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**DEVELOPING A STATISTICAL FRAMEWORK FOR THE MEASUREMENT OF ENABLING
TECHNOLOGIES AND THEIR APPLICATIONS:**

DRAFT GUIDELINES FOR COLLECTING AND INTERPRETING TECHNOLOGY DATA

Paris, 4-6 June 2012

This document has been prepared by members of the NESTI Task Force on "Measuring Emerging, Enabling, and General Purpose Technologies", led by the Russian Federation, as part of a scoping exercise to develop an integrated framework for the measurement of enabling technologies and their applications.

This document sets out in more detail the principles proposed in DSTI/EAS/STP/NESTI(2012)9.

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FOREWORD

This document presents a working draft of a scoping paper on developing a Statistical Framework for the measurement of enabling technologies and their applications.

This document proposes a generic approach for formulating an operational definition of technologies, distinguishing between some aspects of technology lifecycle, recognising emerging S&T areas and their classification principles, suggesting survey strategies and metrics for development, application, diffusion and impact of technologies.

Draft principles for collecting and interpreting technology data, laid out in [DSTI/EAS/STP/NESTI\(2012\)9](#), have been prepared within a NESTI Task Force. This Task Force was set up in 2010 to develop an approach for the regular and robust statistical measurement of *emerging, enabling and general-purpose technologies* (EEGPT). The Framework on EEGPT measurement renewed interest within the NESTI in developing a common conceptual and methodological approach which can be used across the entire field of emerging and enabling technologies and help in monitoring their development, subsequent diffusion and impacts (NESTI 2007) to simplify the work of statisticians by avoiding unnecessary replication of similar conceptual and methodological strategies and guidelines for particular technology domains (*e.g.* ICT, biotechnology and nanotechnology), while potentially also enabling greater consistency of approaches.

As part of this process, a set of preliminary proposals on the general approach [[DSTI/EAS/STP/NESTI\(2010\)23](#)] and key concepts [[DSTI/EAS/STP/NESTI\(2010\)25](#)] have been already presented and discussed during 2010. Since then the Task Force has reviewed existing frameworks and national practices of measuring technology-related issues. The initial findings from the stocktaking exercise on national measurement practices as well as work on operational definitions and classifications were presented at the annual NESTI meeting in June 2011 [[DSTI/EAS/STP/NESTI\(2011\)6](#)]. It was decided to continue work on developing draft guidelines for collecting and interpreting technology data.

Since June 2011, a second round of the stocktaking was carried out to with support from the Secretariat. This finally allowed summarising information from 25 OECD and observer countries on technology areas covered with statistical surveys, review existing approaches, data collection strategies and indicators used for measuring various stages of technology development.

The current document provides a number of proposed draft operational guidelines for technology measurement and includes a number of tentative technology definitions to be used for statistical purposes, principles for identification and classification of potentially growing technology areas, suggestions on the survey strategies and indicators. These are the key components of a framework for collecting and interpreting technology data that would need to be further developed through a broader consultation process. A summary of definitions of technology already available in OECD manuals and the NESTI stocktaking results are provided in the Annex section.

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DEVELOPING A STATISTICAL FRAMEWORK FOR THE MEASUREMENT OF ENABLING TECHNOLOGIES AND THEIR APPLICATIONS – DRAFT GUIDELINES FOR COLLECTING AND INTERPRETING TECHNOLOGY DATA

1. Introduction

1.1. The importance of statistical studies on the development and use of technologies

1. There is widespread interest in the development of statistics on technologies which can be used to provide information support for policymaking through monitoring their development, diffusion and impacts. With the acceleration of technological development due to the continual emergence of new technologies – as well as to the challenges emerged as a result of the processes of technological integration and convergence – the field of S&T is undergoing constant change, and the demand for up-to-date and relevant indicators of change and impact has been increasing.

2. Despite the availability of guidelines providing harmonised approaches for R&D and innovation statistics (*Frascati* and *Oslo Manuals*) and examples of technology measurement where the OECD has made significant contributions over the last decades (*e.g.* ICT and biotechnology statistics), a consistent approach including basic definitions and principles for technology data collection and interpretation has not been elaborated yet. The existing array of S&T indicators available from the OECD and national statistical offices enables a certain number of questions to be addressed and a basis upon which to raise "alarm signals" where necessary.

1.2. Main challenges for statistical measurement of technologies

3. The development and diffusion of new technologies have been accepted as one of the pillars of future innovation-based economic growth against growing number of global challenges. Various studies aimed at early detection of “hot research topics”, disciplinary structure of growing S&T areas and their development as well as statistical surveys essentially focusing on measuring R&D patterns within specific “technological domains” demonstrated that both interational organisations and national statistical offices have been slow in developing and implementing new methodological approaches and indicators for technology measurement. One should admit that statistics actually can hardly fix events related to technology creation and dissemination. Moreover, emerging technology phenomena run counter to the nature of statistics whose design is necessarily orientated to measuring ascertained facts. At the same time, an evolutionary approach is crucial for measuring technology-related trends, therefore it is important to establish a co-ordinated system of statistical tools to cover technology lifecycle including stages of emergence, enableness and general-purpose use of technologies.

4. Technology measurement is constrained by a number of challenges ensuing from the nature of technology. Owing to the impossibility to distinguish between different technologies at an early stage of their lifecycle, statisticians can find themselves facing up a rapidly growing and weakly codified area of knowledge and new practices that are expected to result in an invention or innovation with high economic and societal impacts. Another challenge is that several competing technological solutions to a common question can always be found but one or other wins out, and vice versa – a single technological decision can answer a variety of problems. In other words complex and interdisciplinary character of emerging S&T

areas is followed by limited knowledge about the main sources of growth and potential application. Finally those new observed developments tend to be assimilated into existing statistical categories until their significance is more definitively established.

5. The most relevant problems countries encountering collecting data on EEGPT and reported within the stocktaking exercise held in 2011 are related to methodological issues, in particular:

- a. identification of technology area or lists of technologies in terms of relevance for statistical measurement;
- b. the selection of a proper level of aggregation (a single technology, a (intermediate) technology domain, or a larger technology area);
- c. formulating operational definition of selected technology areas;
- d. the scope of technology-related practices and recognition of statistical units for sampling (core groups) caused by their various activities and continuous evolvement;
- e. understanding by respondents and achieving a relevant response rate;
- f. limited access to existing bibliometric, patent or other databases (*e.g.* Web of Science, Scopus, PATSTAT) for gathering information on S&T frontiers and disciplinary structure.

6. To sum up, statisticians lack standard definitions and classifications for the growing number of technology areas, have to deal with relatively rare populations and incomplete knowledge of outputs and impacts. It should be admitted that no single methodology can suffice to address the abovementioned challenges, rather a multi-factorial suite of databases, surveys, forecasting and foresight approaches, and case studies, provides a mosaic representation of activities, players, linkages and issues within the field. The importance of such a measurement mix for statistical description of EETs requires rethinking available approaches to the development of an operational definition and classification of technologies for statistical purposes; looking at the best national practices in knowledge measurement will be important for learning and for inspiration.

1.3. Scope of the document

7. The question of whether there is scope for developing a coherent and integrated framework for the measurement of new technologies and their applications has been raised at series of NESTI meetings in 2008-2011. Some of the key policy questions driving the need for metrics in these areas as well as consequent responses by statisticians are remarkably repetitive and call upon better-integrated measurement and presentational frameworks. Such an approach will have to answer two key questions: ‘What do we measure?’, and ‘How should we measure it?’.

8. In order to answer these questions NESTI initiated a Framework Project on EEGPT measurement aimed at the elaboration of criteria to distinguish the moment when a specific technology starts to emerge and when it becomes relevant for measurement in terms of R&D expenditure, technology creation, diffusion and use. The project was focusing on:

- a. **the identification of phenomena related to the development, application and impact of technologies** (delimitation of the scope of the framework, elaboration of key definitions, development of specific analytical tools to identify the technologies to be taken into consideration);
- b. **assessing national experiences developed so far in specific thematic areas such as ICT, biotech and nanotech statistics**, with the OECD involvement, in terms of generalising issues addressed, classifications used, populations targeted, measurement instruments applied;

- c. **developing of a “technology-oriented” classification grid**, including criteria for identification of relevant technological domains in line with current statistical classifications dealing both with producer and user perspectives;
- d. **proposing a set of methodological recommendations to assure an adequate level of harmonisation in the statistical production at the international level.**

9. The results of the work are provided in the form of draft guidelines. They include a set of recommendations to the provision of a common definition and general classification principles which can help describe the nature of technology disclosing one or more of its “sub-components” and reflecting its distinctive features. A series of recommendations also focus on the measurement of technologies within the existing statistical frameworks, such as fields of science (scientific disciplines), sectors of R&D performance etc., as well as existing S&T policy frameworks (e.g. priority settings and funding instruments).

