validation by advisory board, inclusion in website, periodic updating etc.*

Type	Description
OUTR	Monitoring of public procurement calls in relation to KETs ✓ *Concerns: definition of objectives and scope, monitoring TED and national sources, identification of interesting leads, registration, distribution etc.*
OUTR	Website management ✓ *Concerns: preparation of material for website, submission to technical partners, updating of website with data and/or reports, factsheets, ad-hoc corrections etc.*

Table 19: Activities of the KETs Observatory

The KETs Observatory shall also monitor public support policies on KETs deployment. In order to do so, there is a need for a network of national experts that will periodically feed in information on national/regional policy trends regarding KETs. One could envisage intensive collaboration with existing platforms (like Erawatch) in order to make efficient use of public funding.

Annually, the KETs Observatory shall develop a number of factsheets. These can be factsheets per KET, or even more integrated, containing data and indicators (based on the indicators types developed during the feasibility study) on KETs deployment, per country and/or on the EU level. Besides the factsheets, we also envisage targeted policy briefs and an annual, more analytical report on the deployment of KETs in Europe vis-à-vis other parts of the world. The frequency of these activities depends largely on the available resources and has to be decided upon in due time.

In view of the expertise of the KETs Observatory and its access to top-experts, it might be interesting that European policy makers can address the KETs Observatory for ad-hoc advice on particular issues. The KETs Observatory should therefore 'reserve' a certain amount of time in its planning.

The KETs Observatory shall be very active in its 'outreach' towards policy makers (regional, national and EU), industry, and academia. Besides the website (https://webgate.ec.europa.eu/ketsobservatory/[99]) a major channel in external communication will be a periodic newsletter. The frequency as well as the content programming may differ. Newsletters can be organised around specific cross-cutting developments, or around specific KETs. Distribution will be digital (through e-mail). Programming of frequency and content, and quality assurance, will be managed by the advisory committee (or a mandated subgroup).

Next, the KETs Observatory shall also organise several events (workshops, conferences) in order to actively share its knowledge and experience, to stimulate networking among KETs producers, users and policy makers. This appeared important for the stakeholders we consulted at the start of this feasibility study. Also under 'outreach', one can envisage the development of so-called tutoring material, like study reports (on market developments, policies etc.), presentations, and legal documents, informing stakeholders about KETs, their background, and their potential. One step further is to have the KETs

[99] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

Observatory monitor public procurement calls with respect to KETs deployment (Europe-wide or even globally). The website will be representing the KETs Observatory to the outside world (as it will be virtual in terms of organisational setup) and will also be the single entry point for obtaining intelligence on KETs and their deployment. The website shall therefore be frequently updated.

7.4 Expertise and governance

7.4.1 Expertise

The KETs Observatory should take the form of a 'light structure' and be mainly virtual in nature. There is no need for a physical presence (in a building) and identity. The KETs Observatory will bring together people and expertise in order to assemble existing information and gather intelligence on current KETs deployment and future potential. The KETs Observatory should have a dedicated staff in order to ensure a smooth and continuous operation. Following groups and/or experts should be involved in the KETs Observatory.

✓ Advisory group

It is important for the KETs Observatory to be closely connected to the "field" and to the KETs Research, Development and Innovation community in order to update quickly and in real-time the evolution of the KETs environment and situation in Europe. This can be ensured by the presence of an advisory committee with external high level experts from different backgrounds.

The main tasks of this group would include, among other:

- To guide and support the overall strategic direction of the KETs Observatory;
- To interact with regional, national and European policy makers on the importance of KETs and their deployment;
- To validate the deliverables of the KETs Observatory before they are made public (from an advisory mandate perspective). The advisory committee should ideally 'embrace' every deliverable;
- To define fields of interest for further studies (ad-hoc studies).

✓ A team of dedicated staff

The KETs Observatory should be run by a team of dedicated staff whose task is to work full-time (or part-time) for the KETs Observatory as this ensures continuity.

