# Key Enabling Technologies (KETs) Observatory

# Methodology Report

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# 1 Introduction

The European Commission (EC) has launched a project involving the set-up and implementation of a Key Enabling Technologies (KETs) Observatory for 2013-2015. The project is realized by a consortium comprising IDEA Consult, TNO, CEA, ZEW, NIW, Ecorys and Fraunhofer ISI (as sub-contractors).

The objective of the KETs Observatory is to provide EU, national and regional policymakers with information on the deployment of Key Enabling Technologies both within the EU 28 and in comparison to other world regions (East Asia, North America). Knowing the recent trends and developments of KETs related technology and products in the EU in comparison to other competing economies may serve as a basis for the construction and implementation of dedicated industrial policies.

Within the framework of this project, different indicators monitoring the deployment of Key Enabling Technologies are compiled. These indicators cover:

- technology (based on PATSTAT data);
- production and demand (based on PRODCOM data);
- trade (based on UN COMTRADE data);
- business (based on ORBIS data);
- composite

For this project, we build on the results from a *Feasibility study for a KETs Observatory* (Idea Consult et al., 2013).[1]

The activities of the KETS Observatory focus on the improvement and implementation of the methodology previously developed in the feasibility phase, and compiling of the actual sets of data for the different indicators. The methodology is designed as such that the resulting data set provides comparable statistics on the deployment of the different KETs over time.

The methodology report contains a clear description of the methodologies used to collect data on technology, production, demand, trade, business and composite indicators. It discusses the steps that have been taken to finalize the methodologies and the feedback we have received from experts.

# 2 Indicator framework

The KETs Observatory attempts to measure the performance and development of KETs in Europe both among the EU-28 member states and vis-à-vis its main competitors in other world regions. In order to monitor EU performance in a comprehensive way, a set of indicators is used to capture performance at different stages of the value chain. The analysis rests on two complementary approaches, the technology generation and exploitation approach and the technology diffusion approach (Figure 1). While the technology generation and exploitation approach looks at the ability of countries to generate and commercialize new knowledge, the technology diffusion approach investigates the likely impacts of KETs on the wider economy.

Indicators regarding the technology generation and exploitation approach include:

[1] See: http://ec.europa.eu/enterprise/sectors/ict/files/kets/final_report_kets_observatory_en.pdf.

- Technology indicators measure the ability to produce new technological knowledge relevant to industrial application.
- Production indicators measure the relevance and dynamics of the production and absorption of KETs-based components.
- Trade indicators measure the ability to produce and commercialise internationally competitive products based on new technological knowledge. Here, export shares or specialization patterns reveal how a country's technological performance in KETs transcends into success in international trade.
- Business indicators measure the ability of industries/businesses to compete in the market for KETs-based products and to transfer new technologies and innovations to industrial applications.

Indicators regarding he technology diffusion approach include:

- Production and demand indicators that show to what extent the EU can use the potential of KETs to improve its competitiveness by manufacturing KETs-based products and by applying them in the production of manufacturing goods both in the sectors that produce KETs as well as, and more importantly, in other industries.

Figure 1 illustrates the position of the indicators used in the KETs Observatory across a deployment value chain that stretches from the invention of new technology (left column) to its application and diffusion (right column).

*Figure 1: Indicator framework*

| "Deployment Value Chain" | | | | |
|---|---|---|---|---|
| *Technology generation and exploitation* | | | | *Technology diffusion* |
| *New Technology* | *Competitive Innovations* | | *Commercialisation* | *Application* |
| Patents | Production | Trade | Businesses | Production & Demand |
| IPC | PRODCOM | HS | NACE /KETs patents | PRODCOM |
| KETs-related inventions | KETs-based components and intermediary systems | | KETs-related firm activities | KETs-related value cre-ation |

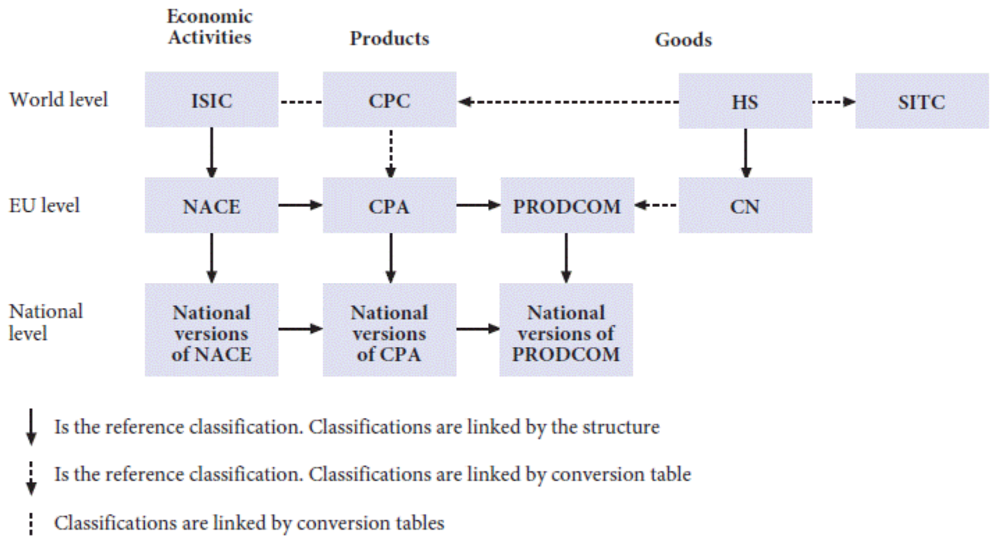
For each source of data needed to generate indicators, different classification taxonomies apply. For each statistical classification system, a set of codes has to be defined that allows identifying KETs-related activities. The following four classification systems are used:

- Technology indicators rest on patent data taken from the European Patent Office's PATSTAT database. Patents are classified by field of technology, employing the International Patent Classification (IPC). The KETs Observatory uses a list of IPC codes that cover technologies directly representing one of the six KETs.
- Trade data are collected from the United Nation's COMTRADE database. Trade data are classified by products based on the Harmonised System (HS). The KETs Observatory uses HS codes that cover products that are directly based on KETs and that represent KET-components or intermediary systems (such as an optical device or a microelectronic unit to be used in a machine or in transport equipment) that can be used to deploy KETs in other manufacturing activities.

- Business data are taken from the ORBIS database of Bureau van Dijk. Businesses are classified by economic activities using the NACE classification system. The KETs Observatory uses NACE codes that cover economic activities that are leading in the commercialisation of KETs.
- Production and demand data are calculated based on the Eurostat Prodcom statistics. These statistics provide a classification of manufactured products. On the one hand, these data are used to indicate competitive KETs-based innovations by covering products that are directly based on KETs and that represent KET-components and elements (see column 2 in Figure 1). On the other hand, for the purpose of indicating technology diffusion of KETs in total manufacturing, the classification is used to identify products that are depending on the use of KETs in order to be competitive (see column 4 in Figure 1).

The HS, Nace and Prodcom classifications are interrelated and apply a common conceptual framework that allows linking a code from one system to codes from other systems (Figure 2). The IPC represents a classification system that is not related to the other three systems.

*Figure 2: The international system of economic classifications*




The KETs Observatory will cover the following countries[2]:

- EU28
- Rest of Europe (Iceland, Norway, Switzerland and Turkey)
- North America (US, Canada and Mexico)
- East Asia (Japan, China (incl. Hong Kong), South-Korea, Singapore, Taiwan, India)
- Other countries: Brazil, Israel, Russia, South-Africa

The country coverage will depend upon the database used and will differ among the indicators. For example, the UN COMTRADE database contains no data on Taiwan, hence no trade data will be available for Taiwan. An international perspective is possible for technology, trade and business indicators, while it is to be examined if this is possible for production and demand indicators (Table 1).

[2] Depending on the availability of appropriate data.

The KETs Observatory will also provide data on regional level e.g. EU28, North America and East Asia.

In addition to indicators at country level, the KETs Observatory will also produce technology indicators at a regional level (NUTS 3) for the EU28. Regional technology indicators will be calculated using information on the location of inventors of KET patents. For the other three indicators, no regional data on NUTS 3 level are available.

*Table 1: Data availability & time coverage*

| | **Technology indicators** | **Production and demand indicators** | **Trade indicators** | **Business indicators** |
|---|---|---|---|---|
| **EU28** | Available | Available[3] | Available | Available |
| **Rest of Europe** | Available | Exploration of available data sources | Available | Available |
| **North America** | Available | Exploration of available data sources | Available | Available |
| **East Asia** | Available | Exploration of available data sources | Available, except Taiwan | Available |
| **Other countries** | Available | Exploration of available data sources | Available | Available |
| **Time coverage** | 2000 - 2011 | 2002 - 2012 | 2002 - 2012 | 2005 - 2012 |

# 3 The technology generation and exploitation approach

## 3.1 Technology indicators

This section describes the definition and data for the technology indicators.

### 3.1.1 Definition of technology indicators

The KETs Observatory uses four technology indicators in order 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.

**(1)** The **significance** indicator gives the share of a certain KET in total patenting activities of a country. This indicator informs about the quantitative importance 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 significance technology indicator SG(T) 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.

- $SG(T)_{kit} = P_{kti} / P_{it} * 100$

[3] 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 (see Appendix III)

P: patent applications (count)
k: KET
i: country
t: year

**(2)** The **specialisation** indicator relates the significance of a certain KET in the country considered to the average significance of that KET in all countries[4]. This indicator tells whether a country puts more or less focus on this KET than other countries do. A high value indicates that a country devotes a higher share of its resources to the production of new technological knowledge related to a certain KET than other countries (on average) do. As the specialisation technology indicator SP(T) 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, the natural logarithm (ln) of the relation of the two shares is used.

- $SP(T)_{ki} = \ln [(P_{kit} / P_{it}) / ((P_{kt} / P_t)] * 100$

**(3)** 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 market share technology indicator MS(T) 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.

- $MS(T)_{kit} = P_{kit} / P_{kt} * 100$

**(4) Medium-term dynamics.** The dynamics of patent activity show 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 technology indicator, only medium-term dynamics is considered, i.e. the change in the number of patent applications between two multi-year periods. The indicator gives the rate of change in the number of patents (MD(T)) between two periods with p-1 being the first period (2001-2005) and p being the second period (2006-2010):

- $MD(T)_{kip,p-1} = (P_{kip} - P_{ki,p-1}) / (P_{ki,p-1}) * 100$

### 3.1.2 Data for technology Indicators

#### *3.1.2.1 Defining KETs based on IPC classification*

Patent activities in KETs are identified based on IPC classes. For each KET, a list of IPC classes is used that represents new technological knowledge related to the respective KET (see Appendix I). The list of IPC classes for each KET was established in the following way:

1) For each KET, a conceptual definition has been developed which builds upon EC (2009a,b) and various other industry sources (see Box 1). For a detailed discussion see the background report of

[4] "All countries" include all countries of the world, and not just the 45 countries considered for this study.

TNO and ZEW on KETs produced for the KET chapter in the European Competitiveness Report 2010 (Klein Woolthuis et al., 2010).

2) Based on this conceptual definition, related IPC classes were identified, building upon earlier technology classification work done by OECD, EU and in various reviews and studies on specific KETs (see Klein Woolthuis et al., 2010).

3) The initial list of IPC classes has been re-examined and improved during a feasibility study for the KETs Observatory (see IDEA et al., 2013). For this purpose, a variety of methods was employed: text field search, matching of patent applicants to business registers, examining patent activities of selected actors with a known track record in a certain KET, and analyzing the activities of organizations that predominantly patent in a certain KET.

4) A further refinement of IPC-based KETs definition was done by consulting experts from CEA and IPTS which lead to some changes in the fields of industrial biotechnology, micro-and nanoelectronics, and photonics.

*Box 1: Conceptual definition of KETs used for patent-based technology indicators*

- Nanotechnology deals with methods to analyzing, 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, and two further IPC classes are also explicitly devoted 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.
- Industrial biotechnology is rather difficult to identify through IPC classes since many classes that cover new technological knowledge related to industrial biotechnology may also cover knowledge linked to pharmaceutical or agricultural applications of biotechnology. For the KETs Observatory, a rather narrow definition is used which focuses on enzymes, micro-organisms, amino acids and fermentation processes and only considers patents that are not related to the fields of medicine or agriculture. 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 fibers as well as the whole field of nanomaterials and specialty materials for electric or magnetic applications. The focus of IPC classes representing advanced materials is on innovations in the areas of layered products, compounds, alloys and nanomaterials.
- Micro- and nanoelectronics covers new technologies related to semiconductors, piezo-electrics and nanoelectronics which all are easily to identify through IPC classes.
- Advanced Manufacturing Technologies covers two types of technologies: process technology that is used to produce any of the other five KETs, and process technology that is based on robotics, automation technology or computer-integrated manufacturing. For the former, such process technology typically relates to production apparatus, equipment and procedures for the manufacture of specific materials and components. For the latter, process technology includes measuring, control and testing devices for machines, machine tools and various areas of automated or IT-based manufacturing technology.

#### 3.1.2.2 Patent Data

The production of new technology is measured by the number of patents. Patent data are a widely used measure for tracking technology development activities. Patents refer to technical inventions that contain new knowledge, have a potential for commercial application and proofed a certain level of technical feasibility. Patents can hence be regarded as a first step in the deployment of new technological knowledge. Nevertheless, patent data are not perfect measures as not all new technologies are patented, and not all patents are commercialized. The great advantage of patent data is that they contain information on the technological area(s) a patent is related to, based on an internationally standardized classification system, the International Patent Classification (IPC) and other systems building upon IPC.

For the KETs Observatory, patent application data are preferred over data on granted patents because of the higher punctuality of application data. While patent applications are typically disclosed 18 months after the date of application, information on granted patents is often available only several years after application date. In order to facilitate international comparability, only international patent applications are considered. International patent applications include patents applied at the European Patent Office (EPO) or through the so-called Patent Cooperation Treaty (PCT) procedure of the World Intellectual Property Organization. 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 organization, a non-profit organization (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 commercialize new technology. Note that most of large, multinational corporations apply patents developed at foreign subsidiaries under their subsidiary organizations (which are legally independent enterprises).

Patent data are taken from the PATSTAT database published by EPO twice a year (typically in April and October). The current version of technology indicators released in February 2014 was calculated using the October 2013 edition of PATSTAT.

Patents that are assigned to more than one KET are fully 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 application procedure will be assigned to the year of the priority date of the initial application at the national office.

For the KETs Observatory, patent data from 2000 on are considered. Owing to the lag between priority date and disclosure of a patent application as well as between applications, complete annual data are only available with a considerable time lag. For example, complete data for the year 2011 are only available with the April 2014 PATSTAT edition.

In total, 45 different countries are considered: EU 28 as well as Brazil, Canada, China (incl. Hong Kong), Iceland, India, Israel, Japan, Mexico, Norway, Russia, Singapore, South Africa, South Korea, Switzerland, Taiwan, Turkey and the USA).

Patent data also allow regional analysis since the address of the applicant and the inventor is known, at least for EPO applications. The regional level of analysis is the NUTS-3 level. Regional patent data refer to the location of the inventors since this best informs about the regional origin of the new technological knowledge underlying a patent application. For patents with inventors from different regions, fractional counting is applied. Regional patent data are taken from the RegPat database maintained by OECD. Regional patent data refer to EPO applications only since address information on inventors is often missing for PCT applications.