10. The **Introduction** outlines the importance of technology measurement and presents a brief structure of the EEGPT project together with the scope and the structure of the proposed draft guidelines. **Section 2** discusses a present understanding of technological phenomena comparing pros and cons of using the most diffused approaches to the measurement of technology rather than developing new data sources. The examples of available international experiences and best national practices in measuring technologies, are mentioned here as an example as well as recommendations for constructing operational definitions and propositions of such definitions along with the technology lifecycle. **Section 3** includes recommendations on the identification of technological areas and developing key classifications. The rationale for specific methodologies aimed at identifying “emerging” technologies at their very first stage of development will be discussed here. The scope of **Section 4** is identification of key measurement issues and indicators, such as R&D personnel and expenditure, technology commercialisation, innovation, usage, etc. In **Section 5**, survey procedures, including identification of statistical units, possible data sources and strategies are presented. Finally, **Section 6** covers recommendations on data dissemination and presentation. The draft guidelines are followed by **Concluding remarks** and **Annexes** summarising available definitions of technologies and national experience in technology measurement.

11. This document also includes a series of recommendations for discussion among the NESTI delegates on problematic issues beyond the scope of the entire document that may require special attention and further development.

2. Present understanding and definitions

2.1. Definition of technology for statistical purposes

12. An extension of the current OECD statistical activities in the S&T field should be expected to be build upon existing definitions and methodologies. By specifically considering “technologies”, a theoretical foundation of such work should be based on relevant documents as the Frascati or the Oslo Manual. Unfortunately, these OECD manuals, dealing with R&D and innovation statistics, respectively, do not provide helpful hints about how to design the production of indicators on “technology”. Moreover, they do not provide users with a clear definition of “technology”.

13. Only two of the OECD manuals actually consider how the concept of “technology” can be defined for statistical purposes: one for compiling *Technology Balance of Payments* (TBP) (OECD 1990), and *Handbook on Economic Globalisation Indicators* (OECD 2005a). The *Patent Statistics Manual* (OECD 2009a) shows how technologies can be classified. These manuals interpret the concept of “technology” in its basic meaning of “technical knowledge”. More specifically, while the Patent Statistics Manual recommends the use of the standard International Patent Classification to identify relevant technological

areas, the TBP Manual points out that the concept of “technology” should be qualified in terms of “utilisation” (*i.e.* “potential use” and economic value, as for patents in general), “scope of application” (generality vs. specificity), and “novelty and exclusivity”. Thinking about “technology” as a combination of definite pieces of technical knowledge, or “techniques”, may be useful in creating statistical frameworks for emerging technologies. In the Handbook on Economic Globalisation Indicators the technology definition is based on an E. Mansfield study (1983) and defined as a “stock of (physical or managerial) knowledge which makes it possible to make new products or new processes”, that includes “implying the constant addition of new knowledge to existing knowledge that may make the existing knowledge totally or partially obsolete” (OECD 2005a, p.166). As this knowledge is quite heterogeneous, the *Handbook* proposes measuring it in embodied forms of tangible and intangible goods (equipment, software, etc.) and incorporated in patents, licenses, know-how or technical assistance, external databases (Internet), published research findings, knowledge acquired through take-overs or mergers, or through cooperation with other firms or sectors (OECD 2005a, p.166). A supplementary distinction lies in identifying high-tech sectors and products, based on an R&D intensity criterion or information contained in Standard International Trade Classifications.

14. A quick overview of different fields of study shows that the concept of “technology” is unclear, subject to multiple interpretations and potentially misleading.¹ The main problem lies on the widespread use of the concept that (in addition to the basic definition of being the “practical application of knowledge”)² includes references to specific techniques (*i.e.* the “self-assembly” nanotech technique for microprocessors), single devices (*i.e.* the transistor technology), as well as to “assemblage of different techniques” (*i.e.* the “laser” technology), technological domains (*i.e.* “biotechnologies”), or complex technological systems (*i.e.* the “aircraft gas turbine”)³ and also to potential applications of “technologies” (*i.e.* the “green technologies”).

15. The concept of “technology” is also at serious risk of misunderstanding when used in different cultural and linguistic contexts. This point can be clarified in comparison with the complementary term of “techniques”. According to the OECD TBP Manual, this problem exists in the French language⁴ but it seems even more relevant for the German and Russian languages.⁵ An analysis of this potential inconsistencies in the understanding of the concept of technology may prevent further difficulties in developing a generally agreed system of technology classification.

1. “Early on I found out that words were a problem in technology. [...] Many of the ones used most heavily – “technology” itself, innovation”, “technique” – have overlapping and often contradicting meanings. [...] “Technology” has at least half-a-dozen major meanings, and several of these conflict.” (Brian Arthur 2009).

“Although in common parlance ... [the] material aspect often is the concept of technology tacitly refers to, such a limited meaning is ambiguous and misleading” (Marx 2010).

2. Four main meanings are provided by the *Merriam-Webster Dictionary*:

1. the practical application of knowledge especially in a particular area;
2. a capability given by the practical application of knowledge;
3. a manner of accomplishing a task especially using technical processes, methods, or knowledge;
4. the specialized aspects of a particular field of endeavor.

3. “... a jet engine (or more generally, any technology) consists of component building blocks that are also technologies, and these consist of subparts that are also technologies, in a repeating (or recurring) pattern” (Brian Arthur 2009).

4. “In French, ... [are used] ... two separate concepts: “technique” is defined as a body of methodical processes based upon scientific knowledge that are used in production, and “technologie” as the study of techniques, tools, machines and materials.” (OECD 1990, p. 10).

5. “In German and other European languages, a distinction exists between “Technik” and “Technologie” that is absent in English, as both terms are usually translated as “technology” (Schatzberg 2006, pp. 487-488). In Russian, similarly, “techniques” usually mean hardware equipment, while “technology” is mostly applied to processes.

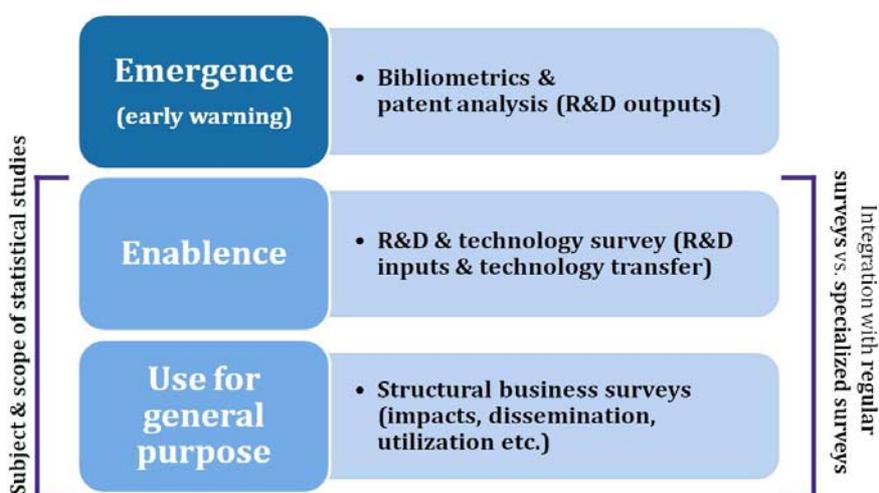
16. For the purposes of this paper, technology is considered as mechanisms of knowledge application through which humans can effect transformations of the world (of things, of materials, of energy, of symbols, of organisms). Moreover, emerging technologies are taken then as meaning application of new knowledge, or knowledge that is itself "emerging" (*i.e.* underdeveloped) to create new or improved ways of transforming the world, where these transformations are ones that are, or are likely to be, ones of widespread social and/or economic significance. When the transformations are ones that are (or can be) very widely employed, and when the new technologies offer radical improvements in the price or other desirable characteristics of these transformations, one can take a look at new transformational technologies that have the capacity to be used to trigger technological revolutions. There can be components (*e.g.* microprocessors), platforms and symptoms (computers, the Internet, social media, etc.), and techniques (*e.g.* text processing) that are widely used.