The main tasks of this core team would be:

- To nurture and further optimize the methodological backbone of the KETs Observatory as developed in underlying feasibility study;
- To manage the experts panels involved;
- To collect the data to update the indicators on a periodic basis;

- To gather data and information via networks of national/regional experts in Member States and European organizations;
- To sort and analyse the information;
- To validate the interpretation of the information by a wider range of stakeholder consultations;
- To produce analytical reports and communicate the findings (through website, newsletter, etc.);
- To advise the European Commission on KETs deployment related aspects;
- To represent the KETs Observatory to the outside worlds.

✓ Expert panels

- As has been argued previously, the KETs Observatory needs to involve expert panels in its activities. Expertise needs to be mobilized with respect to technology, industry, and classification.

✓ A team of national/regional correspondents

Finally, the team of country/regional correspondents would be responsible for the preparation of the country/region specific reports on the public policies on KETs; for example, these experts should monitor and report on the policy development with respect to KETs in their country/region.

7.4.2 Governance

Figure 48 shows how the different parties involved in the KETs Observatory are positioned towards each other. It shows the 'governance' of the KETs Observatory, or the way that the KETs Observatory will be operated.

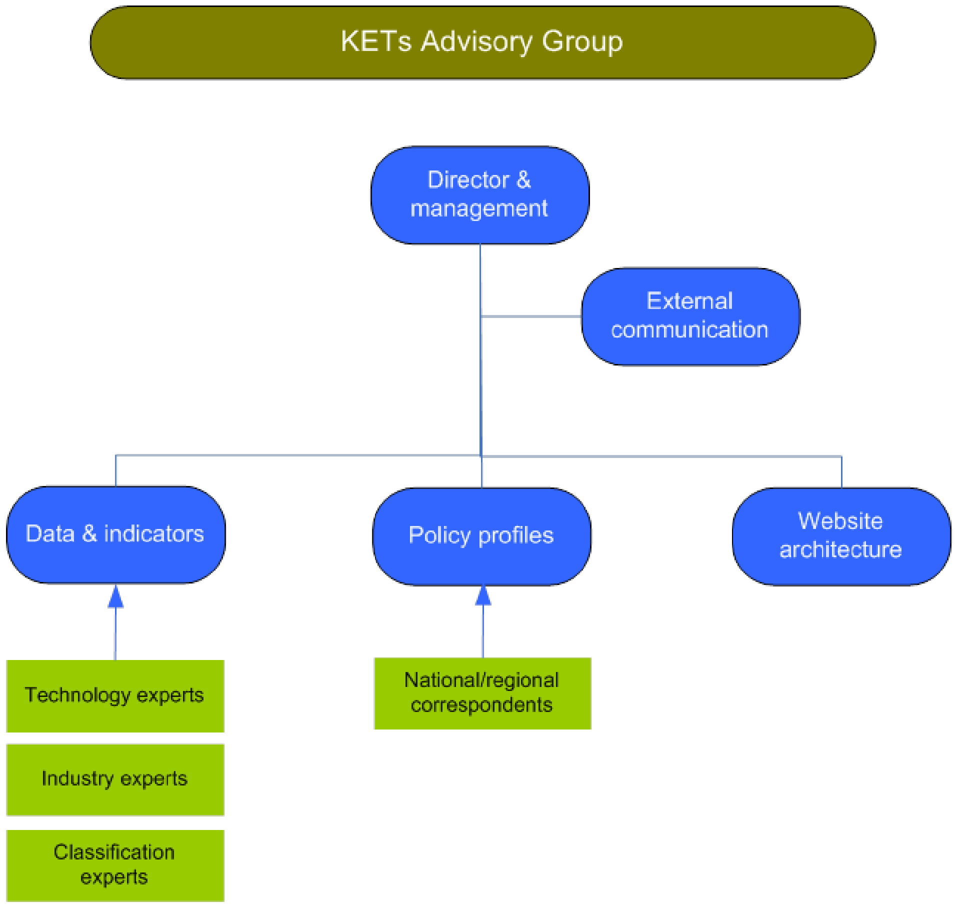


Figure 48: Structure and governance of the permanent KETs Observatory

Strategic guidance will be provided by the advisory group consisting of high-level experts. The members of this group will be appointed by the European Commission. The KETs Observatory itself (which will be outsourced) will be run by a director (an expert in the area of RTDI and industry policy), and supported by a small management team. Furthermore, there will be a number of expertise areas/units. The "Data & indicators" unit will be responsible for the development of the earlier mentioned 'final lists' of KETs components and companies. This group will also manage the technology experts, the industry experts and the classification experts.