## 3.2 Competitive innovations

This section discusses the definition of production and trade indicators. It details the conceptual approach of selecting KETs-relevant Prodcom and HS codes for the technology generation and exploitation approach. The selection of KETs-relevant Prodcom codes in this approach is different compared to the selection of Prodcom codes in the technology diffusion approach. This is due to the fact that the technology generation and exploitation approach only covers products that are directly based on KETs and that represent KET components or intermediary systems that can be used to deploy KETs in other manufacturing activities, whereas the technology diffusion approach investigates the likely impacts of KETs on the wider economy. Therefore, the selection strategy of the technology diffusion approach is broader (see section 2 and section 0).

### 3.2.1 Definition of production indicators

Production indicators provide insight in the supply. The corresponding production indicators are similar in nature to the technology indicators and can be interpreted accordingly. The indicators comprise: (1) Significance, (2) Specialisation, (3) Market Share, and (4) Medium-term Dynamics. The demand indicators are constructed in a similar way. We use Y to denote the volume of production in order to avoid confusion with the patent indicators.

**(1) Significance** (SG) measures the share of output (Y) in a certain KET over a country's total output. A high value indicates that a significant part of a country's resources are used to produce products related to the respective KET. Significance (SG) of production P of a certain KET k in country i in year t:

- $SG(Y)_{kit} = Y_{kti} / Y_{it} * 100$

**(2) Specialisation** 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. A high value indicates that a country devotes a higher share of its resources to the production of products related to a certain KET than other countries (on average) do. 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):

- $SP(Y)_{ki} = \ln [(Y_{kit} / Y_{it}) / ((Y_{kt} / Y_t)] * 100$

**(3) Market share** 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:

- $MS(Y)_{kit} = Y_{kit} / Y_{kt} * 100$

**(4) Medium-term dynamics** inform about trends in output. Medium-term dynamics (MD) in production of country i for each KET k between period p-1 being 2007-08 and period p being 2011-12:

- $MD(Y)_{kip,p-1} = (Y_{kip} - Y_{ki,p-1}) / Y_{ki,p-1} * 100$

### 3.2.2 Definition of trade indicators

Overall, the KETs Observatory uses five trade indicators, which are defined similarly to the respective indicators used for technology and production. Therefore, they can be interpreted accordingly. However, owing to the specific nature of trade as an interaction rather than an output activity, some deviations occur. In the following, we introduce and briefly describe each of the five trade indicators. Namely, the indicators comprise (1) Significance, (2) Specialisation, (3) Market Share, (4) Medium-term Dynamics, and (5) Trade Balance.

**(1) Significance** is measured as the share of a country's exports in a certain KET over the country's total export. Hence, the indicator reveals how important a particular 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:

- $SG(E)_{kit} = E_{kit} / E_{it} * 100$

**(2) Specialisation** is measured by the so-called Revealed Comparative Advantage (RCA), a standard indicator in trade analysis. This indicator relates the ratio of exports to imports in a certain country for a respective KET over the export to import ratio for total manufactured goods. A positive (negative) Revealed Comparative Advantage (RCA) means that the export to import ratio by KET is higher (lower) than the export to import ratio for total manufacturing. It therefore indicates a positive (negative) trade specialization for the respective 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 ratio for a certain KET over the export to import ratio in the country's total trade):

- $SP_{ki} = \ln [(E_{kit} / I_{kit}) / (E_{it} / I_{it})] * 100$

**(3) Market share** is measured as the share of exports from a certain country over total exports of all 44 countries considered.[5] It therefore indicates how much a country contributes to the total exports of all countries. Market share (MS) of country i in total exports for each KET k in year t:

- $MS(E)_{kit} = E_{kit} / E_{kt} * 100$

**(4) Medium-term dynamics** inform about trends in exports. The indicator measures the rate of change in exports over time. Instead of comparing year-to-year changes, a measure for medium-term dynamics is used. Thus, changes in two-year averages of two multi-annual periods are compared. This procedure avoids a too strong influence from business cycle effects. Average medium-term dynamics of exports [D(E)] of country i for each KET k between period p-1 being 2007-08 and period p being 2011-12:

- $MD(E)_{kip,p-1} = (E_{kip} - E_{ki,p-1}) / E_{ki,p-1} * 100$

Finally, **(5) trade balance** measures the difference between exports and imports in relation to the total trade volume (exports plus imports) of a country. A positive value shows that a country exports more than it imports in a certain KET, which, in turn, 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:

- $TB_{kit} = (E_{kit} - I_{ikt}) / (E_{kit} + I_{kit}) * 100$

[5] China and Hong Kong are regarded as one country. For this purpose, total exports and imports of China (including Hong Kong) are cleaned by bilateral (intra-regional) trade flows. Taiwan is missing in trade analysis, because the country is not covered by international trade databases (UN Comtrade, OECD).

### 3.2.3 Data for production, demand and trade Indicators

The list of Harmonized System (HS) codes, which is used in trade analysis, has been derived in a two-step way. First, a list of relevant Prodcom codes has been established. Second, this list of Prodcom codes has been transferred into the HS classification system.

#### *3.2.3.1 Defining KETs-based components and intermediary systems based on Prodcom*

The initial list of Prodcom codes as identified in the feasibility study for the KETs Observatory (see IDEA et al., 2013) has been re-examined and improved using a variety of methods:

1. First, KETs applications have been assigned to manufacturing sectors or manufacturing activities to identify those sectors or activities (corresponding to NACE groups and classes) in which the particular KETs-related patent activities are concentrated. This approach is based on the assumption that the invention of new technologies and their exploitation stick together.
2. Second, relevant KETs based components have been identified on the basis of existing literature, web searches, and expert views. The so-identified KETS based components have been used to compile lists of adequate Prodcom codes which represent KETs components or - in a few cases - intermediary systems.
3. Knowing that Prodcom codes - as a rule - consist of different more or less innovative products, the final list of codes can be interpreted as potentially KETs-based products. Overall, the list incorporates substantial KETs-related innovations even though not all single products are innovative.
4. Finally, Prodcom codes that represent end-products rather than components are excluded[6].
5. Feedback from experts within the consortium, results from the expert workshops organized by TNO, comments from external experts and information from KET-specific studies and reviews have been exploited.

#### *3.2.3.2 From Prodcom to HS-codes*

Trade data is extracted from the UN COMTRADE database. Owing to its worldwide coverage, this database is particularly suitable for an international comparison of trade indicators. An alternative database is COMEXT, which employs more detailed 8-digit product codes. However, as the COMEXT database only covers Europe and therefore does not allow for international comparison, it has been decided to use the UN COMTRADE database. UN COMTRADE provides export and import data on a 6-digit level according to the Harmonized System (HS).

To select the relevant HS codes for trade indicators, the refined list of Prodcom codes has been used. Whereas the *Feasibility Study* (Idea et al., 2013) employed a conversion table from Prodcom (8-digit-codes) to CPA (6-digit-codes) and from CPA to HS 2007 (6-digit-codes), we now directly convert Prodcom codes to HS codes when applicable. Thereby, conversion is pursued as following:

- The first six-digits of Prodcom codes are identical with the superior CPA-code (CPA: Classification of Products by Activity). The digits 7 and 8 further allow differentiating within the respective product group. Thus, using the superior CPA code (6-digit-code) as a reference to select the adequate HS code (6-digit-code) implies overestimating trade flows. This is because the HS codes often cover additional 8-digit product groups not being identified as KETs-related.

[6] For example, Biofuels are excluded from the list of Prodcom codes for Industrial Biotechnology (IB) because of its end-product character. Furthermore, the demand of biofuels has less to do with the availability of IB technology, but is driven by idiosyncratic factors such as regulations, price and preferences that differ at the country-level.

- However, for most (160 out of 181) Prodcom codes (8-digit-codes), one can use convergence tables to 8-digit CN codes (used in the European Comext database as subgroups of HS codes, cf. Figure 2) to directly link them to one single 6-digit HS-code. In those cases, the respective Prodcom code matches CN codes whose digits 7 and 8 are equal to zero.[7]
- With regard to the 21 remaining 8-digit Prodcom codes that cannot directly linked to one HS-code, we only included the appropriate HS codes, if at least half of the respective CN-codes are covered. This has implications for three KETs namely Photonics, Industrial Biotechnology (IB) and Advanced Manufacturing Technologies (AMT).

To check the quality of this approach with regard to over- or underestimation of trade flows for IB, photonics and AMT, we used EU-trade data that is provided in CN 8-digit codes to develop weighting factors for the affected HS-codes. To explain the weighting approach in more detail, an illustrative example is given for the CN-code 84.83.40.90 that represents the AMT "other transmission elements". In a similar way, the weighting approach has been applied to all twenty-one 8-digit codes, which are not directly linked to a HS-code. This implies that these codes are weighted based on their export and import market shares in EU-intra and EU-extra trade 2010 to 2012. As Table 2 shows, only one out of eight CN-codes is relevant, hence the product group is not included in the initial approach (i.e. the approach without weighting). However, the export and import shares of the single CN-code in EU-intra and extra-trade between 2010 and 2012 would lead to the inclusion of HS-code 848340 with the weighting factor of 0.25 %.

*Table 2: Weighting approach for trade analysis – Illustrative example*

| | Imports (in €) | Export (in €) |
|---|---|---|
| 84834021 | 400720552 | 853399568 |
| 84834023 | 176677374 | 403172171 |
| 84834025 | 85322166 | 163290171 |
| 84834029 | 634845185 | 1526981443 |
| 84834030 | 114076328 | 174393201 |
| 84834051 | 1035084295 | 2176596415 |
| 84834059 | 196556791 | 483996160 |
| 84834090 | 823591506 | 1420461049 |
| Sum | 3466874198 | 7202290178 |
| Share (in %) | 23,8 | 19,7 |

| Weighting Factors and Newly Included Product Groups | | | | | Weighting | |
|---|---|---|---|---|---|---|
| CN | HS2007 | | Imports | Exports | Without weight | With weight |
| 84834090 | 848340 | AMT | 23,8 | 19,7 | 0 | 0,25 |

When contrasting the results for selected trade indicators (i.e. market share, trade balance and significance) with and without weights, it becomes evident that in the three KETs that are affected by the ambiguous convergence (i.e. Photonics, Industrial Biotechnology and Advanced Manufacturing Technology), the results remain similar, irrespective of the weighting approach. As Figure 3 depicts, in all three KETs, the market share and trade balance remain almost similar irrespective of including

[7] Cf. COMMISSION REGULATION (EU) No 860/2010 of 10 September 2010 establishing for 2010 the 'Prodcom list' of industrial products provided for by Council Regulation (EEC) No 3924/91

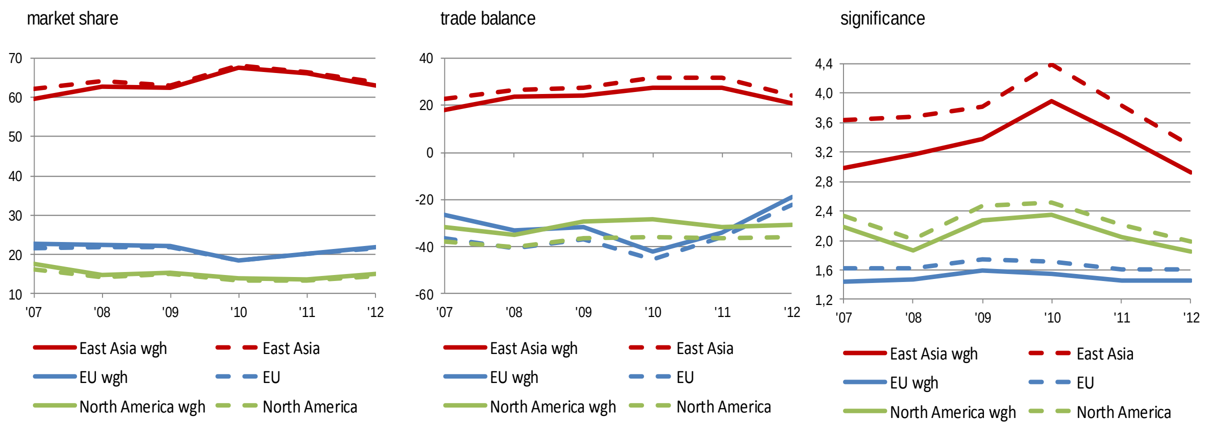
weights. Regarding the significance indicator, the deviation is somewhat more visible. Yet, the general trends remain the same.

Given the small, negligible deviation between the two approaches (see Figure 3), the weighting approach is not applied for calculating the indicator values reported in the KETs Observatory. This is partly owed to the fact that only the absolute values of the relevant KET´s exports and imports change to a small extent, while the relative values remain relatively stable. Therefore, weighting only affects the trade indicators significance and medium-term dynamics. In contrast, all other trade indicators are not affected by the weighting. Furthermore, the dominant products, which drive the results in the individual KETs, are not affected by the weighting, a fact that also explains the small deviation between the two approaches. Moreover, weighting also adds an artificially arbitrary element to the calculation assuming that the EU intra and extra trade structures are also valid for other global regions.

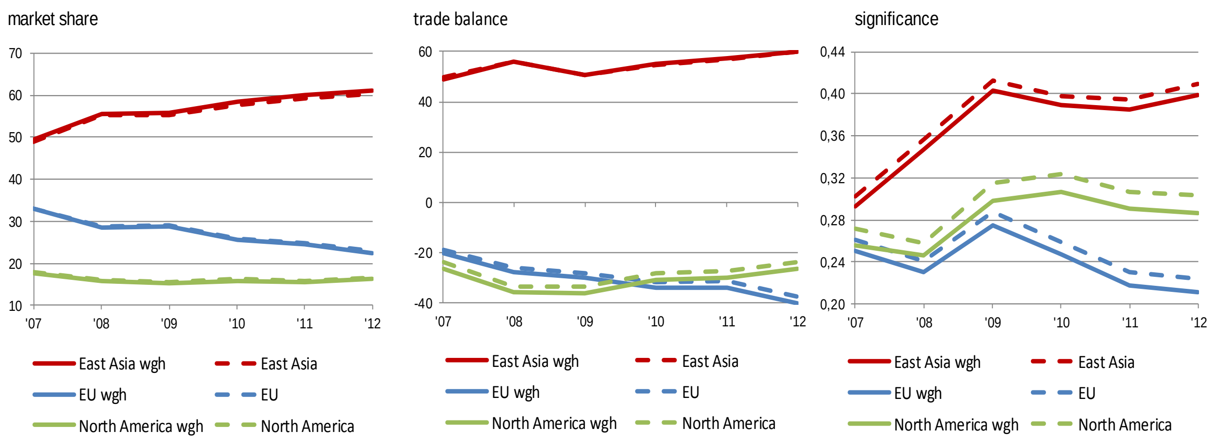
The current version of trade indicators released in June 2014 comprises data for the years 2002 to 2012, except for AMT which comprises data for the years 2007 to 2012[8].