2.2. *Technology lifecycle and design of a new framework*

17. The need for a Framework should be stressed where most, if not all, the existing activities can be accommodated, assuring an acceptable degree of continuity with the statistics currently produced and disseminated by member countries. In such a perspective, the interest by member countries towards data collection in areas like "emerging technologies", "enabling technologies" and "general-purpose technologies" has to become the main reference for the Framework, which will have to be designed in order to answer the questions usually asked by national policymakers on the level of development of specific technological areas, as well as on the economic and societal impacts of technology diffusion.

18. In order to meet such a key requirement, this paper proposes a modular structure for the Framework. It is based on three areas of activities reflecting three stages of technology lifecycle (respectively): emergence, unbalance and use for general purposes. For each area, a consistent set of definitions, methodologies and collection practices is proposed in order both to give continuity to current statistical activities and to develop new fields of statistical production.

Figure 1. Measuring emerging, enabling and general purpose technologies: the structure of the Framework



19. Concerning **emerging technologies**, a specific module can be developed for the preliminary (and regularly updated) identification of the technological fields, which will have to be covered by the statistical activities. This document includes a description of the possible strategies for technology identification with the requirements and a number of options (including the application of techniques like foresight, bibliometric or patent analysis) and provided in a form of recommendations. In addition, the Task Force could also produce at least two further modules – for data collection and data dissemination. As for the data collection dimension, it will be recommended, most probably, to include specific questions on “emerging technologies” in existing surveys, so that no new statistical activities will have to be implemented. A specific module, in terms of a set of tables could be proposed for data dissemination.

20. **Enabling technologies**, encompass a number of statistical activities already in place in several OECD countries, is basically including the current statistics on ICT, bio- and nanotechnologies. The effort by the Task Force could be focused here in promoting the harmonisation of definitions and practices currently adopted in the mentioned fields. A module should then include recommendations for a regular update of the definitions (providing some general rules about to manage this process), as well as a general assessment of the relationship between the international systems of classification adopted by the community of official statisticians and the classification commonly used to define or measure these technological fields. Again, specific guidelines for the design and undertaking of statistical ad-hoc surveys (as well as, for the inclusion of technology-specific questions in existing surveys) could be given. Finally, a common agreed structure for data dissemination and use should be delivered. Obviously, in this particular area of activity, the initiatives of the Task Force will take into account the relevant work already done at national and international level, including the extensive production of methodological documents and manuals.

21. When addressing the topic of the **technologies for general purposes**, a much cautious approach has to be taken. This field has been addressed from several perspectives although not by NESTI. The basic need in this area is that of answering some key questions usually addressed by the policymakers, the media or the general public about the impact of technologies (mainly “new” technologies) on the society as a whole. On the one hand, policy attention is focusing on whether the increasing diffusion of specific (but only generically identified) groups of technologies – like “green technologies”, “advanced manufacturing” or “energy technologies” – could affect (or are already affecting) human life in the near future. On the other hand, a big question is raised about how to measure the overall economic and social impact of any technology: whether in terms of increasing GDP, or increasing well-being (in a “beyond GDP” approach), or even by measuring the success of a technology in its ability to support the achievement of the UNESCO’s Millennium Development Goals (MDGs). In this area, an extensive work of research could be envisaged to produce meaningful definitions and proposals for statistical measurement in a context where the usual tools of official statistics seem not ready usable. Nevertheless, also in this case a module for data collection and a module for data dissemination will be produced, probably at a lesser detailed level than for the previous fields, and make available to NESTI.

22. The next part of the document presents some results from the work undertaken by the Task Force over the last year. A large effort has been focused on the definition of a consistent “conceptual framework” designed to give a common interpretation to all the technological phenomena which are the object of our analyses. In this perspective, a three-dimensional approach has been used to give a visualisation of the “continuum” which is connecting the development and evolution of a new technology by means of the R&D processes, to its full application in several industrial and domestic context, until the full exploitation of its potential in terms of economic and social benefits. This should clarify that the different fields described above are fully interlinked among them.

2.3. Operational definitions of technologies at different levels of development

23. The development of statistics on “technologies” should refer to a general framework based on the conceptual distinction among three distinct – though deeply intertwined – phenomena: the emergence of new technological “fields”, the diffusion of “enabling” technologies through processes of convergence and the widespread application across industries, and the pervasive impact of “general purpose technologies” on a broad range of social and economic processes.

2.3.1. Definition of technology

24. For present purposes, the general and extended definitions of technology contained in the OECD Glossary of Statistical Terms and OECD Productivity Manual and subsequently in the respectively are applied:

“Technology refers to the state of knowledge concerning ways of converting resources into outputs”
Source: OECD, Glossary of Statistical Terms, 2008, p. 536.

“Technology has been described as “the currently-known ways of converting resources into outputs desired by the economy” (Griliches, 1987) and appears either in its disembodied form (such as new blueprints, scientific results, new organisational techniques) or embodied in new products (advances in the design and quality of new vintages of capital goods and intermediate inputs). In spite of the frequent explicit or implicit association of productivity measures with technical change, the link is not straightforward”.

Source: OECD, Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth, 2001, p. 11.

25. Definitions constructed for measurement of specific “technological phenomena” should be focused on broader “technological areas” rather than rather on specific “technologies” or ‘set of practices’ that is almost impossible to define in terms compatible with the statistical standards.

26. When dealing within broad technological phenomena, it is recommended to provide both a single definition of a selected technology and a list-based definition. A **single definition** is helpful to depict general understanding of the selected technology area and distinguishing borderline activities, while a **list-based definition** is helpful for operationalising core definitions for statistical purposes with certain subareas and techniques. List-based definitions are indicative rather than exhaustive, and provide interpretative guidelines for interpreting technology-activities evolving in the period of data collection. Examples could be found in OECD Frameworks for biotechnology and nanotechnology statistics.

Recommendation 1. Clear boundaries will have to be identified among the phenomena covered by statistical surveys dealing with “technologies” in member countries. Such boundaries should be based on the adoption of a common “glossary” and a set of regularly updated definitions.

27. A commonly-agreed terminology will allow for an acceptable level of comparison of statistical data produced at international level, even taking into account the diversity of technological development processes across OECD and observer countries.

Recommendation 2. A “glossary” of the terminology to be used for surveys on “technological phenomena” should be developed by the OECD by relying on contributions from different areas of expertise, under the co-ordination of experts on S&T indicators. Member countries should formally adopt such glossary as a guideline for statistical activities.

28. The adoption of the glossary could help to identify some “minimum requirements” in terms of definitions and wording to be followed in data collection (questionnaire design, survey documentation) and production/dissemination. A process of clarification and/or disambiguation for a limited number of terms/concepts could be sufficient to achieve the planned objectives of harmonisation.

2.3.2. Definition of emerging technologies

29. An initial working definition of emerging technologies has been proposed in the context of the NESTI Task Force to help structure the guidelines for surveys and statistics:

Emerging Technologies are current developments resulting from contemporaneous advances in a given field of knowledge and that are rapidly developing with a potential to result in inventions and/ or innovations with significant societal and economic impacts.

Source: [DSTI/EAS/STP/NESTI\(2011\)6](#), p. 6.

30. The phenomenon of the “emergence” of new technologies does refer to a limited number of rapidly growing “hot research topics” and “techniques” (as described, for instance, by a single or a group of publications or patents) identified on a regular basis by going through a “tree selection” process involving multidisciplinary and international competencies. It could also be illustrated through emergence of new and development of related S&T disciplines as well as appearance of scientific citations in patents and increasing level of R&D intensity.

31. By following the general approach of not producing additional “classifications” presented in the EEGPT Framework a regularly updated “list” of emerging technology areas (which is the concept as close as possible to that of “emerging technologies” which has not been used deliberately in this context) could provide a robust basis for harmonisation of statistics at international level.