The group "Policy profiles' shall be responsible for the collection and processing of regional/national policy intelligence regarding KETs deployment and associated support measures taken. This group will also be in charge of the national correspondents who will monitor and report regional/national issues. Third, a more technical unit will deal with the website architecture (this can be partly outsources to a specialized company). Last but not least, an essential function shall relate to "External communication" which needs to be of a high level.

7.5 KETs newsletter

Including a newsletter within the structure of the KETs Observatory will ensure that the KETs Observatory stays visible along its period of operations. The newsletter will include analysis of data with focus on a particular KET or a particular indicator or a particular region of the world. Stakeholders will be informed of new available data for particular indicators.

The newsletter may also report on relevant policy measures with regard to KETs deployment. For example, in case an interesting policy measure in launched, the newsletter may highlight its content. The newsletter may also contain information on the evaluation of relevant policy measures and it could report on the outcomes of the workshops that will be organized with technical and industry experts.

The newsletter will be published every two months. This period will allow ensuring that it always contains novelty. It is also the right timeframe for the KETs Observatory team to produce meaningful analysis. The average length of the newsletter will be about 4 pages to allow the readers to grasp the main messages quickly.

The KETs Observatory newsletter can be found in appendix 5. This version of the newsletter is based on output from the feasibility study. Next to general information, it provides a detailed look at the technology indicator significance, for the KET advanced materials. Moreover, it also focuses on a particular country namely the US. The KETs Observatory Newsletter is posted on the website and can be used for publication.

8 Conclusion

Underlying feasibility study has the aim to provide the Commission with a detailed proposal on how to set up a "KETs monitoring mechanism" or KETs Observatory. The focus of the undertaken activities lied mainly on the conceptual and methodological level. As existing data can only be roughly linked to specific KETs and to deployment activities, an innovative and conceptual approach has been developed to map and measure KETs deployment.

The feasibility study has shown that the developed methodology works and leads to interesting and relevant insights. However, there is certainly a need to optimize the input to calculate the indicators. Currently, the initial lists of companies, IPC, PRODCOM and HS codes have been refined. A further essential step is to validate these lists using technology, classification and industry experts. In addition, a dedicated survey should be set up to identify the location of production facilities of particular companies and to validate the weighting factors reflecting the level of KETs involvement. The suggested routes for optimization of the permanent KETs Observatory will allow a further improvement of the developed indicators and should be run in parallel. This implies for example that all technology indicators have the potential to become of high quality and reliability. It is however important to be aware that optimization will not guarantee that all indicators turn green as some optimization routes are more difficult to pursue than others. In addition, a resource planning and governance structure for the functioning of the permanent KETs Observatory has been developed.

A pilot launch of the KETs Observatory has been launched and can be consulted at https://webgate.ec.europa.eu/ketsobservatory/[100]. It is important to notice that the values of the indicators are subject to change as they are calculated within the framework of this feasibility study. These values are subsequently not validated and should be handled with caution.

This feasibility study shows that it is possible to set up a KETs Observatory to monitor the deployment of KETs. However, additional steps are necessary to validate the input and output of the data.

[100] The website is currently available at the following address : https://webgate.ec.europa.eu/ketsobservatory/