*Figure 3: Selected trade indicators unweighted and weighted (wgh) approach*

Photonics

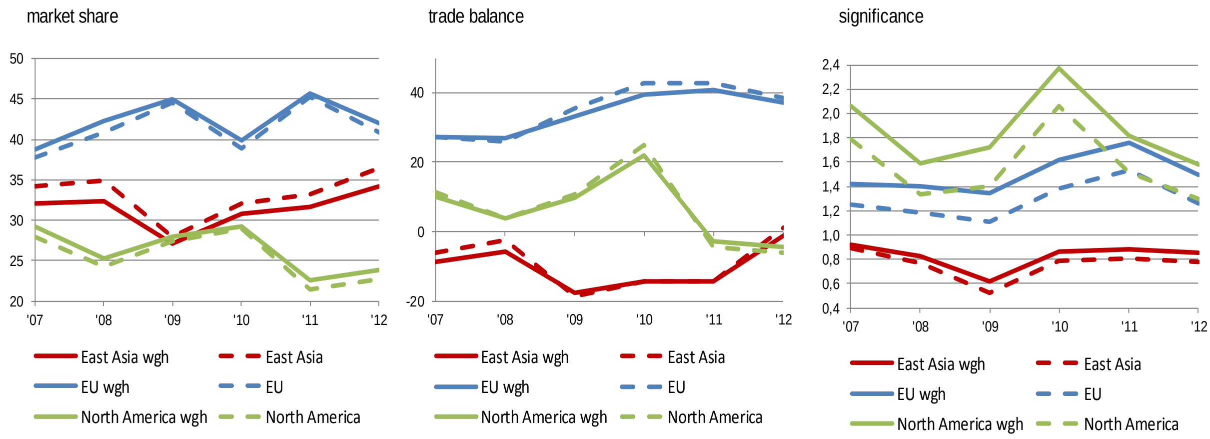



Industrial Biotechnology




8 This is owed to profound changes in HS codes that inhibit a meaningful comparison over time.

Advanced Manufacturing Technology




### 3.2.3.3 *Adjustment for intra-regional trade*

On the global level (i.e. for a comparison between the EU-28, East Asia, and North America), all trade indicators have been adjusted for intra-regional export and import flows and hence refer to extra-regional trade only. This is particularly relevant for the interpretation of export market shares in regional comparison. Merely considering total exports (i.e. exports to any other country) would overestimate the share of the EU-28, as within the EU-28, most exports flow to other EU member states. Simultaneously, it will underestimate the shares of East Asia and North America since both regions comprise few large countries with vast domestic markets (USA, Canada, and Mexico for North America; China including Hong Kong, Japan, South Korea, Singapore, and India for East Asia[9]).

In contrast, on the country level, trade indicators are calculated as the sum of all exports (respectively imports). They reveal a country´s performance compared to the group of all 44 countries considered in the analysis. Besides, along the KETs Observatory, for EU-28 countries trade indicators will be calculated for intra-trade and extra-trade separately. This helps to investigate how single European countries succeed in international competition with KETs-related components within and outside the common market.

## 3.3 Commercialization

This section discusses the definition of the business indicators and details the methodology developed to select relevant business data with regard to KETs.

### 3.3.1 Definition of business indicators

The KETs Observatory employs four indicators to measure a country's business performance in each KET area. The indicators represent significance, specialisation, market share and dynamics. All indicators are calculated for turnover and employment.

9 Taiwan is missing in trade analysis, because the country is not covered by international trade databases (UN Comtrade, OECD) (see footnote 5).

(1) The **significance** (SG) indicator puts the size of the KETs business activities of a particular country against the size of its national economy, and is therefore a measure of relative performance. A high values indicates that the country dedicates a substantial share of its resources into the respective KET. This indicator is defined by the total employment or turnover in a certain KET and country divided by that country's GDP.

- $SG(B)_{kit} = Bx_{kti} / GDP_{it} * 100$

**(2)** The **specialisation** (SP) 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 or turnover divided by the average significance of that KET in all countries considered). The indicator tells whether a country puts more or less focus on this KET (in terms of employment or turnover) than other countries do

- $SP(B)_{ki} = \ln [(Bx_{kit} / GDP_{it}) / ((Bx_{kt} / GDP_{t})] * 100$

**(3)** The **market share** (MS) informs about the share of global KETs activities that a country represents. This indicator, in contrast to the previous indicators, is strongly influenced by the size of a country. The indicator is measured by dividing the total employment or turnover in the respective KET area of a certain country (nominator) by the total employment or turnover in all countries for which data is available.

- $MS(B)_{kit} = Bx_{kit} / Bx_{kt} * 100$

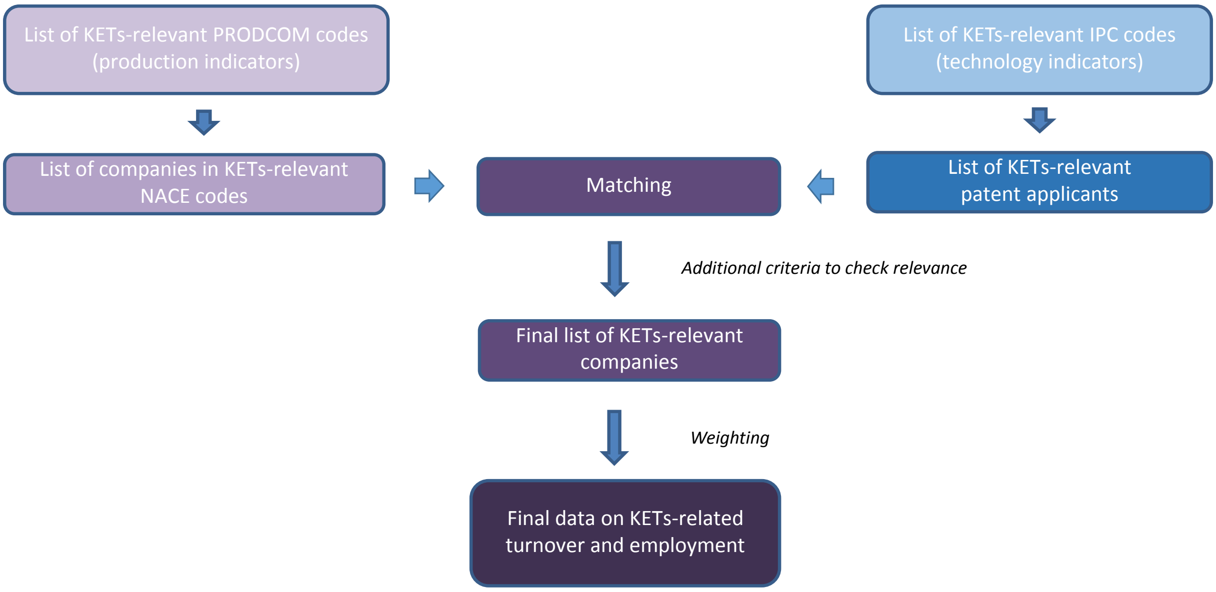
**(4) Medium- term dynamics** of employment or turnover shows whether a country is on an upward or downward trend. This indicator can reflect changes year-by-year, or evaluate changes over two time periods. In this study, the first period (p-1) refers to 2007-2008, while the second period (p) refers to 2011-2012.

- $DA(B)_{kip,p-1} = (Bx_{kip} - Bx_{ki,p-1}) / (Bx_{ki,p-1}) * 100$

### 3.3.1 Data for business Indicators

The process of identifying KETs relevant companies includes a three-step approach (see Figure 4). First, a selection of relevant NACE codes occurred, followed by a selection of relevant patent applicants. Finally, a matching and weighting procedure was performed.

*Figure 4: Identification process of KETs relevant companies*



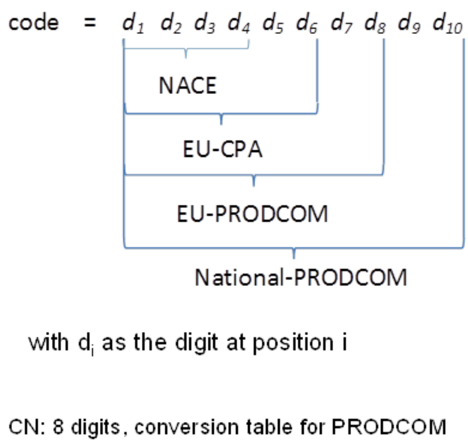

### 3.3.1.1 Selection of relevant NACE codes

In order to identify and select companies that are active in the deployment of the six KETs, we build upon the approach that has been used to compile the production and trade indicators in the technology generation and exploitation approach, as such leading to a logical and necessary consistency between the different approaches and types of indicators produced. Hence, the business indicators measure the ability of EU industries to compete in the market for KETs-based products and to transfer new technologies and innovations to industrial applications.

The final list of Prodcom used to identify relevant HS codes for each of the six KETs is used as input to identify relevant NACE codes[10]. Figure 5 illustrates the linkage between Prodcom and NACE codes. The first four digits are the classification of the producing enterprises 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. Based on the final list of Prodcom codes of the technology generation and exploitation approach, the relevant NACE codes can be identified.

[10] In the feasibility study, it was suggested to validate the definition of each KET and its components as a necessary step to compile final lists of companies. After discussing this option with several experts (external and internal), the consortium has decided not to engage in the discussion of the precise definition and delineation of each KET in terms of components. Instead, it was decided to use the final list of Prodcom/HS codes as input to identify relevant NACE codes.

*Figure 5*: Classifications and their linkages




The approach leads to a narrow selection of NACE codes as we aim to focus on companies that are active in developing and exploiting KETs related technology and products as they are an input for many industries, have a large diffusion and spillover potential. This implies that we focus on companies active in enabling industries, which are of a strategic nature for Europe, rather than in final markets. These companies are leading or have the potential to become leading in innovations that will contribute to the competitiveness of end-markets today and/or in the near future.

Identification of relevant companies

For each 4 digit NACE code, the number of companies and the location of their headquarters are compiled based on the database Orbis[11]. Orbis is a financial-economic database that contains comprehensive information on both listed and unlisted companies worldwide, with an emphasis on private company information. The database is owned by Bureau van Dijk and has information on 120 million private companies worldwide (around 70 million European companies, 40 million US companies and 15 million Asia-Pacific companies). SMEs tend to be less represented in Orbis as there are different thresholds per country for submitting an annual account to the national public body and also because of thresholds related to the inclusion of companies in the database Orbis.

In the Orbis database, one can distinguish between primary NACE codes (which represents the NACE-activity a given company gains the most turnover from) and secondary NACE codes (which represents the other NACE- activities of a given company). For the current purpose we select only companies that have one of the KETs-relevant NACE code as their primary NACE code. This is because, varying from country to country, particularly the assignment of secondary NACE codes to companies can be quite unreliable.

#### *3.3.1.2 Selection of patent applicants*

In the second step, we build upon the approach that has been followed to calculate the technology indicators. Our point of departure is a list of all applicants that applied 10 or more patents from 2005 to 2010 at EPO or PCT. For each applicant, we have the total number of patent applications and the number of patents falling in each of the 6 KETs. A threshold of 10 or more patents is applied as below this threshold, the list contains a lot of individuals and research institutions.

[11] This is in line with the recommendation on improvement of the methodology for the KETs Observatory as indicated in the Feasibility study for a KETs Observatory (Idea Consult et al., 2013, p121):

*In order to calculate the business indicators, it is necessary to obtain access to Orbis.*

Identification of relevant patent applicants

In order to identify companies that are active in taking KETs related patents, all individuals and research institutions are removed from the list. Next, as a single firm often appears under different names in the patent database, there is a need to aggregate the companies and check if it concerns the same company. This results in a list of companies active in taking patents in a particular KET.

#### *3.3.1.3 Matching & weighting*

The list of companies in KETs-relevant NACE codes is matched with the list of KETs-relevant patent applicants. The matching procedure results in a number of successful matches. From this list, companies belonging to the same group were removed. In addition, companies were checked for having relevant activities in the area of a particular KET using three criteria. A first criteria is to check for the main NACE activity of a company in the respective KET area. This check is needed as some companies (especially large multinational groups) have multiple NACE codes and not all of the allocated NACE codes are relevant. For example, the identified company, JX Holding is an oil producer, and has no relevant activities related to MNE. A second criteria is to control for companies with a very low KET patent share, since these companies have the highest risk of having no actual KETs activities. The companies below the 2,5% percentile of KETs patent share were excluded from the list. A third criteria is the sales to KET patent ratio (= total sales divided by total number of patents in the respective KET). Some companies have very high sales volumes compared to the number of KET patents they have. It is therefore unlikely that the sales of these companies is driven by their KET patents. Therefore, companies that exceed the 97.5% percentile of the sales to KET patent ratio are excluded. Applying these criteria results in a reduced set of companies in each KET which can be regarded as companies with significant technology-related activities in the respective KET.

This list of companies is then used to extract data from Orbis with regard to turnover and employment. For the KETs Observatory, data from 2005 on are considered. For EU-28, time series are available for the period 2005-2012. On a regional level (EU-28, North America, East Asia), only data for 2012 is available due to budget constraints. Only data from the global ultimate owner of a specific company is retained.

It is important to estimate the KETs relevant activities of a company with regard to turnover and employment. Small companies tend to focus their activities in a particular area. Medium-sized firms are more diversified while large companies have activities in many economic areas and only part of them is related to the deployment of KETs. Hence, the total turnover of a large company cannot be assigned 100% to a specific KET as this would imply an overestimation of the KETs-related turnover creation. Moreover, the turnover from large companies totally discard the turnover from small and medium sized companies in a particular country as a multinational company often generate more turnover than the combined turnover of all SMEs in that particular country. As a consequence, it is important to assign weights as companies may have several activities that are only partially related to KETs.

Estimating the relevant share of KETs related activity in the total turnover of a company is done by means of patents. Based on the data of the technology indicators, we can calculate the share of patents in a particular KET for each KET patent applicant. That share can then be used to estimate the associated turnover and employment. For example, in case 10% of all patents of a patent applicant are taken in a particular KET, 10% of the turnover and employment of that applicant will be assigned to that KET.

In interpreting the business indicators, it is important to keep in mind that employment and turnover are assigned to the headquarters of a company. Therefore, business indicators inform about the decision power present in particular countries.

Turnover and employment are assigned to the headquarters of a company as it is very difficult to assign this to the different subsidiaries of multinational companies. In order to determine the actual employment and turnover that is being realized in a specific subsidiary in a particular country, one needs information on the KETs activity of individual subsidiaries.

Some multinationals provide figures (turnover and employment) with regard to specific subsidiaries, although this is not the case for all multinationals, especially not for East-Asian companies. Provided that the information is available, it would even not be sufficient as input for the KETs Observatory. What is needed to estimate the KETs relevant share, is precise information on the actual activity of that subsidiary in the area of KET and its contribution to the subsidiary's turnover and employment. Unfortunately, this information is hardly available as companies prefer not to share that (sensitive) information.

## 3.4 Composite indicators

On the basis of the single indicators, composite indicators can be calculated in order to describe and analyze the performance of a country in a given KETs-deployment field. The methodology is designed such that the resulting set provides comparable statistics on the deployment of different KETs over time. The calculation of the composite indicator and robustness checks will take place in the period November 2014 – March 2015. These calculations will provide information about the sensitivity of possible composite indicators, relationship between single indicators etc. which are crucial for the finalization of the methodology on composite indicators.

### 3.4.1 Aim

A composite indicator is a single real-valued metric which is derived from a set of indicator components by some (mostly linear) aggregation method[12]. Basically, the construction of composite indicators consists of several steps, and for each of these steps different useful methodical approaches exist[13]. In particular the methods used in practice differ, in:

- Identifying adequate and relevant single indicators,
- Imputation of missing data points and treating outliers for single indicators,
- Transforming and normalizing indicators, weighting and aggregation of the single indicators.