Recommendation 3. A collective process could be implemented to define/update a list of “emerging technologies”. The process should start by collecting inputs from experts in a range of S&T fields about “what is new” and is expected to rapidly develop in the near future in their own areas of expertise. Countries performing “technology forecasting” exercises (as well as, foresight, bibliometric and patent analyses) could contribute to the process with specific inputs. At a second stage, a preliminary list of “emerging technologies” credited with a high potential for growth will be submitted to the assessment of a group of national experts by adopting a “tree selection” process which will result in the identification, by consensus, of a list of 10 to 15 “emerging technologies” to be asked about in statistical surveys.

32. In the Task Force, the organisation of such selection process (as well as the issue about who should take on the responsibility for it) has been thoroughly discussed. In order to allow for participation by Member Countries as wide as possible, the TF would recommend the OECD to take the lead of the process and assure a regular updating of the list.

Recommendation 4. The main recommended use of the list of “emerging technologies” will be that of asking national R&D performers about any on-going R&D project aimed at further developing them.

33. As the primarily developed list of emerging technologies can be used in R&D surveys, full consistency with the *Frascati* framework of the related questions will have to be assured (for instance, in terms of expenditure or personnel involved in such activities). A model questionnaire can be proposed at OECD level then to improve the international harmonisation of these statistical activities.

34. As far as the research on new techniques or technologies is concerned, data is to be collected in the four sectors defined by the Frascati Manual (OECD, 2002, p.53-72). A relevant result of such activity could be that of understanding the diffusion of the R&D on the most promising technologies between sectors.

Recommendation 5. Additional measurement areas, which could be relevant to associate with the “emergence” of new technological areas, include complementary information to R&D on knowledge codification, IPR protection and technology transfer activities. R&D surveys are the most appropriate vehicles for these questions.

35. Since the list of “emerging technologies” would likely include a number of highly dynamic technology fields, a full coverage of them could allow for a reasonably comprehensive view of technology development strategies in OECD countries. The TF suggests that the “post R&D” stage of technology development, as well, can be measured by collecting relevant information through the R&D surveys.

2.3.3. Definition of enabling technologies

36. An initial working definition of enabling technologies has been proposed in the context of the NESTI Task Force to help formulate guidelines for surveys and statistics.

Enabling technologies can be described as inventions or innovations that are likely to be applied in a foreseeable period of time to drive radical change in the capabilities of a user in its use of other technologies.

Source: [DSTI/EAS/STP/NESTI\(2011\)6](#), p. 6.

37. This stage of technology lifecycle could be characterized with a close interaction between researchers, policy makers and organisations around an agenda building process, when spontaneous and open socio-cognitive patterns are to be limited by user needs and expectations, policy issues and national interests. Examples are EU Key enabling technologies, and official lists of S&T priority areas available in several OECD and observer countries. It should be noted, that some enabling technologies may not be emerging, in the sense that they involve upgrading and more fully exploiting a known technology, but many of them may experience challenges in reaching commercialisation stages.

38. Additional characteristics that can help distinguish the relevant stage of technology lifecycle, particularly in companies, may include high R&D intensity, intensification of technology transfer flows from academia to industry, introduction of new applications to the market, appearance of new goods & services enabled by new technologies and requirement from business sector of competencies for technology development/processing.

39. The identification of each single technology domain to be included among the so-called “enabling technologies” will have to be based on a double definition approach, including the above-mentioned “single definition” and a “list-based definition”. Both definitions will have to be checked and potentially revised with a certain frequency, but should be expected to be applicable for at least 5 years in order to justify the effort to put those definitions together across relevant stakeholders.

40. Following the experience with the *OECD Framework for Biotechnology Statistics*, a regular assessment of the developments that have taken place over 3-5 years will be advisable in connection with the ever-changing nature of “technology areas”. As the “outcome” of the processes of technology development is considered, the single domain will have to be identified in a quite detailed way. By definition, the processes of “technological convergence” (which could lead to a partial overlapping among different statistical domains – e.g. bio- and nanotechnologies) are not taken into consideration in the data

collection process (even though this could affect the results which will refer to definitions of partly overlapping domains).

Recommendation 6. Evidence on the diffusion of “enabling technologies” will be collected in line with the standard procedures already in place in the domains of “ICT usage” and “Biotechnology” statistics. The following areas will have to be covered for existing (and future*) domains, according to users’ needs:

- R&D activities linked with the domain;
- Diffusion of the domain’s specific techniques (technologies) and related goods among enterprises;
- Diffusion of the domain’s specific techniques (technologies) and related goods among public institutions;
- Usage of the domain’s specific techniques (technologies) and related goods by individuals and households.

(* A “Nanotechnology” statistics domain could be added in the near future).

41. Two key concepts will have to be employed in the surveying of “enabling technologies”: **diffusion and usage**. They refer, on the one hand, to the actual contribution of specific technologies, when are being “used”, to improve both the industrial processes (or service delivery in the public sector) and the ability of individuals to perform several tasks, on the other hand, to the specific feature of some technological domains to be “pervasive” across industries and social groups.

42. Some peculiar indicators have been developed so far to measure both the rate of “usage” and the rate of “pervasiveness” of ICTs or Biotechnologies. Further developments will have to follow possible extensions in the potential applications of such technologies.

Recommendation 7. National surveys on “emerging technologies” should adopt a consistent terminology in line with the relevant international guidelines (Frascati Manual and Oslo Manual for R&D and innovation measurement respectively, OECD Guidelines for Measuring Productivity to develop operational definition for technology and specialized OECD Guidelines for Information Society and Biotechnology statistics). An increasing integration among ICT, bio- and nanotechnology and similar statistical domains would be desirable.

43. Most of the existing experiences should be taken as they are, even though more consistency on terminology and basic concepts could be easily achieved. A step-by-step strategy could be planned with the objective of producing comparable results.

2.3.4. Definition of general-purpose technologies

44. An initial working definition of enabling technologies has been proposed in the context of the NESTI Task Force to help formulate guidelines for surveys and statistics.

General purpose technology (GPT) are enabling technologies which are or have significant potential to be widely used across the entire economy.

Source: [DSTI/EAS/STP/NESTI\(2011\)6](#), p. 6.45. GPTs are characterised by more sustainable relations between various actor-networks involved to share beliefs that they are spawning innovations in multiple technological areas. Previous research (Helpman & Trajtenberg, 1994; Lipsey, Bekar & Carlaw, 1998) has suggested that a GPT must have at least four attributes: (1) pervasiveness, (2) an innovation spawning effect, (3) scope for improvement, and (4) wide dissemination. These characteristics could also be

complemented with evidence of impact on employment and economic growth, articulated needs (*e.g.* in forms of new educational curricula and job vacancies) for competencies for technology support and services, and integration of new positions or groupings to national classification systems.

46. Beyond the concept of “technology use”, a broad “impact” on social and economic processes can be observed as a result of the pervasive adoption of “general purpose technological knowledge”, as well as of the implementation of deliberate actions of technology policy. The measurement of such phenomena exceeds the field of action of previously described statistical activities and needs the development of dedicated methodologies.

47. A definition of what would be the “impact” of technology (at least, for measurement purposes) cannot be easily found in the literature. Possibly several types of “impact” should be addressed in order to identify their specificities even before assessing the role of technology in producing them (*e.g.* the process of economic and “technological” catching-up by less developed countries: whether the diffusion of goods with technological contents would be a cause or an effect of the development process is highly arguable). This area has to be regarded as highly innovative and largely unexplored. Nonetheless, an increasing demand for indicators, for instance, on the role that “green technologies” can play in supporting growth while preserving the environment, can be identified from both analysts and policy-makers. Similar expectations can be met by dealing, for instance, with “cognitive technologies”, “energy technologies”, or even “appropriate technologies” in the context of the development processes.

Recommendation 8. A standard set of metrics could be developed in partnership with other groups to assess for the phenomena of “technological divide”.

48. The issue of “technological divide” is not just relevant for the barriers to accessing the most common instruments currently used to produce and exchange digitalised information, it is very much a social and political issue which affect the possibility that large populations could access higher standard of life, or even an acceptable level of medical care (as drugs and health treatments are not available to the same extent for all).