9 Appendix 1: Indicator fiches

9.1 Indicator fiche for the technology indicators

Main indicator	***Technology indicators***
Operational indicators	***1) Significance in total patent activities*** ***2) Specialisation on the production of patents*** ***3) Market share in global production of patents*** *4)* ***Medium-term dynamics of KETs patents***
Relevance	*The technology indicator provides information on the development of new technological knowledge in KETs that has an immediate relevance for commercial exploitation. The technology indicators inform about the outcome of R&D and other innovative activities that are to be transferred into new products or new processes*
Linkage with one or more KETs	*Relevant for all KETs*
Source	*PATSTAT database of the European Patent Office (EPO)* *Explanation: Patent applications are assigned to KETs based on IPC (International Patent Classification) codes.*
Last update & periodicity of updating	*Updated twice a year. Last update: March 2012, covers patent applications up to 2009 plus a fraction of patent applications in 2010. Next update: November 2012.*
Statistical presentation	***Data description:*** *Patstat is a database that contains information on patent applications and granted patents at almost all national patent offices worldwide as well as international patent applications at the EPO and through the PCT (Patent Cooperation Treaty) procedure at the WIPO (World Intellectual Property Organisation). For the KETs Observatory, only EPO/PCT applications are considered. For each EPO/PCT patent, information on the applicant (country), the priority date (earliest date within a patent family) and IPC codes is used.* ***Geographical classification and level:*** *Patent applications are assigned to countries based on the country of the applicant. All countries worldwide are covered.* *In addition, patent applications can be assigned to regions (e.g. NUTS 3 level) based on the location of the inventors (ZIP code). Since complete information on inventor locations is only available for applications at the EPO and not for applications through the PCT procedure, regional data are limited to EPO applications.* ***Sector coverage:*** *Patent data covers patent applications by applicants from all economic sectors, including public organisations, universities and individuals.* *Patent applications cannot be directly assigned to sectors of economic activity. However, patent applicants can be assigned to sectors. Such information is not contained in patent data but has*

	to be added through a time-consuming procedure which requires matching applicant names with directories of companies and other organisations that includes information on sector affiliation. For the KETs Observatory, no sector data on patent applications are produced. ***Time coverage:*** *Based on the priority date of a patent application, data can be broken by days. For this project, annual data are produced for the time period 2000-2009. The dynamic indicator covers the period 2000/04 to 2005/09.* ***Concepts and definitions:*** *The KETs Observatory uses patent application data instead of data on granted patents because of higher timeliness of application data. Patent applications are disclosed 18 months after the date of application, while information on granted patents is often available only several years after the date of application.* *Based on the most detailed level of IPC codes, a conversion table has been established that links IPC codes to KETs. Only patent applications at the EPO and through the PCT (Patent Cooperation Treaty) procedure at the WIPO (World Intellectual Property Organisation) are considered in order to ensure international comparability of data. Patent applications are measured at the level of patent families and are assigned to application years based on the earliest priority date within a patent family.* *For patent applications with applicants from more than one country, fractional counting is used to determine the number of patent applications per country.*
Quality assurance	*Patstat data are high quality data produced by EPO based on patent files. This is particularly true for applications at the EPO and through the PCT procedure, which are used here. For patent applications at national patent offices, data quality may vary.*
Accuracy and reliability	*Patent applications are widely used to measure the production of new technological knowledge that has an immediate potential to being commercialised. They are comparable across countries, technologies and time, they are available for all countries and a long time series, and they can easily be broken down by fields of technology based on IPC codes. However, patent data carries some shortcomings. First, not all patent applications are granted which means that some patent applications to not represent new technological knowledge. Secondly, the economic value of individual patents varies a lot which may restrict the accuracy of patent count data. Thirdly, strategic patenting of companies can result in an inflation of patent applications which does not necessarily represent an expansion in new technological knowledge. Fourthly, not all new technological knowledge is patented which may result in some underrepresentation and may limit comparability across sectors. Despite these shortcomings, patent data are generally viewed as the most reliable technology indicators for international and intertemporal comparisons.*
Cost and burden of collection	*The current price of the Patstat database is €1150 for the annual subscription (which includes two editions per year). A single edition costs €560. Due to the size of the Patstat database, processing patent data requires a high capacity IT infrastructure.*
Other comments	-
Reference	*www.epo.eu/patstat*