The accuracy of the composite deployment indicators is dependent upon the accuracy of the individual indicators that are used to calculate the respective deployment indicator. Hence, the level of validity and reliability of each single indicator will account to the overall quality of the composite indicators.

[12] Grupp, H., Schubert, T. (2010): Review and new evidence on composite innovation indicators for evaluating national performance. In: Research Policy, Vol. 39, pp. 67-78.

[13] OECD (2008): Handbook on Constructing Composite Indicators Methodology and User Guide, Paris.

At the heart of aggregating various technological and economic variables into a composite index is the question of how the elements relate to the whole, for instance, how and what each of the sub-indicators contribute to explain the overall phenomenon or concept that should be represented by the final composite indicator. As the field of KETs is of complex and multidimensional nature, the composition of strengths and weaknesses in terms of composite indicators may result in quite different results. Therefore it is necessary to make sure that the specific and chosen composition of indicators is more suitable or superior to any other of this set of possible mappings in terms of robustness.

The following sections aim at:

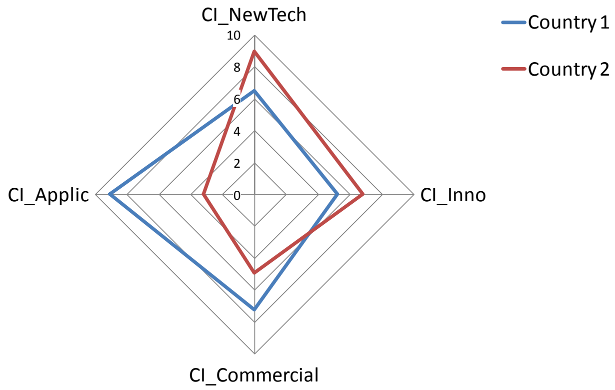
- revisiting the feasibility of the composite indicators in terms of their interpretability and adequacy for policy-making purposes
- tracing back the most central aspects of aggregating the individual indicators into composites regarding the steps of normalization and in particular of weighting the single indicators
- testing and providing alternative options for the composite indicator.

### 3.4.2 Planned approach

Generally, there is no superior technical or systemic approach for building up the inherent logic of composite indicators, because different compositions of indicators have not only their individual pros and cons, but also differ in their interpretation. Hence, the decision which composite indicator design is appropriate in the end highly depends on the intended policy purpose. This is because the composite indicators are not an end it themselves, but are supposed to provide a solid and feasible basis for policy making in the field of KET-related STI-policy of the European Commission. Hence, we propose an approach which provides a relevant interpretation from our view and which fits quite well to the indicator framework developed in the project. We provide an interpretation and discussion of pros and cons in order to enable alternative thoughts. Moreover, it has to be remarked that the subsequent calculations have to show a high robustness.

The composite indicators should in principle build upon all group of indicators (technology, production & demand, etc.) as each of these indicator groups is of high relevance for reflecting the innovation and commercialization processes of countries and KETs. The indicator groups are sorted along a “Deployment Value Chain” proceeding from technology generation and exploitation to diffusion (see Figure 1). If one composite indicator is calculated for each KET in each of the four stages (New Technology, Competitive Innovations, Commercialization, and Application), this would lead to 24 indices (6 KETs * 4 stages). As this is a large number, we will focus on 4 or 5 indices which are meaningful and easy to understand. The respective interpretation will inform about the performance of a certain country in a certain KET regarding the different stages of technology maturity and closeness to market application. One could easily identify whether a certain country is e.g. highly competitive in new technologies and competitive innovations but not relatively successful in its wide application. A potential and appealing visualization of the respective position of a country could be a spider web (Figure 6).

*Figure 6: Prototype of results' visualization*




### 3.4.3 Methodological construction and robustness of composite indicators

Constructing a composite indicator involves several stages where judgments have to be made on: identification and selection of relevant individual indicators, treatment of missing values, selection of transformation and normalization method, choice of weighting scheme, and selection of aggregation method. These judgments affect the final composite indicator and its meaning. To improve the robustness of composite indicators and to increase its transparency by accessing the sources of uncertainty, the sensitivity analysis should be performed. Besides of theoretical, conceptual arguments, the decision on each stage can be based on statistical analysis of the data.

The first important step is to identify whether all indicators, included in the calculation of a composite indicator, are unique and relevant. The reduction of the number of single indicators might simplify the interpretation of a composite indicator and improve its policy message. The number of statistical procedures can be performed to decide on selection of particular indicators. For instance, by investigating the correlation matrix the redundant indicators can be identified. A very high correlation between the single indicators (e.g. multiple patent data or simultaneous data on R&D-expenditure and R&D-personnel) might point to redundancy which leads to an overweighting of neighboring indicators in causal analyses. To prevent a double counting, the reduction has to be obtained. There are two options: either to exclude one of the indicators from the analysis (i.e. based on the experts' opinion) or to combine the highly correlated variables into a variable index[14]. On the other hand, if a single indicator is not correlated with the others, the decision has to be made whether its inclusion in the calculation of a composite brings any value. Alternative methods like factor analysis or principal component analysis can be useful for a better understanding of the data structure of the composites. For instance, it is possible to explore whether the theoretically specified dimensions (technology, product, demand, trade and business) are well balanced from the statistical point of view. If the statistical dimensions do not correspond to the theoretical dimensions, then a revision should be considered. Moreover, by means of factor loadings the irrelevant single indicators, which cannot explain well the differences between the countries, can be identified and omitted.

[14] Schubert, T., Neuhäusler, P., Frietsch, R., Rammer, C., Hollanders, H. (2011): German Innovation Indicator. Methodology Report.

Another approach to examine the robustness of composite indicators can be a selective omission of a certain indicator. If some countries do not perform well in a certain indicator, its exclusion might "tune" the ranking in favor of these countries[15].

**Normalization** is required to bring different indicators to the same unit. Several normalization procedures have been used in the literature so far: ranking, standardization, rescaling, distance to a reference country, categorical scales. Since each of them has different strengths and weaknesses, the data properties, as well as the objective of composite indicator should be considered when choosing the most suitable type of normalization procedure. Indeed, the methods differ in their sensitivity to outliers and extreme values, highly skewed indicators, as well as the extent to which information gets lost during the normalization. For instance, the rescaling procedure, which stretches or shrinks the original scale on one interval that is constant for all indicators, is sensitive to outliers and extreme values. However, it preserves the numerical differences between the observed values. Another method is the scaling method based on the quantile position of one observation. This means that instead of using the observed values (possibly in a rescaled version) the quantile position of this observation is used[16]. This procedure is robust to outliners, but might lose a lot of information, if the differences in the observed values have a sensitive meaning. Further issues, which can guide the selection of a normalization procedure, include: whether exceptional behavior needs to be rewarded or penalized, whether information on absolute levels matters, whether benchmarking against a reference country or group of countries is requested, whether the variance in the indicators needs to be accounted for, whether the new time points become available[17]. Moreover, the **robustness check** should be extended to changes in the country set of the underlying data. This implies, whenever countries with extreme values become part of the set, changes in the normalized values might be induced that do not correspond to changes in the original indicators.

In order to come up with a robust normalization method that best fits the framework of KET deployment indicators, the procedure proposed in the Feasibility Study will be tested and evaluated against some alternative methods. We will explore, for example, alternative approaches which measure the relative position of a given country's indicator against a reference point. The reference country (or a group of countries) can be: an average country, a benchmarking country, or a "best performer". Some other methods of normalization such as Min-Max normalization (which, for example, is done in the EU's Innovation Union Scoreboard) or categorical scale can also be applied.

The next step in the construction of a composite indicator consists of aggregating the rescaled indicators via weights. However, to provide valuable information, composite indicators should be robust with respect to changes in the applied weights. Such robustness check includes the questions whether the composites are sensitive to changes in their indicator basis and changes in their weights. Such weights, however, are not self-explanatory; even the number and kind of components to use in such an aggregation is difficult to deduce systematically from theory.

[15] Grupp, Hariolf; Mogee, Mary Ellen (2004): Indicators for national science and technology policy: how robust are composite indicators? In *Research Policy* 33 (9), pp. 1373–1384.

[16] Schubert, T., Neuhäusler, P., Frietsch, R., Rammer, C., Hollanders, H. (2011): German Innovation Indicator. Methodology Report.

[17] Nardo, Michela; Saisana, Michaela; Saltelli, Andrea; Tarantola, Stefano (2005): Tools for composite indicators building. In European Commission, Ispra.

With regard to literature three different methods are commonly applied:

1. Using unweighted averages;
2. Optimization to the most favorable weights along a “Benefit of the Doubt” method;
3. Variance-maximizing weights in terms of principal component or factor analysis.

Again, each of these methodological approaches has its own advantages and disadvantages. While equal weighting appears to be preferable because it evades the problem of defining weights in a more or less arbitrary fashion, it might imply problematic "economic" trade-offs between the singly indicators. In contrast, a “Benefit of the Doubt” method allows for country- or technology-specific weights to account for context specificities. Principal component analysis or factor analysis methodology is a statistical procedure to define the weighting scheme, which is based on the contribution of each indicator to the overall composite.

As long as there is no strong methodological requirement (e.g. dealing with outliers, down-weighting of highly correlated indicators to avoid overestimation of underlying factors, assuring for representativeness according to basic population), we generally propose to use no weights, because content wise it is always difficult and somewhat arbitrary to legitimate them. Here, one would have to think about whether there are strong arguments of an unequal weighting of the sub-indicators, e.g. whether from a political point of view the generation of “new technology” is of equal importance than i.e. commercialization or deployment of new technologies. The eschewal of weights would avoid arbitrariness and increase the intersubjectivity and objectivity of the results.

In **addition to the composite indicators**, other methods to summarize results will be explored. One possible way is to apply non-parametric analysis such as the Free Disposal Hull analysis for linking input oriented indicators (e.g. technology) to output oriented indicators (e.g. production and trade) which has been used within the KETs Exchange of good policy practices Study[18]. Another way is to classify countries with respect to the relative (i.e. size-adjusted) level of activities and dynamics in each KET, distinguishing countries that further expand a leading position, countries that lose ground from a leading position, countries that catch-up and countries that fall further behind.

We will assess the impact of the method on the results by visualizing and interpreting differences compared to the proposed methods in the feasibility study. Moreover, we will discuss the pros and cons of each method for the present case, in particular considering the aspect whether the applied method and weights are economically plausibility and provide valuable and reliable information. The result of this task will be a proposal for a method (or mix of methods) to calculate and present summary results.

[18] IDEA Consult & ZEW (2012), Exchange of good policy practices promoting the industrial uptake and deployment of Key Enabling Technologies, Background Report to the European Competitiveness Report 2012, Brussels: European Commission, DG Enterprise and Industry.

# 4 The technology diffusion approach

## 4.1 Application

This section describes the methodology developed for the technology diffusion approach. The technology diffusion approach attempts to investigate the likely impacts of KETs on the wider economy by looking at products that rely, at least to some extent, on the use of KETs, i.e. innovations in one of the six technology areas considered as key enablers for manufacturing. The technology diffusion approach hence complements the technology generation and exploitation approach which looks at the ability of countries to generate and commercialize new knowledge in the area of KETs.

The methodology is designed such that the resulting set provides comparable statistics on the deployment in production of the different KETs over time, resulting in indicators on production and demand, based on Prodcom data.

### 4.1.1 Definition of production and demand indicators

Indicators on production and demand are calculated, such that they provide insight in the changes over time of the importance of the different KETs, and in the relative importance of a KET in comparison to the other key technologies. We use Y to denote the volume of production in order to avoid confusion with the patent indicators.

#### *4.1.1.1 Production indicators*

- Significance $SG$ measures the share of production $Y$ in a certain KET $k$ of a country $i$ with respect to its total production in a year $t$, and is given by:

$$^{Y}SG_i^k(t) = \left(Y_i^k(t)/Y_i(t)\right)\ X\ 100$$

  with $Y_i(t)$ as total production in country *i* at year $t$.

- Specialisation $SP$ in a year $t$ relates the significance of a certain KET $k$ in a specific country $i$ to the significance of that KET $k$ across all (EU28) countries and hence indicates whether a country puts relatively more resources in producing this KET than other countries do. It is given by:

$$^{Y}SP_i^k(t) = \ln\left[\left(Y_i^k(t)/Y_i(t)\right)/\left(Y^k(t)/Y_i(t)\right)\right]\ X\ 100$$

  with $Y^k(t)$ as total production in KET *k* of the EU28 in year t.

- Market share $MS$ in a year $t$ gives the share of production of a KET $k$ for certain country $i$ in total production of all countries considered. It is given by:

$$^{Y}MS_i^k(t) = \left(Y_i^k(t)/Y^k(t)\right)\ X\ 100$$

- Medium-term dynamics MD in a year $t$ provides further insight on the trends in output of a certain KET in a specific country $i$ between period $t-1$ and $t$, given by:

$$^{Y}MD_i^k(t, t-1) = \left(\left(Y_i^k(t) - Y_i^k(t-1)\right)/Y_i^k(t-1)\right)\ X\ 100$$

#### 4.1.1.2 Demand indicators

For the calculation of the demand indicators, for which import and export data based on PRODCOM are used, the results of the assessment on the relevance and weighing of the entries are applied.[19]

With total Exports for a specific KET per year given by:

$$E_t^k(t) = \sum^{C^k} e_{c_x^k}(t) \times W_{c_x^k}(t)$$

where $E_i^k(t)$ reflects global export per country *i* per KET *k* at time *t*; and total Import given by:

$$I_t^k(t) = \sum^{C^k} i_{c_x^k}(t) \times W_{c_x^k}(t)$$

where $I_i^k(t)$ reflects global import per country *i* per KET *k* at time *t*; we define Demand as:

$$D_i^k(t) = Y_i^k(t) - E_i^k(t) + I_i^k(t)$$

where $D_i^k(t)$ reflects demand per country *i* per KET *k* at time *t.*

In practice, $D_i^k(t)$ is calculated within the framework of this project by Eurostat. Data are provided if and only if all underlying data are available for Eurostat (i.e. the complete set of $Y_i^k(t)$, $E_i^k(t)$ and $I_i^k(t)$ can be used for the computation of $D_i^k(t)$). In all other cases the subsequent demand value is regarded as missing.

With the aim of obtaining insights on a more aggregate level, this variable is also calculated for the six KETs together. In principle, this means that production for all KETs together is the simply the sum over the six KETs. However, in case no data was available for one or more of the KETs, no aggregate could be calculated such that this value is regarded as missing.

Note that demand as defined within the framework of our analysis results sometimes in negative values. In practice that is a known problem of these data within the framework of economic analysis, and not caused by our methodology. Basis for these issues is twofold:

- Production, import and export value are provided by different sources (manufacturers and customs authorities). It is subsequently possible that a product is clustered in different Prodcom entries for manufacturing and import / export.
- Especially for smaller countries with limited manufacturing capacity, but large harbour facilities, demand tends to be negative for specific product groups that are widely traded. The large transit of goods involving limited but significant adding of value (such as repackaging) results in a positive trade balance (i.e. export value exceeds import value). Combined with limited domestic production, this results in negative demand for of these specific goods.

[19] Note that for 2002, no aggregate EU27 was available for import and export per KET, this was only available for 2003-2012. The average proportion of the sum over EU countries to the aggregate EU27 was calculated per import/export and per KET over these years. Then, we used the product of this average times the sum over the country specific number to calculate the aggregate numbers in 2002.