Recommendation 9. A basic distinction has to be done between “economic” and “non-economic” impact of technologies. Specific methodologies will have to be developed to measure the “impact” of technologies in both cases: in terms of GDP, on the one hand, and in terms of “well-being”, on the other hand.

49. A double strategy could be adopted here. The current effort to incorporate “technology” (as R&D performance, software development, technology applications, etc.) in the calculation of collective wealth (for instance, in terms of the National Accounts’ GDP) provides a mechanism for understanding and, actually, measuring the “economic” role of S&T phenomena. At the same time, the attempts by several research, social and political institutions to evaluate what is “beyond the GDP”, as not-yet-measurable spill-overs of several activities which could improve the overall living standards of a population, are offering unexpected inputs to account for the contribution of “technologies” to improve people’s lives, etc.).

Recommendation 10. Methodologies to assess the level of “social acceptability” of new technologies, as well as the level of understanding of S&T issues by the general public and the efforts by scientists and technologists to perform S&T activities according to the principles of social responsibility, should be developed.

50. In a comprehensive effort of measurement, the potential negative “impacts” of the diffusion of new technologies should not be ignored. Issues like public concerns about the spreading of technological applications, which might be seen as potentially harmful or unethical are already largely covered by opinion polls. Unfortunately, these surveys are rarely adopting a standard terminology and agreed methodologies. Some steps towards increased harmonisation could also be proposed in this respect.

3. Technology identification and classification

51. The development of a statistical definition for technologies is strongly linked to wider S&T measurement standards, and, in particular, to key classifications as a possible basis for a classification “matrix” for developing technological fields in order to identify the objects of statistical observations. In order it requires developing criteria and approaches for identification of key technology trends.

3.1. Identification of key technology areas

52. Scientific papers and patents are regarded as the main types of data used for identification of key technology areas. The statistical analysis of information contained in papers and patents permits to assess actual state of knowledge and to identify research and technology areas which are most likely to develop in the future. Visualization of results as conceptual and institutional maps helps to evaluate a relative importance of different areas and future tendencies.

3.1.1. Information sources: scientific publications and patents

53. The main data sources for scientific papers (research articles, proceedings papers, etc.) are **international bibliographic databases** (such as Web of Science or Scopus) typically containing information on a journal and a title of a paper, authors, addresses and affiliations, granting, abstracts, keywords and references (Roth, 2005). The great advantage of these databases is homogeneity, formalisation and comparability of data.

54. However, certain limitations should be taken into account:

- Access to these databases is generally expensive;
- These databases are selective (they do not index all of the relevant scientific literature);
- English-language bias (non English scientific papers are typically poorly covered).
- Different publication patterns across disciplines (citation and co-authorship can be more common in some fields than in others)

55. National citation indexes, thematic or generalist online collections of scientific papers, reports, and other types of documents may be used to complete these data. Open access competitors of closed bibliographic databases are developing in recent years (Google Scholar, Amazon.com and others). But the open access data indices are neither uniform nor cleaned from precision errors.

56. The most important **patent databases** are provided by the following authorities: European Patent Office (EPO), United States Patents and Trademarks Office (USPTO), The Organisation for Economic Co-operation and Development (OECD), Japan Patent Office (JPO), and The World Intellectual Property

Organisation (WIPO). Though each of them has its own limitations, they generally provide data on inventors, assignees, a title, keywords and references.

57. It is important to contrast foreign patenting with data of domestic patent offices, especially in case of countries, like the Russian Federation, having a small number of patents in international databases.

58. Although harmonised approach for bibliometric data analysis is not developed yet a few strategies applicable for identification of new technology areas and trends are provided below. For patent statistics the *OECD Patent Statistics Manual, 2009* presents standardised practice for analysis of basic information about patent data used in the measurement of S&T and provides recommendations for the construction of indicators of technological activity, as well as guidelines for the compilation and interpretation of patent indicators.

3.1.2. Possible strategies for identification of key technology areas with the use of bibliometric data

59. The main **quantitative approaches** for detecting key technology areas are based either on **keywords** in papers or **citations** to papers. Standard statistical software is used to perform simple descriptive analysis, as well as more sophisticated types of clustering, network, or factor analysis (Small, 2006, Upham and Small, 2010).

60. **Keywords** are a major tool for detecting structure of knowledge and trends in the development of promising technological areas. There are generally two approaches to get a list of relevant keywords for analysis:

- lists of keywords are provided by experts based on their knowledge of a given technological area;
- keywords are extracted from a relevant set of papers or patents (*e.g.*, by calculating words *occurrence frequency*).

Analysis techniques:

- Calculating keywords frequency or keywords co-occurrence along a timeline permits to compare the evolution of technological areas over time and to identify the hottest, growing and declining topics through temporal graph visualization (Su and Lee, 2010).
- Network analysis of keywords is most typically used to identify a structure of technology areas and relations between areas (degree of centrality, association strength). The co-word analysis permits to calculate a number of connections between the actors (papers or patents) in order to reveal thematic clusters. These clusters are visualized as conceptual knowledge maps (*e.g.* see Yoon et al., 2010). Two-dimensional knowledge maps associate keywords and actors (authors of papers or patents), institutions and countries.

61. Large clusters of popular topics growing in a recent time indicate a trend in knowledge development that will likely continue in the future. Changes in connections between clusters seem to be a sign of the appearance of new topics. Networks based on co-occurrence frequency of keywords may also show topics that are not developed enough, but may be promising due to their position in a network (Morel, Serruya, Penna, and Guimaraes 2009).

62. **Citation-based techniques.** Data on citations are obtained through citation indexes containing lists of references in papers as well as patents to other papers and patents.

- Citation indicators (absolute number of citations received by papers or patents, relative citation rate, etc.) are used to assess an impact of a technology area. Areas with high rates of citation

impact are likely to continue developing (Rueda, Martin, Gerdtsri, & Daim 2006).

- Inter-citation analysis where citing and cited papers or patents are matched and co-citation analysis linking papers or patents citing the same source are visualized in citation networks. Clusters received by co-citation analysis reflect cognitive structures of research specialties (Sullivan et al., 1977; Shibata, Kajikawa, Takeda, and Matsushima 2008). Co-citation-analysis is particularly useful to identify hot technology areas emerging in the intersection of different fields. A disadvantage of citation analysis is a time-lag between publication and citation of published material.

63. **Matching scientific papers and patents.** Keywords and citation techniques are used in order to compare scientific papers and industrial patents which are major indicators of the future development of knowledge. Citation patent-to-paper analysis helps to identify connections between science and industry (Narin, Hamilton, and Olivastro 1997; Michel and Bettels, 2001).

64. However, the comparison and linking of patents and papers is limited by the computational challenges involved and the problem that subject categories used in papers and patents generally do not always match. Finally, in different countries, scientific papers are cited by patents differently alongside other types of non patent literature.

65. Quantitative methods, based on keywords and citation analysis in papers and patents, have some obvious **advantages** for identification of key technology areas:

- *objectivity*: unlike expert opinion, automated procedures and techniques assure a statistical validity of results;
- *convenience*: analysis does not take much time; software is constantly improved;
- *intuitiveness*: graphs and maps visualizing the results of statistical analysis are easy-to-see even to non-experts.

66. However, these methods also have some important **limitations**:

- *technical problems: biases and non-stability of databases (the journals data set is constantly changing), issues of unification of authors' names and addresses, etc.*
- *methodological problems: incompleteness of the image of knowledge based on written publications, networks, maps; persistence of manual procedures (e.g., control of keywords by experts); availability of data.*

67. The ultimate purpose of using these methods is that of identifying clusters of techniques, sharing some common features, which are rapidly evolving in terms of number of patents/publications. Ideally, a list of “emerging technologies” should be produced on the basis of national S&T priorities as a result of an international cooperation with at least a bi-annual frequency. This will allow all OECD member countries to use such a list to monitor the level of development of these areas in their own countries.

3.2. *Elaborating criteria for technology classifications*

68. Current classifications of technologies focus most attention on a few specific domains – and these may be defined in several, sometimes contradictory, ways. Biotechnology is a good case in point, being still in its specific segments considered an emerging technology but also influenced by a process of convergence – and as having the potential of “enabling” other technologies to be applied in several fields having “general purpose” implications.