9.2 Indicator fiche for the production indicators

Main indicator	***Production indicators***
Operational indicators	***1) Significance of production*** ***2) Specialisation on production*** ***3) Market share in production*** *4)* ***Medium-term dynamics of production***
Relevance (link with "deployment")	*The indicator production provides information on the deployment of KETs in terms of actual manufacturing production in the EU of KETs components.*
Linkage with one or more KETs	*Relevant for all KETs*
Source(s) (name of database/owner)	*Eurostat PRODCOM database* *Explanation: based on the PRODCOM code the production value and the volume of sold production can be determined at Member State and EU level.*
Last update & periodicity of updating	*Updated annually. Last updated: May 2012. Next update: May 2013*
Statistical presentation	***Data description:*** *Concerns the production of manufactured goods based on PRODCOM.* *In PRODCOM products are identified by an 8-digit code* *◦ the first four digits concern the classification of the producing enterprise given by the Statistical Classification of Economic Activities in the European Community (NACE) and the first six correspond to the CPA* *◦ the remaining digits specify the product in more detail* *Most PRODCOM product codes correspond to one or more Combined Nomenclature (CN) codes, but some (mostly industrial services) do not.* ***Geographical classification and level:*** *EU27 countries are covered for the selected time frame.* ***Sector coverage:*** *Especially for smaller countries, data per PRODCOM entry is not always provided because of confidentiality issues. If the production within a code can be easily traced towards a producer, results are not given. Total coverage of PRODCOM related entries is about 20% - 40%* ***Time coverage:*** *For this project, the time period 2005 – 2010 is used. The dynamic indicator covers the period 2005/07 to 2008/10.* ***Concepts and definitions (please explain the main data concepts):*** *For each KET, relevant PRODCOM entries are selected. Total output per KET equals the sum of the production of the respective KETs related codes.*
Quality assurance	*Production data are produced by Eurostat, building on input from NSOs. Quality assurance is described in a report accompanying the annual data, drafted by the PRODCOM Working Group. For more information see http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/prom_esms.htm).*
Accuracy and reliability	*The coverage of selected PRODCOM entries per KET is poor. The actual selection of PRODCOM entries is subject to debate as clear and unambiguous definitions for KETs as well as a KETs based product are lacking. Application of KETS is spread over many different PRODCOM, and the KETs level of these codes varies, but seldom equals 100%. There is also overlap between the selected PRODCOM entries for the different KETs, which hinders summation of indicators over all*

	technologies.
Cost and burden of collection	*The Eurostat PRODCOM database is freely available.*
Other comments	*If the accuracy and reliability issues are not addressed (see report on how to improve quality of the indicators), the resulting values for the indicators should not be used.*
Reference	*http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/introduction*

9.3 Indicator fiche for the demand indicators

Main indicator	***Demand indicators***
Operational indicators	***1) Significance of domestic demand*** ***2) Demand specialisation*** ***3) Market share in total European demand*** ***4) Medium-term dynamics of demand*** ***5) Export share*** *6)* ***Import share***
Relevance (link with “deployment”)	*The indicator production provides information on the deployment of KETs in terms of the demand for KETs components in the EU.*
Linkage with one or more KETs	*Relevant for all KETs*
Source(s) (name of database/owner)	*Eurostat PRODCOM database* *Explanation: based on the PRODCOM code the domestic demand can be calculated by subtracting the value of export from import plus production (see fiche on production indicators) at Member State and EU level.*
Last update & periodicity of updating	*Updated annually. Last updated: May 2012. Next update: May 2013*
Statistical presentation	***Data description:*** *Concerns the export and import of manufactured goods based on PRODCOM.* *In PRODCOM products are identified by an 8-digit code* *◦ the first four digits concern the classification of the producing enterprise given by the Statistical Classification of Economic Activities in the European Community (NACE) and the first six correspond to the CPA* *◦ the remaining digits specify the product in more detail* *Most PRODCOM product codes correspond to one or more Combined Nomenclature (CN) codes, but some (mostly industrial services) do not.* ***Geographical classification and level:*** *EU27 countries are covered for the selected time frame.* ***Sector coverage:*** *Coverage on PRODCOM level is almost 100%.* ***Time coverage:*** *For this project, the time period 2005 – 2010 is used. The dynamic indicator covers the period 2005/07 to 2008/10.*