The subsequent demand indicators are defined as follows:

- Significance $SG$ of domestic demand for a certain KET $k$ of a country $i$ with respect to total demand in a year $t$, and is given by:

$$^{D}SG_i^k(t) = \left(D_i^k(t)/GDP_i(t)\right)\ X\ 100$$

with $GDP_i(t)$ as total added value in country *i* at year $t$.

- Market share $MS$ in a year $t$ gives the share of demand of a KET $k$ for certain country $i$ in total demand of all countries considered. It is given by:

$$^{D}MS_i^k(t) = \left(D_i^k(t)/D^k(t)\right)\ X\ 100$$

- Medium-term dynamics MD in a year $t$ provides further insight on the trends in demand of a certain KET in a specific country $i$ between period $t-1$ and $t$, given by:

$$^{D}MD_i^k(t, t-1) = \left(\left(D_i^k(t) - D_i^k(t-1)\right)/D_i^k(t-1)\right)\ X\ 100$$

- Export quotient $EQ$ of country $i$ in KET $k$ in year $t$:

$$^{D}EQ_i^k(t) = \left(E_i^k(t)/Y^k(t)\right)$$

- Import quotient of country $i$ in KET $k$ in year $t$:

$$^{D}IQ_i^k(t) = \left(I_i^k(t)/D_i^k(t)\right)$$

### 4.1.2 From technology to production: definitions and steps

Within the framework of the KETs Observatory, indicators are compiled reflecting the value created by the deployment of KETs. A methodology linking technologies to production statistics has therefore been formulated comprising two consecutive steps:

- Step 1: Identification of relevant Prodcom entries for the KETs.
- Step 2: Assessment of the value created by the deployment of KETs for the selected Prodcom entries.

This section shortly introduces these steps and the relevant definitions that provide the framework for the corresponding actions. The following section describes how these steps were implemented.

#### *4.1.2.1 KETs and Prodcom*

The EC adopted the concept of Key Enabling Technologies as a basis for industrial policy in general, and R&D&I policy in specific (see Box 2).

*Box 2: KETs definition*

The EC defines KETs as (EC, 2009a[20], 2009b[21], 2012a[22]): *"KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalize on their research efforts."*

Six individual KETs have been identified by the EC: Nanotechnology (NT), Micro- and Nanoelectronics (MNE), Industrial Biotechnology (IB), Photonics (PHOT), Advanced Materials (AM), and Advanced Manufacturing Technologies (AMT). [23]

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[20] EC (2009a) Preparing for our future: Developing a common strategy for key enabling technologies in the EU. COM(2009) 512, Brussels: European Commission.

[21] EC (2009b) Current Situation of Key Enabling Technologies in Europe. COM(2009) 1257, Brussels: European Commission.

[22] EC (2012a) A European strategy for Key Enabling Technologies – A bridge to growth and jobs. COM(2012) 341, Brussels: European Commission.

[23] *Note that in case the KETs* experts scored Category 1 as well as Category 2 (i.e. for AM, PHOT, MNE, NT), the highest score was adopted:

$$w_{c_x^k} = max\left(w_{c^k_{x,Category1}}, w_{c^k_{x,Category2}}\right) \text{ for } k = \{MNE, Photonics, IB, AM, NT\}.$$

We subsequently calculate the corresponding weighting factors:

$$W_{c_x^k,\bar{t}} = \frac{e^{w_{c_x^k,\bar{t}}}-1}{e^3-1} \text{ and } W_{c^k_{d_x},\underline{t}} = \frac{e^{w_{c_x^k,\underline{t}}}-1}{e^3-1} \qquad (1)$$

and the intermediate weighting factors:

$$W_{c_x^k}(t) \ = W_{c_x^k,\underline{t}} + \frac{W_{c_x^k,\bar{t}} - W_{c_x^k,\underline{t}}}{(\bar{t}-\underline{t})}\left(t-\underline{t}\right) \qquad (2)$$

The different *Actions* as described before ultimately result in an estimation of the value created by the deployment of different KETs.

With the identification of the set of relevant PRODCOM entries per KET:

$$C^k = \{c_x^k : c_x \in k\} \text{ with } k = \{MNE, AMT, Photonics, IB, AM, NT\}$$

we link each relevant PRODCOM entry $c_x^k$ to a score $w_{c_x^k} \in \{0,1,2,3\}$ according to Table 5, for $t = \left(\bar{t}\ , \underline{t}\right)$ from the two extremes in the timeframe to be covered (i.e. $T = \left\{\bar{t}, \dots, \underline{t}\right\} = \{2002, \dots, 2012\}$.

Figure 9 gives the relation between the score and the corresponding weighting function, according to (1). Note that we use a non-linear, exponential scale, in line with the *Photonics Leverage project*; because it was found there that the leverage effect of the deployment of a technology becomes increasingly more prominent.

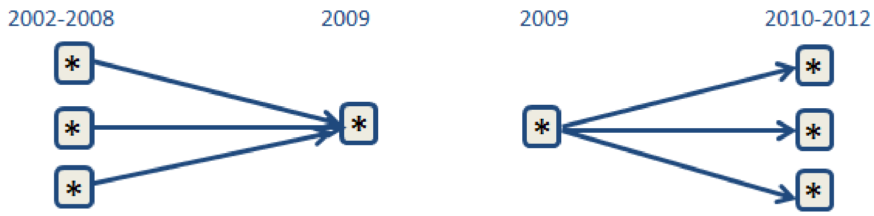
Note from (2) that we assume for simplicity a linear development in time for the weighting factors. This assumption is based on current research by TNO indicating that absorption / uptake of technologies in time does not follow a uniform path. In practice this implies a linear interpolation of the weighting factors between 2002 and 2012. The weighting factors for 2013 are based on a linear extrapolation.

As mentioned before, we have taken the 2009 classification of PRODCOM as a reference year for the assessment. As the PRODCOM entries are subject to change over time, the selected codes and corresponding weighting factors are valid just for the year 2009 itself. For the computation of the weighting factors for the whole period of our analysis, the 2009 codes were subsequently converted using coding details from linkage tables, which were available from the EU Ramon database.

In some cases however, PRODCOM codes are combined into one, or split up into multiple codes over the years. There are four type of cases encountered during conversion from 2009 both back- and forwards:

(i) One single code in 2002-2008 changed into one other code or remained the same in 2009; or one single code in 2009 changed into one other code or remained the same in 2010-2012. In this case, the code in 2002 and 2012 are simply assigned the weights of the experts and the weights for the years in between are interpolated.


(ii) Aggregation between 2002-2008 and 2009 or disaggregation after 2009, such that one single code in 2009 is split up into multiple codes in the years before or after. In this case, all these codes are assigned the weight of this single code in 2009.




(iii) Disaggregation between 2002-2008 and 2009 or aggregation after 2009, such that multiple codes in 2009 correspond to one single code in the years before or after. In this case, the single codes in 2002-2008 or 2010-2012 are assigned the maximum of the weights of the codes in 2009. This might be problematic, as this weight will probably be higher than originally intended by the experts.
Regarding the production values, the first implication of (iii) type of cases, is that the production values could be too high in the year that disaggregation occurred due to maximal weights assigned, such that growth in the subsequent year is too low. In case of aggregation after 2009, production values would be too high in the year after aggregation, resulting in an overestimated growth in this year. In both cases, this would however be a once-off remarkable growth, as production values in the years before (after) disaggregation (aggregation) are also too high as these codes are also assigned too large weights. However, the occurrence of (iii) type of cases is limited (approximately 100 out of 2000).

(iv) Some codes could be introduced somewhere between 2002-2008 or in 2009, or dropped after 2009. In this case, the experts might considered these codes relevant for the years

Analysis indicates that in practice there are no existing datasets that classify statistics according to technology-fields like KETs. Within the framework of this study the Prodcom database and its accompanying classification have been identified as a basis for the collection of statistical information on the deployment of the KETs in the European economy (see *Box 3*). 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. It therefore provides an optimal basis for the appropriate coverage of the different KETs. The strength of this approach

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2002 and 2012, while there are no such codes in one of these years. This might be problematic as these codes are not included for the years before introduction of the code, or the years after dropping the code.

Implications of (iv) type of cases is that PRODCOM codes relevant to the KET(s) would not contribute to the production value in this year, such that the value is too low. This means that growth in the year of introduction of codes could be somewhat overestimated. This is however a once-off occurrence. Furthermore, we observe that cancelling codes after 2009 does not occur in the selected PRODCOM codes, and the rate of occurrence of the first case, in which codes are introduced before 2009, is minimal with 24 times (relative to approximately 2000 codes).


Furthermore, aggregate (containing T- or Z-) codes (aggregated headings which were introduced to allow comparison with trade data) were removed from the lists of PRODCOM entries.

The corresponding value created by deployment of a KET in a certain year is given by:

$$Y_i^k(t) = \sum^{C^k} y_{c_x^k}(t) \times W_{c_x^k}(t)$$

with $y_{c_x^k}$ as the sales figure from the PRODCOM database for the selected PRODCOM entry $c_x^k$ (i.e. production value). $Y_i^k(t)$ reflects production per country *i* per KET *k* at time *t.* The ultimate calculation of the production, import and export value resulting from the deployment of KETs is conducted by EUROSTAT. $Y_i^k(t)$ is computed if and only if all underlying data are available for Eurostat (i.e. the complete set of relevant $y_{c_x^k}(t)$ can be used for the computation of $Y_i^k(t)$). In all other cases the subsequent production value is regarded as missing.

With the aim of obtaining insights on a more aggregate level, this variable is also computed for the six KETs together. In principle, this means that production for all KETs together is the simply the sum over the six KETs. However, in case no data is available for one or more of the KETs, no aggregate can be calculated such that this value is regarded as missing.

Appendix I: Description of KETs summarizes further redefinition of the KETs by the EC.

furthermore lies in the fact that all output and trade of KETs based products manufactured is recorded according to Prodcom entries.[24]

*Box 3: Prodcom classification*

| |
|---|
| *Prodcom provides statistics on the production of manufactured goods for mining, quarrying and manufacturing.[25] The term comes from the French "PRODuction COMmunautaire" (Community Production).Prodcom classifies product-groups according to an 8-digit code. Prodcom contains about 3900 different types of manufactured products. The first four digits are similar to the better known NACE classification.[26]* |

### 4.1.3 From KETs to Prodcom-based data: two consecutive steps

In order to assess the value created by the deployment of KETs, two consecutive steps have been defined. These are in line with (and building on) the results of the *Feasibility study for a KETs Observatory (*Van de Velde et al., 2013)[27].

#### *4.1.3.1 Step 1: Identification of relevant Prodcom entries.*

In order to link KETs to production statistics, we adopt the concept of a *KETs based product* as introduced by the EC (see *Box 4*).

*Box 4: KETs based product*

| |
|---|
| In its 2012 communication, the EC defines a KETs based products as (EC, 2012a):[28]<br><br>*(a) an enabling product for the development of goods and services enhancing their overall commercial and social value;*<br>*(b) induced by constituent parts that are based on nanotechnology, micro-nanoelectronics, industrial biotechnology, advanced materials and/or photonics;*<br>*and, but not limited to*<br>*(c) produced by advanced manufacturing technologies.* |

The *Feasibility study* indicated that this definition provides a good basis for the demarcation of KETs based products. But it does not suffice as a tool to consistently include or exclude KETs based Prodcom entries, and subsequently weight them. The approach for the selection of relevant Prodcom entries has therefore been extended (in line with the definition of *Box 4*), distinguishing between three different types of KETs based products, such that a uniform and practical approach for the selection of relevant Prodcom entries is created (see *Table 3*)[29].

[24] For further information on the Prodcom database, see *Appendix III:* Prodcom *database*.
[25] In practice, Prodcom covers sections B and C of the Statistical Classification of Economy Activity in the European Union (NACE 2). Note that the set of Prodcom entries also covers relevant services.
[26] NACE stands for *Nomenclature générale des activités économique dans les Communautés Européennes*, or Statistical Classification of Economic Activities in the European Community.
[27] Van de Velde et al., (2013) Feasibility study for an EU Monitoring Mechanism on Key enabling Technologies. Study prepared for the European Commission, DG enterprise and Innovation.
[28] Note that only (a) and (b) are selective criteria for the selection of KETs based Prodcom entries.
[29] We refer to products (including components and end-products) as most of the value created / added by KETs will take place in the end user product stage (actual deployment). We include all these different types of KETs based products because some KETs are more process related than others (specifically IB, and to a lesser extent

*Table 3: Categorisation of KETs based products*

| | |
|---|---|
| ***Category 1:*** | ***Products in which a KET is deployed that enables their functionality*** (i.e. a product "with a KET in it") |
| ***Category 2:*** | ***Products that are produced by deploying a KET in the manufacturing stage***. In practice this implies that this category covers products manufactured by means of AMT. |
| ***Category 3:*** | ***Production equipment that deploys a KET*** (i.e. production equipment "with a KET in it"): In practice this implies that this category covers AMT. |

Implementation of the methodology requires the involvement of KETs experts on IB, MNE, AM, NT and PHOT for the selection of relevant Prodcom entries that contain products in which a KET is deployed, or that are produced with the help of a KET (i.e. type (1.) and type (2.) of the typology of KETs based products). Experts on AMT were asked to identify all Prodcom entries covering KETs based equipment (i.e. type (3.) of the typology). An overview of the types of KETs based products covered is given in Table 4 (i.e. all fields covered with an "X").[30] As indicated, the practical implementation process of this selection procedure is described in the next section.

*Table 4: Types of KETs based products for further analysis*

| **KET** | **Category 1:** **Product with a KET** | **Category 2:** **Product deploying KET in its manufacturing** | **Category 3:** **Production Equipment with a KET** |
|---|---|---|---|
| *IB* | X | X | - |
| *MNE* | X | X | - |
| *AM* | X | X | - |
| *NT* | X | X | - |
| *PHOT* | X | X | - |
| *AMT* | - | - | X |

The demarcation of the KETs by means of our categories implies that:

- AMT covers only equipment for manufacturing, and all KETs based equipment is clustered under AMT.
- Non KETs-based equipment used for the manufacturing of KETs based products (e.g. conveyer belts, pipes, etc.) is not included in AMT.
- Production by means of Advanced Manufacturing Technologies is attributed to the individual KETS, and not to AMT itself.

AM). With these KETs, the innovative element is not so much in the end-product, but rather in the equipment or the process to manufacture this product. Taking only the first category into account would exclude relevant Prodcom entries, and ultimately lead to a wrong estimation of the value created by the deployment of KETs.

[30] This approach indicates a change from the selection procedure adopted for the *Feasibility study*, and subsequently results in a renewed, and very much extended, list of Prodcom entries per KET. Reason for this deviation in approach is that we need a uniform process for the selection of Prodcom entries per KET (i.e. a uniform approach towards the further demarcation of KETS) in order to be able to compare indicators per KET over time. In the *Feasibility study* this was not the case: NT, PHOT and AMT were (almost exclusively) restricted to Category 1; IB (because of its very nature) was limited to Category 3; and MNE was limited to just a subsection of Category 1 (i.e. "chips"). Within the framework of this project, we adopt an approach that allows for the selection of Prodcom entries over all three categories as identified in Table 4.