69. Among the variety of approaches a few principles can be outlined. Technology areas, for example can be grouped by process, related **field of knowledge** (discipline), **application area**, **product group**, etc. The challenge is to deal with the processes of technology application, which are extremely difficult to define and ever changing. Another challenge is defining an application field. If technologies can be defined as knowledge outputs with the potential to change substantially the way products are manufactured/provided, the initial use of existing classifications (by economic activity, for instance) can be applied to identify the relevance of technologies to respective application areas. Another possibility is to focus on “technology packages” (sets of technologies, sometimes originated from different fields of science) required for manufacturing certain products (product groups).

3.3. *Classification principles and levels of classification*

70. The classification approach proposed by the Task Force is aimed at avoiding most of the difficulties experienced with the current “classifications”, by considering three basic criteria which should be used to identify the main features of any “technology” or “technique”:

- a. the **field(s) of knowledge (science)** on which its development has been based (science base, or origin);
- b. the **industries (products)** where it is actually applied (application);
- c. the **socio-economic areas/factors** mostly influenced by its diffusion and adoption (impact purpose).

71. In order to clarify this proposal, it has to be said that some technologies will be classified only in terms of their scientific base (for instance, the so-called “emerging” technologies or techniques which have not yet found any specific application), while other technologies – not just resulting from the “convergence” of research from several scientific domains, but already diffused into the economy – could be, more effectively, classified also in terms of the industries where they are applied (*e.g.* extracting, manufacturing or service technologies) or in terms of expected societal impact (“energy saving” or “green” technologies). This approach should allow for providing the statistical framework with a robust classifications base (as only official statistical classifications, at least at the initial stage, will be used in this context) but also to be able to deal with the demand by users – mainly, by policymakers – of an evidence about the results of their investments in science and technology.

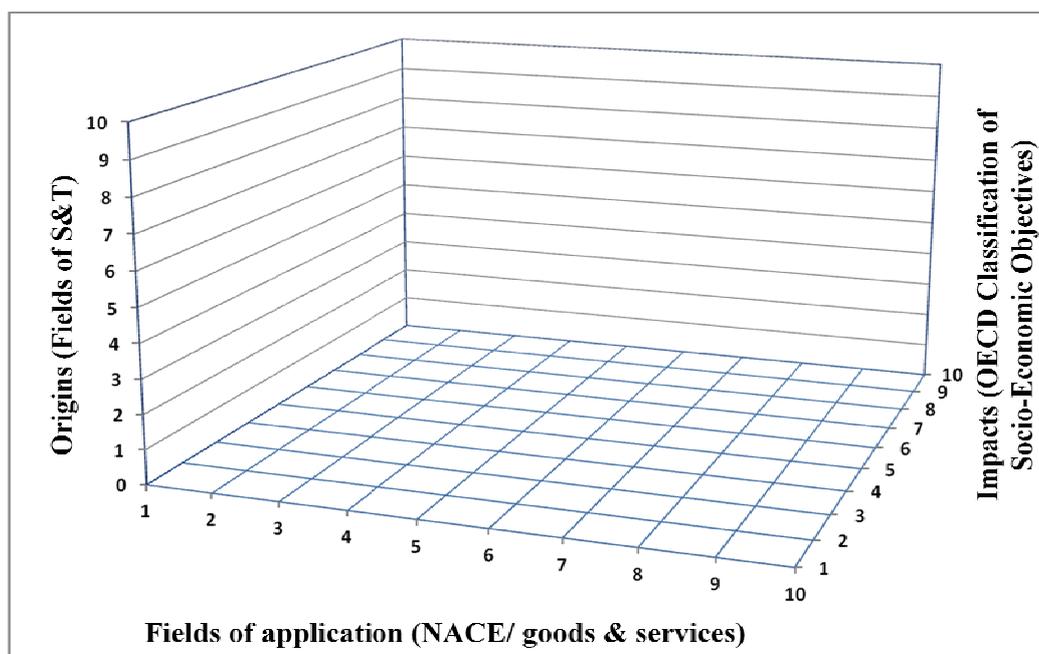
72. By considering that current classifications have, as a major shortcoming, the limitation of considering only a single aspect of technology development, it should be stressed that the proposed classification system allows for a “multi-dimensional” classification of technical knowledge which could be further developed in the future along two main lines of activity: improvement of the existing statistical classifications and testing of a new multi-dimensional classification of technologies.

Recommendation 11. The use of existing official classifications (ISIC/NACE by industry, FOS by fields of science, NABS by socio-economic objective, etc.) is recommended in statistical data collections about “technological phenomena”. No further classifications are requested to implement an acceptable level of international harmonisation in this field.

73. It was suggested by the EEGPT TF to rely on a “glossary” and a set of definitions to support the data collection activities. The production of a new classification of “technologies” (as well as an integration of the current FOS classification) has been considered unfeasible because of the evolving nature of the technologies as “social processes” and the problems with bringing different opinions on the definition of technologies to an agreement.

74. Figure 2 portrays a visualisation of the proposed classification system. In this figure the main conventional statistical classifications used currently in the international S&T statistics domain can be found: the Frascati Manual Classification of the Fields of Science and Technology (FOS) classification, the classification of economic activities adopted at international level (either NACE or ISIC, which can be broken down by products by applying the related classifications used in the statistics on production), and the classifications of Socio-Economic Objectives (e.g. Eurostat's Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets (NABS) 2007 classification or corresponding national classifications). Having adopted these classifications it does not mean that the Task Force is considering them fit to be ultimately used in the new statistical framework. As an example, the FOS classification still relies on traditional boundaries among scientific fields and gives a few options to deal with multi-disciplinarity. At the same time it attempts to reflect most recent technological advancements by levelling such multi-disciplinary horizontal areas as ICT, bio- and nanotechnology similarly to more traditional fields of science in a linear structure. On the other hand, new technologies are shaping new industries, and the current classification of economic activities may not reflect these quite recent changes. More in general, there will be the need, in the near future, to invest resources in evaluating the currently used classifications and, if needed, to develop the new ones more suited to the measurement of technology.

Figure 2. A 3D visualisation of the proposed system of classification for technologies



75. Regarding the development of a totally new classification system for “technologies”, the Task Force is considering this as a by-product of the actual statistical activity. The indicator system that will emerge from the new statistical framework will assist the elaboration of criteria to distinguish the moment when a specific technology starts to “emerge”, when it becomes relevant for measurement in terms of “scientific productivity” and technology creation, diffusion and use, which products (or services) will be affected by relevant changes as a result of its application (enableness), which changes in the social and economic system will be caused by its diffusion. These are the criteria that – in connection with a common definition and general classification principles which can help to describe the nature of new technology uncovering one or more of its “sub-components” and reflecting distinctive features of it – can help to identify the position of each single technology in the 3D matrix, by highlighting its process of evolution from one position to another.

76. Other types of data could be reflected in the cells of this 3D matrix should be mentioned. For example, economic accounts would conventionally primarily deal with money (the value of inputs and outputs) or with people (the number of workers [-or FTE workers] engaged here). But other data sets could be brought to bear, perhaps via satellite accounting or similar – for example the wave of studies of the diffusion of robotics across manufacturing, or PCs/Internet across the whole economy, yield data that could be fitted into such cells (for instance, the share of enterprises using ICT, the per capita ICT investment).

77. Another possible path of development missing from the current framework, is the use of occupational and educational levels (ISCO and ISCED) that demonstrate the need for new competencies for technology development/processing. Going further still, one could see the accounting matrix extended into social accounting: the situation of the household economy, where some SOEs are instantiated, and where money and time are spent consuming (and often producing with the aid of) new technologies. Quite a lot of information society statistics examine this sort of thing – and Social Accounting Matrices (SAMs) can be used to depict digital divides and the like.

78. Returning to the discussion of the identification and characterisation of EEGPTs, further development of such approaches should be a by-product of the actual statistical activity. The indicator system that will emerge from the new statistical framework will assist the elaboration of criteria to distinguish the moment when a specific technology starts to “emerge”, when it becomes relevant for measurement in terms of “scientific productivity” and of technology creation, diffusion and use, which products (or services) will be enabled (or impacted otherwise) by relevant changes as a result of its application (potency), which changes in the social and economic system will be caused by its diffusion.