	Concepts and definitions (please explain the main data concepts): *For each KET, relevant PRODCOM entries are selected. Total trade per KET equals the sum of the export minus import of the respective KETs related codes.*
Quality assurance	*Production data are produced by Eurostat, building on input from NSOs.*
Accuracy and reliability	*The coverage for production of selected PRODCOM entries per KET is poor. The actual selection of PRODCOM is subject to debate as clear and unambiguous definitions for KETs as well as a KETs based product are lacking. Application of KETS is spread over many different PRODCOM, and the KETs level of these codes varies, but seldom equals 100%. There is also overlap between the selected PRODCOM entries for the different KETs, which hinders summation of indicators over all technologies.*
Cost and burden of collection	*The Eurostat PRODCOM database is freely available*
Other comments	*If the accuracy and reliability issues are not addressed (see report on how to improve quality of the indicators), the resulting values for the indicators should not be used.*
Reference	*http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database.*

9.4 Indicator fiche for the trade indicators

Main indicator	*Trade indictors*
Operational indicators	*1) Significance in total exports* *2) Specialisation on trade* *3) Market share in exports* *4) Medium-term dynamics of exports* *5) Trade Balance*
Relevance	*The main indicator "trade" provides information on the position of the EU and other countries in international trade in KETs components. Export shares or specialization patterns are output indicators showing how a country's technological performance in KETs can be transferred into global trade success.*
Linkage with one or more KETs	*Relevant for all KETs*
Source	*UN Comtrade (United Nations Commodity Trade Statistics) database, produced by the International Merchandise Trade Statistics Section of the United Nations Statistics Division* *Explanation: export and import data are classified according to the Harmonized System (HS) in 6-digit-codes, those were assigned to KETs using a convergence table between CPA and HS*
Last update & periodicity of updating	*Updated continuously. Last viewed October, 23rd 2012, covers complete data up to 2010*
Statistical presentation	***Data description:*** *Over 170 reporter countries provide the United Nations Statistics Division (UNSD) with their annual international trade statistics data detailed by commodities and partner countries. All commodity values are converted from national currency into US dollars using exchange rates supplied by the reporter countries, or derived from monthly market rates and volume of trade.* *Commodities are classified according to Standard International Trade Classification (SITC), the Harmonized System (HS) (from 1988 with revisions in 1996, 2002 and 2007) and Broad Economic Categories (BEC). For the KETs Observatory HS 6-digit-codes are considered.* ***Geographical classification and level:*** *Trade data are provided at the country level. All countries worldwide except for Taiwan (TW) and Kosovo (KV) are covered.* ***Sector coverage:*** *The Comtrade database covers all trade in raw materials (including agricultural and mining products) and manufactured products. Trade in services is not covered.* *Comtrade allows to measure trade for all six KETs based on conversion tables from PRODCOM (8-digit-codes) to CPA08 (6-digit-codes), and from CPA08 to HS2007 and HS2002, most CPA 6-digit-codes correspond to at least one HS 6-digit-code, but some (i.e. repair and installation of machinery and equipment) do not and in some cases the correspondence between HS2007 and HS2002 is ambiguous.*

	Time coverage: *Comtrade data based on HS2002 and HS2007 are available from 2002 on. For the KETs Observatory, annual data for 2002 to 2010 are produced. Complete data for the most recent year are available approximately 20 months after the end of that year. The dynamic indicator covers the period 2005/07 to 2008/10.* ***Concepts and definitions (please explain the main data concepts):*** *Trade statistics track the value and quantity of goods traded between different countries. Exports of goods consist of sales from residents to non-residents, imports consist of purchases from non-residents to residents. Customs value imports at the higher CIF price, which includes cost, insurance and freight, while* exports *are valued at the lower* free on board (FOB) *price, thus the import value of the same commodity will be slightly higher than the export value.* *Traditionally, customs records are the main source of statistical data on international trade. They are collected by national statistical units and transferred to international databases.* *Following the adoption of the Single Market on 1 January 1993, customs formalities between EU Member States were removed, and so a new data collection system, Intrastat, was set up for intra-EU trade. In this system, intra-EU trade data are collected directly from trade operators, which send a monthly declaration to the relevant national statistical administration.*
Quality assurance	*UN Comtrade is the largest depository of international trade data. It gives instant access to more than 1.75 billion records on merchandise trade from over 200 reporting countries or areas covering 48 years of data and more than 6,000 different products. Data is of high quality and up-to-date and available on the internet.*
Accuracy and reliability	*Commodities are reported by country in the current classification and revision (HS2002 in most cases) and are converted to all used classifications thus providing long time series.*
Cost and burden of collection	*For single users annual fee differs between $121 and $910 US-Dollar (depending on different limits per query). For multiple users an unlimited access costs $6.065 p.a. Processing trade data requires a high-capacity IT infrastructure.*
Other comments	
Reference	*http://comtrade.un.org*