#### 4.1.3.2 Step 2: Assessment of the value created by the deployment of KETs for selected Prodcom entries.

Assessing the contribution of a technology to the value of a product is not straightforward. Literature (e.g. economic theory) provides no feasible point of departure for such an exercise on "translating" deployment of technology into value creation. For the assessment of KETs related value creation, the methodology builds on the concept of *leverage* (see *Box 5*) as adopted within the framework of the *Photonics Leverage project* (see (TNO et al., 2011)).[31]

*Box 5: Definition of leverage*

| |
|---|
| Leverage is defined, based on (TNO et al., 2011) as: *the proportional contribution of a specific KET to the resulting ultimate value of a KETs based product. This is reflected in (measured by) the contribution of the deployment of a specific KET to the competitiveness of KETs based products, either by providing/enhancing the functionality in the end device, or by reducing the associated production costs.* |

The Photonics Leverage project indicated that it is not possible to estimate directly the contribution of the deployment of a technology to the value of the end-product. The subsequent approach adopted in the project however provides a practical as well as proven methodology for the assessment of the impact of technology. The project has resulted in figures (on market and employment characteristics) that are widely adopted and quoted. In practice the methodology offers a basis for compiling robust (i.e. accurate, consistent and reproducible) indicators on production, demand and trade in the EU.

Adoption of the concept of leverage implies in practice that KETs experts were asked to assess the contribution of the deployment of a KET to the competitiveness of a selected *Prodcom* code. Prodcom entries are subsequently scored with the help of a semi-qualitative scale. The corresponding quantified scores are than used in a later stage to calculate the share of the production value of a Prodcom entry resulting from deployment of KETs.

Scoring contribution to the increase in competitiveness as a measure to estimate value creation might seem like a devious approach. But the starting point of the KETs strategy is that it is crucial for EU economic growth. The deployment of KETs is subsequently about enabling innovation and increasing competitiveness. The methodology therefore refers to the increase in competitiveness as it addresses (i.e. captures) the innovative capacity / aspects of KETs.

### 4.1.4 Approach

The actual / practical implementation of the abovementioned steps involved a series of actions, including workshops. These actions are described in detail in the following section.

#### 4.1.4.1 Action I: Further definition of KETs

During the *Feasibility study for a KETs Observatory* (Idea et al., 2013), it became clear that the existing descriptions of KETs (as defined in various policy documents such as (EC 2009a)) are not (mutually) exclusive.[32] This implies that a basis for the decision on inclusion or exclusion of a certain

[31] See: www.photonics21.org/download/Leverage_Internetversion.pdf of TNO, Technologia, Electronics, Sensors, Photonics Knowledge Transfer Network (2011) The Leverage Effect of Photonics Technologies: the European Perspective. Study prepared for the European Commission, DG Information Society and Media under reference SMART 2009/0066

[32] See Note *that in case the KETs* experts scored Category 1 as well as Category 2 (i.e. for AM, PHOT, MNE, NT), the highest score was adopted:

$$w_{c_x^k} = max\left(w_{c^k_{x,Category1}}, w_{c^k_{x,Category2}}\right) \text{ for } k = \{MNE, Photonics, IB, AM, NT\}.$$

We subsequently calculate the corresponding weighting factors:

$$W_{c_x^k,\bar{t}} = \frac{e^{w_{c_x^k,\bar{t}}}-1}{e^3-1} \text{ and } W_{c^k_{d_x},\underline{t}} = \frac{e^{w_{c_x^k,\underline{t}}}-1}{e^3-1} \qquad (1)$$

and the intermediate weighting factors:

$$W_{c_x^k}(t) = W_{c_x^k,\underline{t}} + \frac{W_{c_x^k,\bar{t}} - W_{c_x^k,\underline{t}}}{(\bar{t}-\underline{t})}\left(t-\underline{t}\right) \qquad (2)$$

The different *Actions* as described before ultimately result in an estimation of the value created by the deployment of different KETs.

With the identification of the set of relevant PRODCOM entries per KET:

$$C^k = \{c_x^k : c_x \in k\} \text{ with } k = \{MNE, AMT, Photonics, IB, AM, NT\}$$

we link each relevant PRODCOM entry $c_x^k$ to a score $w_{c_x^k} \in \{0,1,2,3\}$ according to Table 5, for $t = \left(\bar{t}\,, \underline{t}\right)$ from the two extremes in the timeframe to be covered (i.e. $T = \left\{\bar{t}, \dots, \underline{t}\right\} = \{2002, \dots, 2012\}$.

Figure 9 gives the relation between the score and the corresponding weighting function, according to (1). Note that we use a non-linear, exponential scale, in line with the *Photonics Leverage project*; because it was found there that the leverage effect of the deployment of a technology becomes increasingly more prominent.

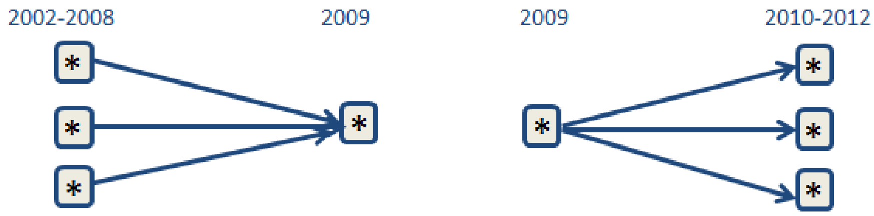
Note from (2) that we assume for simplicity a linear development in time for the weighting factors. This assumption is based on current research by TNO indicating that absorption / uptake of technologies in time does not follow a uniform path. In practice this implies a linear interpolation of the weighting factors between 2002 and 2012. The weighting factors for 2013 are based on a linear extrapolation.

As mentioned before, we have taken the 2009 classification of PRODCOM as a reference year for the assessment. As the PRODCOM entries are subject to change over time, the selected codes and corresponding weighting factors are valid just for the year 2009 itself. For the computation of the weighting factors for the whole period of our analysis, the 2009 codes were subsequently converted using coding details from linkage tables, which were available from the EU Ramon database.

In some cases however, PRODCOM codes are combined into one, or split up into multiple codes over the years. There are four type of cases encountered during conversion from 2009 both back- and forwards:

(v) One single code in 2002-2008 changed into one other code or remained the same in 2009; or one single code in 2009 changed into one other code or remained the same in 2010-2012. In this case, the code in 2002 and 2012 are simply assigned the weights of the experts and the weights for the years in between are interpolated.


(vi) Aggregation between 2002-2008 and 2009 or disaggregation after 2009, such that one single code in 2009 is split up into multiple codes in the years before or after. In this case, all these codes are assigned the weight of this single code in 2009.




(vii) Disaggregation between 2002-2008 and 2009 or aggregation after 2009, such that multiple codes in 2009 correspond to one single code in the years before or after. In this case, the single codes in 2002-2008 or 2010-2012 are assigned the maximum of the weights of the codes in 2009. This might be problematic, as this weight will probably be higher than originally intended by the experts.

Regarding the production values, the first implication of (iii) type of cases, is that the production values could be too high in the year that disaggregation occurred due to maximal weights assigned, such that growth in the subsequent year is too low. In case of aggregation after 2009, production values would be too high in the year after aggregation, resulting in an overestimated growth in this year. In both cases, this would however be a once-off remarkable growth, as production values in the years before (after) disaggregation (aggregation) are also too high as these codes are also assigned too large weights. However, the occurrence of (iii) type of cases is limited (approximately 100 out of 2000).

(viii) Some codes could be introduced somewhere between 2002-2008 or in 2009, or dropped after 2009. In this case, the experts might considered these codes relevant for the years 2002 and 2012, while there are no such codes in one of these years. This might be problematic as these codes are not included for the years before introduction of the code, or the years after dropping the code.

Implications of (iv) type of cases is that PRODCOM codes relevant to the KET(s) would not contribute to the production value in this year, such that the value is too low. This means that growth in the year of introduction of codes could be somewhat overestimated. This is however a once-off occurrence. Furthermore, we observe that cancelling codes after 2009 does not occur in the selected PRODCOM codes, and the rate of occurrence of the first case, in which codes are introduced before 2009, is minimal with 24 times (relative to approximately 2000 codes).

product / Prodcom code is lacking. The demarcation of the individual KETs is an essential exercise for the compiling of data for the indicators. As a basis for selection of relevant Prodcom entries, underlying products/technologies were therefore identified by TNO experts that constitute the individual KETs.[33] [34]

#### 4.1.4.2 Action II: Pre-selection of Prodcom entries

In order to further support the identification and assessment of relevant Prodcom entries, a pre-selection of relevant Prodcom-codes per KET was made by TNO experts, with the help of the list containing the sub-technologies / product categories demarcating the KETs. This first assessment concerning inclusion or exclusion was done on 4-digits level (i.e. NACE level).

#### 4.1.4.3 Action III: Identification of KETs experts for the workshops

For the ultimate selection of Prodcom entries, and subsequent assessment of the value created by the deployment of KETs, experts were identified from Fraunhofer, CEA and TNO (i.e. from each RTO

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Furthermore, aggregate (containing T- or Z-) codes (aggregated headings which were introduced to allow comparison with trade data) were removed from the lists of PRODCOM entries.

The corresponding value created by deployment of a KET in a certain year is given by:

$$Y_i^k(t) = \sum^{C^k} y_{c_x^k}(t) \times W_{c_x^k}(t)$$

with $y_{c_x^k}$ as the sales figure from the PRODCOM database for the selected PRODCOM entry $c_x^k$ (i.e. production value). $Y_i^k(t)$ reflects production per country *i* per KET *k* at time *t.* The ultimate calculation of the production, import and export value resulting from the deployment of KETs is conducted by EUROSTAT. $Y_i^k(t)$ is computed if and only if all underlying data are available for Eurostat (i.e. the complete set of relevant $y_{c_x^k}(t)$ can be used for the computation of $Y_i^k(t)$). In all other cases the subsequent production value is regarded as missing.

With the aim of obtaining insights on a more aggregate level, this variable is also computed for the six KETs together. In principle, this means that production for all KETs together is the simply the sum over the six KETs. However, in case no data is available for one or more of the KETs, no aggregate can be calculated such that this value is regarded as missing.

Appendix I: Description of KETs.

[33] This is in line with the first recommendation on improvement of the methodology for the KETs Observatory, as indicated in the *Feasibility study for a KETs Observatory* (Idea et al., 2013, p92):

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.*

[34] See *Appendix II: KETs taxonomy*. Note that this taxonomy of KETs (i.e. this list of identified sub-technologies and product-fields) forms a coherent set; the choices made in the demarcation for a specific KET should be considered in view of the selection for other KETs. It is inevitable however that there is a certain overlap between the different KETs.

one for each KET).[35] These "external" experts were selected such that their specific knowledge and expertise covers the sub-technologies / product-fields as identified in the previous Action II.[36]

#### *4.1.4.4 Action IV: Preparatory work by KETs experts:*

The KETs experts assessed the pre-selection of entries and the leverage effect of the deployment prior to the workshop, as input for further validation during the actual meeting.[37]

In practice, it is not straightforward to assess the value created by the deployment of KETs. As indicated, an approach has been embraced based on the methodology adopted to measure the leverage effect of Photonics Technologies (see (TNO et al., 2011). The methodology adopted in this *Photonics Leverage project* implies that contribution to the change in competitiveness is used as a measure to estimate value created by the deployment of a KET. The project indicated that it is not possible to estimate directly the contribution of the deployment of a technology to the value of the end-product. We refer to change in competitiveness as it addresses (i.e. captures) the innovative capacity / aspects of KETs.

In order to measure the leverage effect, the KETs experts were asked to score the pre-selected Prodcom entries according to the scale as described underneath in Table 5. As indicated:

- KETs experts on AMT were asked to focus on **KETs based equipment**.
- All other KETs experts were asked to distinguish between a **Product with a KET**, and a **Product with a KET in its production process**.

The KETs experts were asked to assess the impact of the deployment of the different KETs not only for the current situation (i.e. 2012, the final year covered by the Prodcom database), but also with respect to the situation 10 years ago (i.e. 2002). This allows for the creation of time-series of data addressing value created by the different KETs.

Basis for the assessment was the list of Prodcom entries according to the 2009 specification. In practice, the set of Prodcom entries is modified each year, resulting in the adoption of new codes, clustering of existing codes or making redundant of existing codes to better capture the changes in output.[38] We chose for the 2009 specification because that was also used in the *Feasibility study*. We

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[35] This is in line with the second and third recommendation on improvement of the methodology for the KETs Observatory, as indicated in the *Feasibility study for a KETs Observatory* (Idea et al., 2013, p93):

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.*
   ➔ *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 code35. 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 the selection of Prodcom entries would be a consultation of classification experts.*

[36] *A complete overview of all* experts is available upon request. As indicated before, during the *Feasibility study for a KETs Observatory* (Idea et al., 2013), KETs experts were involved in the identification of relevant Prodcom entries, as a way to test the methodology for data collection. It became clear during this selection process that KETs experts in general are not familiar with the Prodcom classification.

[37] The KETs experts were thoroughly briefed with the help of dedicated instructions, the list of sub-technologies / product-groups, and the pre-selection of Prodcom entries. They received all relevant input about a week before the workshops. Preparation as described in this Action IV has required about half a day.

[38] About 5% of all Prodcom entries changes each year.

chose to present the experts with just one set in order not to further complicate the assessment process.