4. Measurement issues and indicators

79. A technology area, as mentioned above, is regarded as an object for statistical observation. Therefore it is to be identified, described and scaled in terms of S&T and economic inputs, outputs and outcomes on the basis of definition and classifications described earlier.

80. It is proposed to attribute the measurement to traditional classifications of sectors and activities related to technology and innovation cycles such as R&D, technology commercialisation and transfer and allied innovation activities, manufacturing etc. For the purpose of this paper, these activities should be considered against the background of a broader scope of knowledge creation and dissemination processes, with particular attention to clear-cut borders between the two. Technologies might thus be observed also in the context of their use, competencies, and progress. Consequently, the measurement approaches can be extended to areas such as energy, environment, education, health, etc. Such a modular approach to statistical measurement allows building up flexible data collection procedures.

4.1. Technology R&D

81. Research and development (R&D) is to be used within the framework of surveys and statistics on public biotechnology R&D is the one published in the *Frascati Manual*:

“Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications”.

Source: OECD, Frascati Manual, 2002, p. 30.

82. Based on this approach, R&D in a given technology domain would include research and experimental development into techniques, products or processes, in accordance with both the technology definitions presented in p.2.3.1. and the *Frascati Manual* for the measurement of R&D. For biotechnology R&D it is recommended to use definitions introduced in the *OECD Framework for Biotechnology Statistics*.

4.1.1. *R&D Personnel*

83. The crucial factor for the technology development is the availability of highly qualified and trained personnel in this field. Units that have intramural technology R&D expenditure are bound to have personnel to carry out relevant R&D projects.

84. Technology R&D personnel ought to be broken down by level of qualification and occupation.

85. **By level of qualification:** personnel engaged in technology R&D is proposed to be classified by formal qualification based on elements of the International Standard Classification of Education (ISCED-97):

- Tertiary level, higher educational institutions (level 5A, ISCED-97)
- with PhD (level 6, ISCED-97)
- Tertiary level, higher vocational education (level 5B, ISCED-97)
- Upper secondary level (level 4, ISCED-97)
- Other qualifications
- Non-specified qualifications

86. **By occupation:** R&D personnel is proposed to be classified in accordance with the International Standard Classification of Occupations (ISCO-88):

- Researchers (Major Group 2: professionals and Unit Group 1237: research and development department managers, ISCO-88)
- R&D technical personnel (Major Group 3: associate professionals, ISCO-88)
- Other R&D supporting staff (Major Group 4: clerks, Major Group 6: skilled agricultural and fishery workers, Major Group 8: plant and machine operators and assemblers, ISCO-88)

4.1.2. *R&D Expenditure*

87. Statistical units or sectors of the economy may have technology R&D expenditure used either within (intramural) or outside them (extramural). According to the *Frascati Manual* the following are proposed to be taken as the main measure of R&D expenditure.

4.1.2.1. Intramural R&D expenditure on a technology domain

88. Technology R&D expenditure is all technology R&D performed by a unit within its own premises, regardless of its source of funds. At the national level, the total of intramural technology R&D expenditure corresponds to all R&D expenditures incurred by R&D performing organisations.

89. Intramural technology R&D expenditure encompasses the labour costs of R&D personnel working for selected technology R&D projects, other current costs for technology R&D (rent, energy, various equipment, etc.) and capital expenditure incurred for the purchase of fixed assets used in technology R&D programmes or projects. This intramural technology R&D expenditure can be broken down in different ways.

By expenditure type

- Labour costs of R&D personnel
- Other current costs
- Capital expenditure

By type of R&D

- Applied research
- Experimental development

90. In line with the proposed definitions of technology and measurement issues basic research is proposed to be excluded as a breakdown as it is focusing mostly on “experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view” (*Source: Frascati Manual 2002, p. 30*).

By R&D objective

NABS 2007 chapters are proposed for the guidelines:

1. Exploration and exploitation of the earth
2. Environment
3. Exploration and exploitation of space
4. Transport, telecommunication and other infrastructures
5. Energy
6. Industrial production and technology
7. Health
8. Agriculture
9. Education
10. Culture, recreation, religion and mass media
11. Political and social systems, structures and processes
12. General advancement of knowledge: R&D financed from General University Funds (GUF)
13. General advancement of knowledge: R&D financed from other sources than GUF
14. Defence

By field of science and technology is proposed to be classified in accordance with Frascati Manual FOS 2007

- Natural sciences
- Engineering and technology
- Medical and Health Sciences
- Agricultural sciences
- Social sciences
- Humanities

By field of technology application

NACE rev. 2 or ISIC rev.3.1 chapters are proposed as the main guidance depending on the technology area under observation.

- A. Agriculture, forestry and fishing
- B. Mining and quarrying
- C. Manufacturing
- D. Electricity, gas, steam and air conditioning supply
- E. Water supply, sewerage, waste management and remediation activities
- F. Construction
- G. Wholesale and retail trade; repair of motor vehicles and motorcycles
- H. Transportation and storage
- I. Accommodation and food service activities
- J. Information and communication
- K. Financial and insurance activities
- L. Real estate activities
- M. Professional, scientific and technical activities
- N. Administrative and support service activities
- O. Public administration and defense; compulsory social security
- P. Education
- Q. Human health and social work activities
- R. Arts, entertainment and recreation
- S. Other service activities
- T. Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
- U. Activities of extraterritorial organisations and bodies

91. For the reason of adequate description of a technological area (domain) certain sections or groupings could be selected.

4.1.2.2. Extramural technology R&D expenditure

92. Extramural technology R&D expenditure corresponds to sums which a unit or organisation reports having paid or committed itself to pay to another unit, another organisation or another sector for the performance of technology R&D during a specific period. This includes the acquisition of technology R&D performed by other units (R&D contracts) and grants given to others for performing technology R&D (R&D grants) and describes spillovers of technology development. Taken beyond the public sector these activities can become a part of R&D and may also indicate technology diffusion processes.

Public sector technology R&D contracts

93. Third parties are entrusted with technology R&D contracts by public sector bodies to perform R&D in certain technology areas for which they are paid. The contracts are usually governed by private law. The contract awarder (public sector) has a direct interest in using the results of the R&D to further its own activities; it can also supervise and monitor the performance of the R&D.

Public sector technology R&D grants

Technology R&D grants are non-refundable financial resources (grants) given to third parties by the public sector to encourage their biotechnology R&D activities. The grant awarder (public sector) has no direct interest in the results of the R&D. It allocates and decides grants. The use of the financial resources made available is by and large determined by the recipient (beneficiary). As a general rule, the provider of funds cannot influence the outcome of the R&D project.

By beneficiary

94. Technology R&D contracts and grants can be broken down by beneficiary:

- Contracts awarded to institution within the country/ abroad
- Grants awarded to institutions within the country/ abroad

95. Public sector technology R&D contracts and grants can also be broken down:

- *By type of R&D*
- *By field of science and technology*
- *By field of technology application*

96. Due to the difficulties in extracting technology R&D expenditure across the sectors of R&D performance (lack of information on sources targeted to technology R&D, variety of funding sources, and other factors that may lead to double counting), the total of extramural expenditure of the country, however, could be still an approximation for technology domain under observation. One of the key points that influence ability of statistical agencies to aggregate totals is coverage and accuracy in data collection. While it is almost impossible to observe all financing organisations and units, taking into account linkages between sectors (*e.g.* intermediary R&D funding agencies that make the link between government sector and higher education sector), focusing on data coming rather from R&D performers than from the funding institutions. This may allow assessing factual technology R&D expenditure with respect to the source of funding if needed.

Proposed breakdown of intramural/extramural technology R&D expenditure by source of funding

Funds from institutions within the country:

- Private enterprise
- Government sector institutions: central and federal governments units, provincial and state government units, local and municipal units.
- Higher education sector institutions
- Private non profit institutions

Funds from institutions abroad:

- Private enterprise
- Government sector institutions
- Higher education sector institutions
- Private non profit institutions
- European Union (*e.g.* Framework Programmes)
- Intergovernmental research organisations (*e.g.* CERN, EMBL, ESO...)