9.5 Indicator fiche for the business indicators indicator

Main indicators	***Business indicators***
Operational indicators	***1) Significance in operating revenue*** ***2) Specialization on operating revenue*** ***3) Market share in operating revenue*** ***4) Business Capacity Dynamics in operating revenue*** ***5) Significance in employment*** ***6) Specialization on employment*** ***7) Market share in employment*** ***8) Business Capacity Dynamics in employment***

Relevance (link with "deployment")	*The indicator business provides information on the deployment of KETs in terms of actual operating revenue and employment in the EU of KETs components.*
Linkage with one or more KETs	*Relevant for all KETs*
Source(s) (name of database/owner)	*Bureau Van Dijk Amadeus database* *Explanation: Amadeus is a database of comparable financial information for approximately 19.3 million public and private companies (at micro level) in 43 countries in Europe (larger than only EU-27)*
Last update & periodicity of updating	*Updated daily. Calculations have been made based on the database version of August 18, 2012. Data analysis has been based on 2010 data because the availability of 2011 company accounts was still relatively low.*
Statistical presentation	***Data description:*** *Concerns comparable financial information for public and private companies across Europe (both Western and Eastern Europe, with a focus on private company information. It contains:* • *Company financials in a standard format so that comparisons of companies across borders can be made* • *Financial strength indicators* • *Directors* • *Images of report and accounts for listed companies* • *Stock prices for listed companies* • *Detailed corporate structures* • *Market research* • *Business and company-related news* • *M&A deals and rumors* • *Maps and cartographic analysis* *(Sets of) Companies can be searched by hundreds of criteria (for example company name, Statistical Classification of Economic Activities in the European Community (NACE), location (NUTS-classification), operating revenue, employees …) over multiple years.* ***Geographical classification and level:*** *Searches are possible up to Nuts3-level, but the municipality and address of the company is available in the Amadeus database.* *The database covers 43 countries in Europe.* ***Sector coverage:*** *All available Nace rev.2-sectors are available up to 4 digits, US SIC classification is also available up to 4 digits* ***Time coverage:*** *For this project, the time period 2005 – 2010 is used. The dynamic indicator covers the period 2005/07 to 2008/10.* ***Concepts and definitions (please explain the main data concepts):*** *See extensive user guide in Amadeus where definitions are given for each available ratio and data from the global account*
Quality assurance	*Bureau Van Dijk (ISO 9001 certified) has high quality standards on the freshness and correctness of data. The annual account data coming from its Information Providers (IP) is updated on a daily basis, thus reflecting the most actual annual account available. The annual accounts from companies across Europe are transformed to a global account scheme so that every company has comparable financial information.*

Accuracy and reliability	*The data is collected by the Information Providers (IPs) of Amadeus at each national official public body in charge of collecting the annual accounts in its country. They are always the official filed and audited accounts. In some East-European countries where the data is difficult to get from a central source, IPs might collect it directly from the companies.* *However legal requirements about what to declare in the annual accounts is varying per country which makes that not all companies have all data available. The number of companies with available data can be calculated per indicator in order to make an assessment of the quality of the indicator possible.* *Small companies tend to be less represented in Amadeus as there are thresholds per country to submit an annual account at the national public body and also because of threshold before companies are included in Amadeus.*
Cost and burden of collection	*Amadeus is a commercial database and cost can be therefore high, at least € 40.000 depending on the type of client, the selected modules, the number of users, …. Data can only be published at an aggregated level (no individual company data can be published according to the license agreement).*
Other comments	
Reference	http://www.bvdinfo.com/Products/Company-Information/International/Amadeus

10 Appendix 2: Refined lists of PRODCOM codes

11 Appendix 3: Refined lists of companies

12 Appendix 4: Policy profiles

13 Appendix 5: KETs Newsletter

14 Appendix 6: Component Approach: detailed explanation