*Table 5: Scoring for Prodcom entries*

| Score | In case: |
|---|---|
| 0 | KETs do not play a role because the Prodcom code is **not KETs based;**<br>or<br>a specific KET was deployed, but the actual use is **not relevant or just of marginal importance for the increase in competitiveness** of the products within the Prodcom entry. |
| 1 | The deployment of a KET is of **intermediate importance for the increase in competitiveness.** Although the KET had impact on competitiveness, other aspects (such as other technologies) had a significantly higher impact. |
| 2 | The deployment of a KET is **important for the increase in competitiveness** of the products within the Prodcom entry, but also some other aspects (such as other technologies) were important to its competitiveness. |
| 3 | The KET is the **crucial** technology for **the increase in competitiveness** of this Prodcom code. |

Scoring the Prodcom entries is about deciding if they are KETs related, and what is the contribution of KETs to the increase in competitiveness. As a way to guide the decision on this last issue, the following line of reasoning was adopted:

*A Prodcom entry contains a set of different products, which are manufactured by a corresponding group of firms. Scoring change in competitiveness for these product is about estimating for these firms the importance of the deployment of KETs (i.e. as a way to enable the functionality or the production process of this set of products), when competing with other companies in this group.*

*Figure 7: Relation between the deployment of KETs and the increase in competitiveness.*

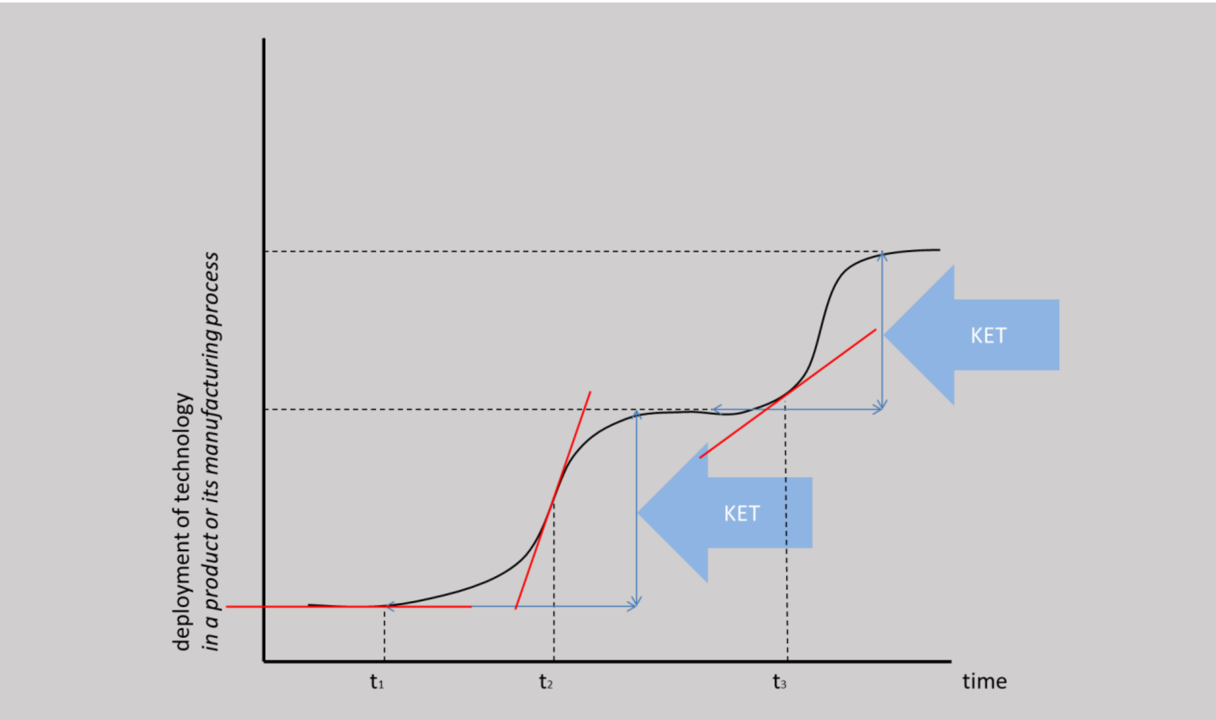


*Figure 7* provides insight in how we view the relation between the deployment of KETs and the increase in competitiveness. We argue that the main drivers for such an increase are (1) improving / creating (new) functionalities of products or services, or (2) improving the manufacturing process (i.e. reducing cost of production). We furthermore assume that such an increase in competitiveness results from a change in the deployment of technology in the product or its production process. We maintain that an increase in the level of deployment of technology results from KETs (if it involves the technologies clustered under the Key Enabling Technologies). This implies that we argue that a technology is a KET if and only if it contributes to the increase in the level of deployment of technology. This assumption is in line with the actual definition of KETs (see Box 2).

We subsequently argue that scoring the contribution of KETs to the increase in competitiveness is about assessing the change in deployment of technology over time. And the steeper the derivative at a certain time *t*, the higher the contribution of KETs to the increase in competitiveness:

$$\Delta\ \mathrm{competitiveness} = \mathrm{f(functionality,\ cost, \dots)} = \frac{d(deployment\ of\ technology)}{dt}$$

As an example: in *Figure 7* at $t_1$ the level of deployment of technology is constant over time, and the technology applied is therefore not a KET. At $t_2$ there is a change in the level of deployment of technology in the product or its manufacturing process, and we argue that this results from the deployment of a KET (if we assume that it involves a technology clustered accordingly). The uptake at $t_2$ of technology is higher than at $t_3$; and we subsequently argue that the contribution to the competitiveness is therefore also higher. The actual scoring depends on the change in deployment of technology in comparison to other factors that define the overall competitiveness of the product.

The assumptions above imply that assessing the contribution of a KET to the value created is not about the absolute deployment of technologies. If technology is applied just to maintain the status quo in the market, it is no more a KET. It is also not about the *potential* contribution to the change in competitiveness of the set of products.

Note that the contribution to the increase in competitiveness is assessed on Prodcom-level, and not on KETs based product-level. This is of relevance because in practice not all Prodcom entries can be assigned for 100% to a specific KET (i.e. containing only KETs based products). In general just a subset of the different products covered by a Prodcom code will be KETs based.[39]

Note furthermore from Table 5 that we impose a certain threshold for the level of contribution of KETs to competitiveness, for Prodcom entries to be included (i.e. contribution should be more than just of marginal importance). We do this to filter out “false positives” in the selection process, such that the identified codes are in line with the current thinking on what is a KETs based product according to the definition of Box 4.

[39] We argue however that this does not affect the validity of the results of such an exercise. As discussed, a similar approach was adopted by the *Photonics Leverage project*, which retrieved weighting factors from an assessment on NACE-level (i.e. a much higher aggregation level).

#### 4.1.4.5 Action V: Workshop

Within the framework of this project, two workshops were conducted with KET experts from TNO, Fraunhofer and CEA (29th of October 2013 on AMT, MNE and Photonics; and 5th of November 2013 on IB, NT and AM) at the TNO office in Hoofddorp. Objective of these workshops was to consolidate the input provided resulting from the preparatory work by the KETs experts within the framework of the previous action (i.e. *Action IV*).[40] The workshops were facilitated by the TNO project team. The KETs experts from TNO guided the content-related discussions if the input from the experts differed for a specific Prodcom entry.

The results of the assessment by the KETs experts from TNO, CEA and Fraunhofer have subsequently been reviewed by the TNO project team, in order to ensure that the scoring balanced over the different KETs (i.e. no bias towards / against a specific KET in weighting factors).

The overall result is a validated list of scores according to the semi-quantitative scale as introduced above, for all relevant Prodcom entries per KET, for two different years. *Figure 8* gives an overview of the number of Prodcom entries identified as being relevant for each KET, and the number of entries per score.[41] The following conclusions can be drawn from our experiences with the process of identifying and scoring the relevant Prodcom entries:

- The experts considered the methodology adopted to be a logical approach as a basis for compiling data on the value created by KETs. The methodology for selecting and weighting entries was perceived as feasible. The whole exercise was considered to be laborious, but also interesting as it allowed them to exchange their views and experiences regarding application of KETs in products. The preparation proved to be essential for the successful completion of the exercise.
- The KETs taxonomy needs further elaboration in the later stages of the project to further clarify the demarcation of the KETs. In practice, the entries were fine, but they need further refinement, for example to exclude overlap within a KET, and between KETs.
- During the workshop itself, there was a discussion mainly on the height of the scores, and not so much on the fact whether or not a Prodcom entry was KET-related.
- In practice all relevant IB codes are of Category 2. The scores for IB were relatively low, as the technology as such is rather new and is not applied widespread over many different Prodcom entries.
- The experts limited AMT to manufacturing equipment that is applied in a production line. Pre-production equipment was excluded (as much as possible).
- In total 2070 entries were identified as being relevant. A large share of these entries is covered by MNE and Photonics. This is caused by the fact that these KETs play an important role in the manufacturing of many products (i.e. Category 2 KETs based products).
- KETs have become more dominant in the different product groups clustered according to the Prodcom: 1794 entries selected for 2002, and 2060 for 2012.
- A limited number of entries (88, or about 4%) has been identified as relevant for multiple KETs, such that the sum of the weighting factors exceeds 1. This holds especially for Prodcom entries falling under NACE 26.11 (manufacture of electronic components), which are addressed by MNE

[40] All experts (including those from the National Statistics Offices) were again briefed about the workshop and their role before the actual meetings.
[41] Note that, as mentioned before, this is the result for the Prodcom codes of 2009 as a reference year.

and Photonics.[42] Our methodology allows for this to happen. In general, this is caused by the fact that: there is overlap in the KETs; that deploying them results in additional impact on functionality (i.e. “cross-fertilisation”); and that it is impossible to identify / isolate in that case the impact of a single KET.

- We believe that we have defined and adopted a methodology which allows for a consistent selection and weighting of Prodcom entries (described as being “logical” approach by the experts). We also believe that we have a good basis (i.e. selection of Prodcom entries) for the compiling of data. We do believe however that further validation by industry representatives could contribute to refining the list.

[42] NACE 26.11 (manufacture of electronic components) refers to: Semiconductor diodes; Transistors, other than photosensitive transistors; Semiconductor thyristors, diacs and triacs; Semiconductor light emitting diodes (LEDs); Photosensitive semiconductor devices (solar cells, photo-diodes, photo-transistors, etc.); Semiconductor devices (excluding photosensitive semiconductor devices, photovoltaic cells, thyristors, diacs and triacs, transistors, diodes, and light-emitting diodes).

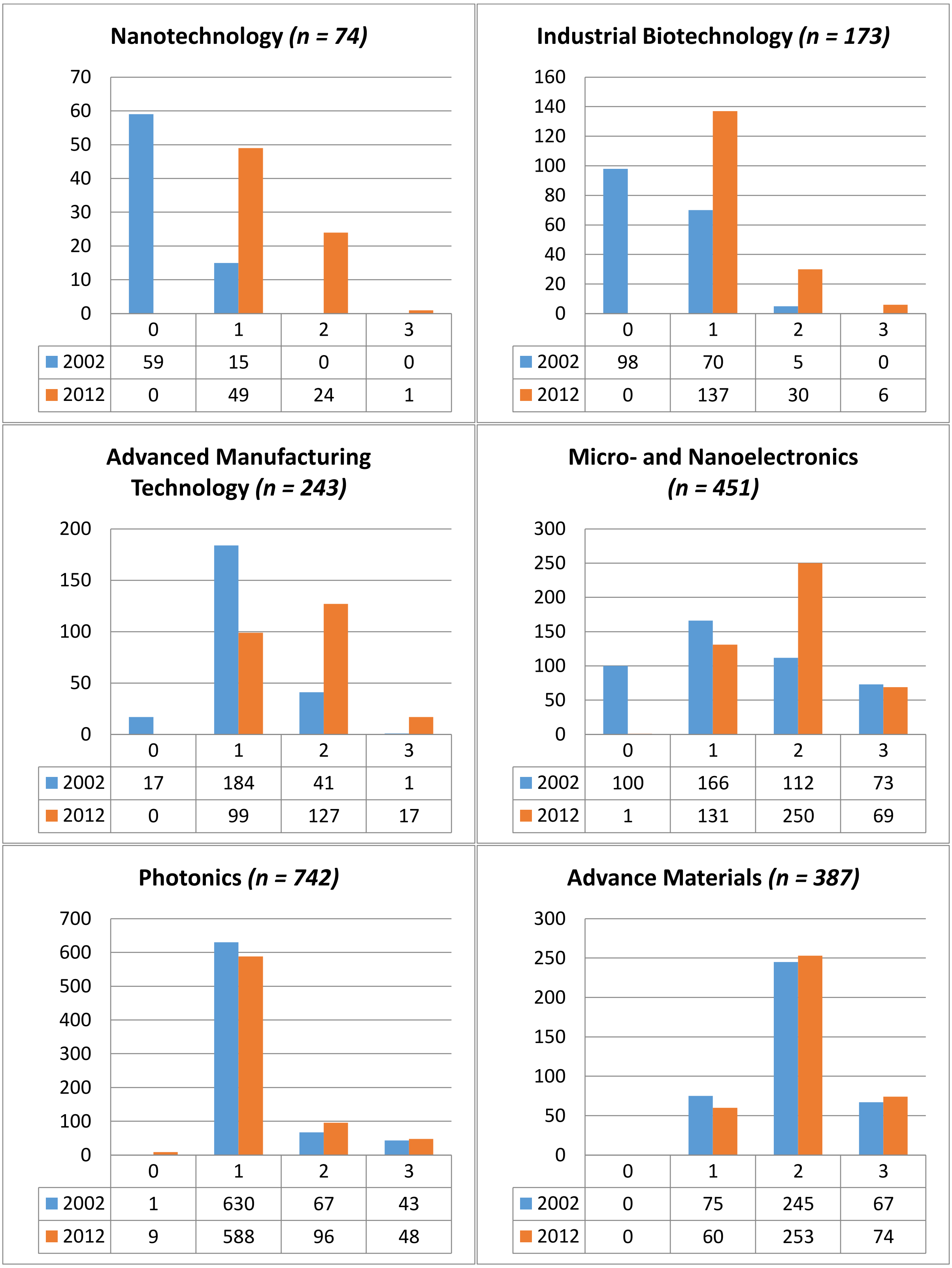



*Figure 8: Number of Prodcom entries scored per weighting class for the different KETs*

### 4.1.5 Estimation of the value created by KETs

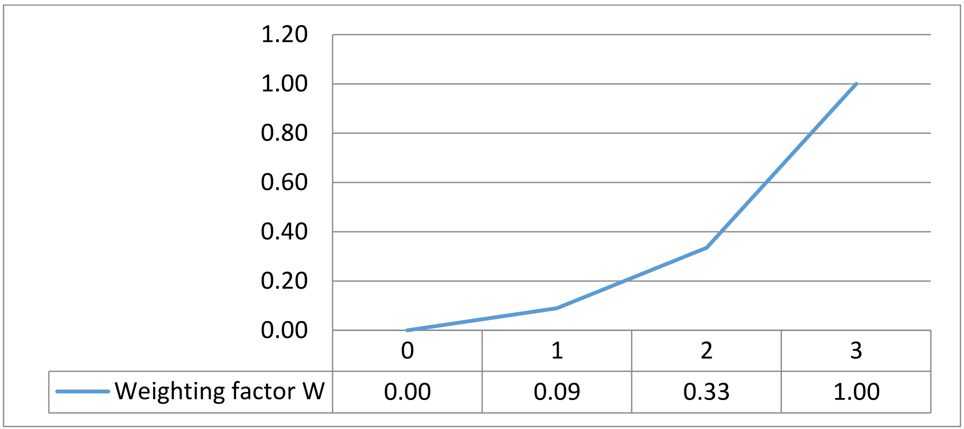
The different *Actions* as described before ultimately result in an estimation of the value created by the deployment of different KETs.

With the identification of the set of relevant PRODCOM entries per KET:

$$C^k = \{c_x^k : c_x \in k\} \text{ with } k = \{MNE, AMT, Photonics, IB, AM, NT\}$$

we link each relevant PRODCOM entry $c_x^k$ to a score $w_{c_x^k} \in \{0,1,2,3\}$ according to Table 5, for $t = (\overline{t}, \underline{t})$ from the two extremes in the timeframe to be covered (i.e. $T = \{\overline{t}, \dots, \underline{t}\} = \{2002, \dots, 2012\}$.

*Figure 9: Weighting factors for production and demand indicators – Technology diffusion approach*




Note that in case the KETs experts scored Category 1 as well as Category 2 (i.e. for AM, PHOT, MNE, NT), the highest score was adopted:

$$w_{c_x^k} = max\left(w_{c^k_{x,Category1}}, w_{c^k_{x,Category2}}\right) \text{ for } k = \{MNE, Photonics, IB, AM, NT\}.$$

We subsequently calculate the corresponding weighting factors:

$$W_{c_x^k,\overline{t}} = \frac{e^{w_{c^k_{x,\overline{t}}}}-1}{e^3-1} \text{ and } W_{c^k_{d_x},\underline{t}} = \frac{e^{w_{c^k_{x,\underline{t}}}}-1}{e^3-1} \qquad (1)$$

and the intermediate weighting factors:

$$W_{c_x^k}(t) = W_{c^k_x,\underline{t}} + \frac{W_{c^k_x,\overline{t}} - W_{c^k_x,\underline{t}}}{(\overline{t}-\underline{t})}(t-\underline{t}) \qquad (2)$$

The different *Actions* as described before ultimately result in an estimation of the value created by the deployment of different KETs.

With the identification of the set of relevant PRODCOM entries per KET:

$$C^k = \{c_x^k : c_x \in k\} \text{ with } k = \{MNE, AMT, Photonics, IB, AM, NT\}$$

we link each relevant PRODCOM entry $c_x^k$ to a score $w_{c_x^k} \in \{0,1,2,3\}$ according to Table 5, for $t = (\overline{t}, \underline{t})$ from the two extremes in the timeframe to be covered (i.e. $T = \{\overline{t}, \dots, \underline{t}\} = \{2002, \dots, 2012\}$.

Figure 9 gives the relation between the score and the corresponding weighting function, according to (1). Note that we use a non-linear, exponential scale, in line with the *Photonics Leverage project*; because it was found there that the leverage effect of the deployment of a technology becomes increasingly more prominent.

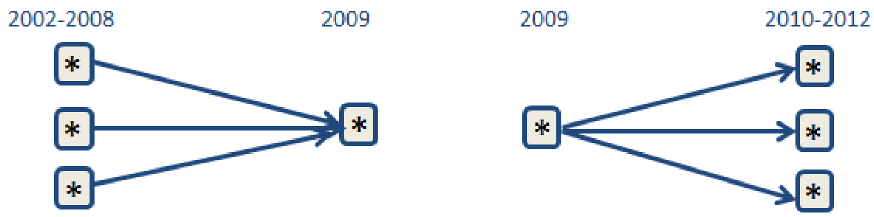
Note from (2) that we assume for simplicity a linear development in time for the weighting factors. This assumption is based on current research by TNO indicating that absorption / uptake of technologies in time does not follow a uniform path. In practice this implies a linear interpolation of the weighting factors between 2002 and 2012. The weighting factors for 2013 are based on a linear extrapolation.

As mentioned before, we have taken the 2009 classification of PRODCOM as a reference year for the assessment. As the PRODCOM entries are subject to change over time, the selected codes and corresponding weighting factors are valid just for the year 2009 itself. For the computation of the weighting factors for the whole period of our analysis, the 2009 codes were subsequently converted using coding details from linkage tables, which were available from the EU Ramon database.

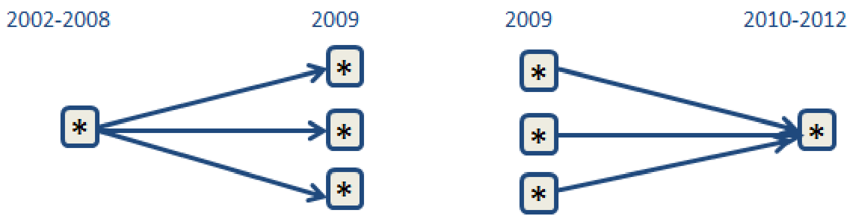
In some cases however, PRODCOM codes are combined into one, or split up into multiple codes over the years. There are four type of cases encountered during conversion from 2009 both back- and forwards:

(i) One single code in 2002-2008 changed into one other code or remained the same in 2009; or one single code in 2009 changed into one other code or remained the same in 2010-2012. In this case, the code in 2002 and 2012 are simply assigned the weights of the experts and the weights for the years in between are interpolated.


(ii) Aggregation between 2002-2008 and 2009 or disaggregation after 2009, such that one single code in 2009 is split up into multiple codes in the years before or after. In this case, all these codes are assigned the weight of this single code in 2009.




(iii) Disaggregation between 2002-2008 and 2009 or aggregation after 2009, such that multiple codes in 2009 correspond to one single code in the years before or after. In this case, the single codes in 2002-2008 or 2010-2012 are assigned the maximum of the weights of the codes in 2009. This might be problematic, as this weight will probably be higher than originally intended by the experts.




Regarding the production values, the first implication of (iii) type of cases, is that the production values could be too high in the year that disaggregation occurred due to maximal weights assigned, such that growth in the subsequent year is too low. In case of aggregation after 2009, production values would be too high in the year after aggregation, resulting in an overestimated growth in this year. In both cases, this would however be a once-off remarkable growth, as production values in the years before (after) disaggregation (aggregation) are also too high as these codes are also assigned too large weights. However, the occurrence of (iii) type of cases is limited (approximately 100 out of 2000).

(iv) Some codes could be introduced somewhere between 2002-2008 or in 2009, or dropped after 2009. In this case, the experts might considered these codes relevant for the years 2002 and 2012, while there are no such codes in one of these years. This might be problematic as these codes are not included for the years before introduction of the code, or the years after dropping the code.

Implications of (iv) type of cases is that PRODCOM codes relevant to the KET(s) would not contribute to the production value in this year, such that the value is too low. This means that growth in the year of introduction of codes could be somewhat overestimated. This is however a once-off occurrence. Furthermore, we observe that cancelling codes after 2009 does not occur in the selected PRODCOM codes, and the rate of occurrence of the first case, in which codes are introduced before 2009, is minimal with 24 times (relative to approximately 2000 codes).


Furthermore, aggregate (containing T- or Z-) codes (aggregated headings which were introduced to allow comparison with trade data) were removed from the lists of PRODCOM entries.

The corresponding value created by deployment of a KET in a certain year is given by:

$$Y_i^k(t) = \sum^{c^k} y_{c_x^k}(t) \times W_{c_x^k}(t)$$

with $y_{c_x^k}$ as the sales figure from the PRODCOM database for the selected PRODCOM entry $c_x^k$ (i.e. production value). $Y_i^k(t)$ reflects production per country *i* per KET *k* at time *t.* The ultimate calculation of the production, import and export value resulting from the deployment of KETs is conducted by EUROSTAT.[43] $Y_i^k(t)$ is computed if and only if all underlying data are available for

[43] As indicated in the *Feasibility study for a KETs Observatory* (Idea et al., 2013), an important weakness of the current set of production data from PRODCOM is that they are incomplete because of for example

Eurostat (i.e. the complete set of relevant $y_{c_x^k}(t)$ can be used for the computation of $Y_i^k(t)$). In all other cases the subsequent production value is regarded as missing.

With the aim of obtaining insights on a more aggregate level, this variable is also computed for the six KETs together. In principle, this means that production for all KETs together is the simply the sum over the six KETs. However, in case no data is available for one or more of the KETs, no aggregate can be calculated such that this value is regarded as missing.

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confidentiality issues (e.g. in case production can be attributed to single and known manufacturer(s)). Only EUROSTAT is able to address this issue, by calculating data on aggregated KETs level. This is in line with the fourth recommendation on improvement of the methodology for the KETs Observatory, as indicated in the *Feasibility study for a KETs Observatory* (Idea et al., 2013, p93):

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. National Statistics Offices should therefore be urged via Eurostat, to represent the output and trade data on KETs level.*
   - ➔ *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.*

For an indication of what is available: 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.

# 5 Appendix I: Description of KETs

Based on (EC 2009a) the team of EC officials monitoring the KETs Observatory project further defined the KETs:

**Nanotechnology** is an umbrella term that covers the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale. Nanotechnology holds the promise of leading to the development of smart nano and micro devices and systems and to radical breakthroughs in vital fields such as healthcare, energy, environment and manufacturing;

**Micro- and nanoelectronics** deal with semiconductor components and/or highly miniaturized electronic subsystems and their integration in larger products and systems. They include the fabrication, the design, the packaging and test from nano-scale transistors to micro-scale systems integrating multiple functions on a chip".

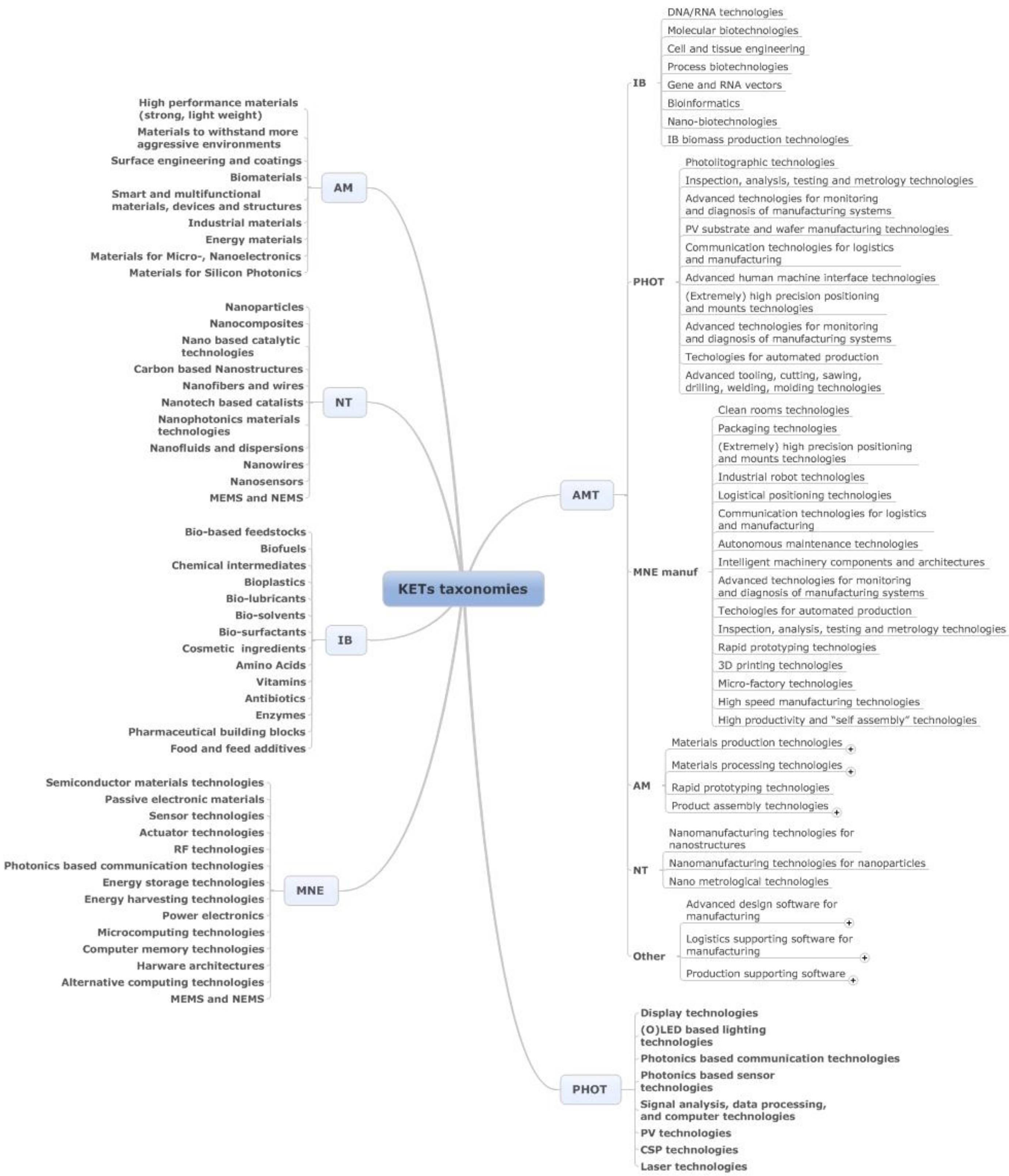
**Photonics** is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Among other things it provides the technological basis for the economic conversion of sunlight to electricity which is important for the production of renewable energy, and a variety of electronic components and equipment such as photodiodes, LEDs and lasers.

**Advanced materials** lead both to new reduced cost substitutes to existing materials and to new higher added-value products and services." Advanced materials offer major improvements in a wide variety of different fields, e.g. in aerospace, transport, building and health care. They facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe.

**Industrial Biotechnology** or white biotechnology is the "application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using microorganisms or components of micro-organisms like enzymes to generate industrially useful products in a more efficient way (e.g. less energy use, or less by-products), or generate substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already on the market. The most mature applications are related to enzymes used in the food, feed and detergents sectors. More recent applications include the production of biochemicals, biopolymers and biofuels from agricultural or forest wastes."

**Advanced manufacturing** encompass the use of innovative technology to improve products or processes that drive innovation. It includes all production equipment that deploys a KET or any other innovative technology, but excludes the actual production as this is attributed to the individual KETs.

# 6 Appendix II: KETs taxonomy



# 7 Appendix III: Prodcom database

The Prodcom based database of Eurostat offers consolidated information on sold production, exports and imports by country. The Prodcom database covers only EU 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.[44]

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

- While trade data records all traded products, production data is often restricted to output data of enterprises with more than 20 employees[45].
- 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.

[44] 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.

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

# 8 Appendix IV: Example of assessment of the technology diffusion approach

This section briefly describes the results of the assessment of the contribution of MNE to the value created within Prodcom entry 29102230.

| PRCCode | Desc_EN |
|---|---|
| **29102230** | Motor vehicles with a petrol engine > 1500 cm³ (including motor caravans of a capacity > 3000 cm³) (excluding vehicles for transporting ≥ 10 persons, snowmobiles, golf cars and similar vehicles) |

This Prodcom entry covers output of the automotive industry "cars" within a specific class. In practice there are different Prodcom entries that cover the entire product group of cars. The corresponding Prodcom entries are in general labeled starting with *"Motor vehicles…."*. There are also different KETs applied in the products of these relevant entries.

In line with our categorization of KETs based products (see *Table 3*), the contribution of MNE to the increase in competitiveness is assessed for the products covered by Prodcom entry 29102230 (i.e. Category 1) as well as for the manufacturing process (i.e. Category 2).

| **Workshop** | | | | **Largest value** | | **Weighting factor** | |
|---|---|---|---|---|---|---|---|
| Product with MNE in it? | | Product deploying MNE in its manufacturing? | | | | | |
| 2002 | 2012 | 2002 | 2012 | 2002 | 2012 | 2002 | 2012 |
| 2 | 2 | 2 | 2 | 2 | 2 | 0,33 | 0,33 |

The experts in the workshop assessed that in 2012 the deployment of MNE in the products covered by Prodcom code 29102230 is important for the increase in competitiveness, but also some other aspects (such as other technologies) were important to its competitiveness. They subsequently gave it a score of 2, as defined in Table 5. They assessed the contribution of MNE in the manufacturing process to be also 2.

The actual score for 2012 is the maximum of the values for 2002 and 2012; equaling 2. This corresponds with a weighting factor of 0.33 as defined in The different *Actions* as described before ultimately result in an estimation of the value created by the deployment of different KETs.

With the identification of the set of relevant PRODCOM entries per KET:

$$C^k = \{c_x^k : c_x \in k\} \text{ with } k = \{MNE, AMT, Photonics, IB, AM, NT\}$$

we link each relevant PRODCOM entry $c_x^k$ to a score $w_{c_x^k} \in \{0,1,2,3\}$ according to Table 5, for $t = (\overline{t}, \underline{t})$ from the two extremes in the timeframe to be covered (i.e. $T = \{\overline{t}, \dots, \underline{t}\} = \{2002, \dots, 2012\}$.

Figure 9. In practice this implies that we argue, based on our methodology, that the value created by MNE within Prodcom entry 29102230 equals 0.33 times the sales value associated with this entry.

For 2002, the experts assessed the contribution of MNE also as a 2. This does not imply that they believe that the same technology is applied. It implies that they believe that the increase in the level of MNE deployed by manufacturers within the Prodcom entry had a comparable contributed to the competitiveness in both years.