97. Measurement of government spending on technology R&D within the targeted programs or set of priority S&T fields, etc. still can be made in line with the Frascati Manual recommendations on GBAORD measurement (further see: OECD 2002, p. 137-150).

4.1.3. R&D Outputs

98. According to the *Frascati Manual* the output of technology-related R&D in general can be measured in several ways. Innovation surveys are an attempt to measure outputs and the effects of the **innovation** process in which R&D plays an important role.

99. Another option is to use indicators on the technology balance of payments and on the use of patents as S&T indicators. Guidelines are also available on bibliometrics and on the analysis of trade data in terms of the “technology intensity” of the products or industries concerned (“Revision of High-technology Sector and Product Classification”, OECD, STI Working Paper 1997/2). These approaches will be discussed below.

4.1.4. Principal variables and breakdowns

100. Regarding R&D measurement, the *Frascati Manual* recommendations could be observed more precisely and more systematically. Different measures and breakdowns (secondary variables) could be described depending on the data availability and goals of analyses. For example, recommendations for measuring technology R&D personnel and expenditure could be further elaborated for each of the four sectors for R&D performance as well as for well established technology domains such as ICT, bio or nanotechnologies (other emerging technologies in perspective), fields of technology application, socio-economic objectives, etc., so the principal variables could help shaping the structure of the chapter. In order to exclude duplication, the *Frascati Manual* should be taken as the key guiding reference for R&D measurement beyond the topics covered with this framework.

4.2. Technology innovation

101. In a broader definition technological innovation activities are

“all of the scientific, technological, organisational, financial and commercial steps, including investments in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products and processes”.

Source: Frascati Manual, 2002. P. 18.

102. For innovation, the key reference is the definition provided in the Oslo Manual:

“An **innovation** is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations”.

Source: OSLO Manual, 2005. P. 46.

103. The concept of technological innovation has been typically interpreted to be associated with the definitions of product and process innovation, partly owing to the guidance in previous versions of the Oslo Manual. It is now apparent that product and process may have a low technological content, while organizational and marketing innovation may in some instances introduce relatively advanced techniques and be supported by R&D:

4.2.1. Product and process innovation

104. Four types of innovations are distinguished: *product innovations*, *process innovations*, *marketing innovations* and *organisational innovations*. Due to the specifics of technology measurement it is proposed to focus in first instance on product innovations and process innovations only as they are closely related to the concept of technological R&D output.

“A **product innovation** is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics”.

Source: OSLO Manual, 2005. P. 48.

105. Following the Oslo Manual product innovations can utilise new technologies, or can be based on new uses or combinations of existing technologies. The term “product” is used to cover both goods and services. Product innovations include both the introduction of new goods and services and significant improvements in the functional or user characteristics of existing goods and services.

“A **process innovation** is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software”.

Source: OSLO Manual, 2005. P. 49.

106. According to Oslo Manual process innovations can be intended to decrease unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products. They include new or significantly improved methods for the creation and provision of services. Process innovations also cover new or significantly improved techniques, equipment and software in ancillary support activities, such as purchasing, accounting, computing and maintenance.

4.2.2. Measured activities for product and process innovations

107. For the purpose of technology measurement the following issues depicting product and process innovations are proposed to be extracted from Oslo Manual as a subject matter.

- *Intramural (in-house) R&D*: Creative work undertaken on a systematic basis within the enterprise in order to increase the stock of knowledge and use it to devise new applications. This comprises all R&D conducted by the enterprise, **excluding** basic research.
- *Acquisition of extramural R&D*: Same activities as intramural R&D, but purchased from public or private research organisations or from other enterprises (including other enterprises within the group).
- *Acquisition of other external knowledge*: Acquisition of rights to use patents and non-patented inventions, trademarks, know-how and other types of knowledge from other enterprises and institutions such as universities and government research institutions, other than R&D.
- *Acquisition of machinery, equipment and other capital goods*: Acquisition of advanced machinery, equipment, computer hardware or software, and land and buildings (including major improvements, modifications and repairs), that are required to implement product or process innovations. Acquisition of capital goods that is included in intramural R&D activities is excluded.
- *Other preparations for product and process innovations*: Other activities related to the development and implementation of product and process innovations, such as design, planning and testing for new products (goods and services), production processes, and delivery methods that are **not** already included in R&D.

Source: Oslo Manual, 2005. P. 97-98.

108. Total expenditure for technology innovation activities comprises current and capital expenditure incurred for the innovation activities defined above. Current innovation expenditures are composed of labour costs and other current costs, including the rental of fixed capital equipment and the lease of intellectual assets.

Technology innovation expenditure

109. While most innovation activities could be separated according to intramural and extramural expenditures as described above full separation may not be feasible. Expenditure for innovation activities may also be broken down into current and capital expenditure.

110. **Current innovation expenditures** are composed of *labour costs* (annual wages and salaries and all associated costs of fringe benefits) and *other current costs* (non-capital purchases of materials, supplies, services and equipment to support innovation activities).

111. Capital expenditures for innovations are defined above as acquisitions.

112. Breakdown using the following classification by **source of funds** can be used:

- Own funds
- Funds from related companies (subsidiary or associated companies)
- Funds from other (non-financial) enterprises
- Funds from financial companies (bank loans, venture capital, etc.)
- Funds from government (loans, grants, etc.)
- Funds from supranational and international organisations (EU, etc.)
- Other sources

114. **Survey questions** on innovation expenditure may be formulated in two ways:

- Total expenditure on technology innovation activities for the firm in a given year or period (= **the subject approach**).
- Total expenditure for specific technology innovations implemented in a given year or during a given period regardless of the year in which the expenditure occurs (= **the object approach**).

115. The **subject approach** covers expenditure for implemented, potential and abandoned technological innovation activities as defined above. In this respect, it is a straightforward extension of traditional R&D measurement.

116. In the **object approach** the sum reported comprises total expenditure on defined technology innovations, or on the main innovation(s), implemented during a given period. As proposed in *Oslo Manual* it excludes expenditure on innovation projects that have been abandoned or are in progress, and on general R&D not connected to a specific application.⁶ This approach seems particularly suitable for innovation surveys starting from a set of identified innovations, but it could also be used in surveys of the innovation activities of enterprises in general.

⁶ It would also be conceivable to adopt an object based approach on the basis of ongoing projects, rather than just innovations already implemented.

4.3. *Technology diffusion, commercialisation and spillovers*

117. Technology development and dissemination through the economy is strongly dependent on the knowledge flows within (inbound diffusion) or outside (outbound diffusion) unit, R&R organisation or enterprise supported by the variety and the structure of links to sources of information, knowledge, technologies, etc. Linkages act as sources of technology diffusion process for an R&D unit or enterprise's innovation activity, ranging from passive sources of information to suppliers of embodied and disembodied technology to co-operative partnerships.

Diffusion is the spread of technologies, through market or non-market channels in a form of innovations and products, from first implementation anywhere in the world to other countries and regions and to other markets and firms. The diffusion process often involves more than the mere adoption of knowledge and technology, as adopting enterprises learn from and build on the new knowledge and technology. Through the diffusion process, technology innovations may change and supply feedback to the original innovator.

Source: based on Oslo Manual, 2005. P. 78.

118. Technology diffusion could be operationalised through a variety of types of linkages:

- “Open” information sources (membership in professional associations, attendance at conferences, subscriptions to journals).
- *Acquisition of technology and knowledge* (purchase of external knowledge and technology e.g. in a form of patents and licenses without active co-operation with the source).
- *R&D, technology and innovation co-operation* (active participation in joint projects with other organisations).

119. Among innovating firms, the purchase of patents or licences in certain technology domains may be intended to support further R&D (in which case it should be counted as such) or to enable exploitation and commercialisation. .

120. In 1990, to cover the methodological aspects of technology diffusion in international perspective OECD prepared a manual entitled “Proposed Standard Method of Compiling and Interpreting Technology Balance of Payments Data (TBP Manual)”.

121. The Manual distinguishes four types of transactions:

- 1) Technology transfers, which can be subdivided into transfers of:
 - Patents.
 - Unpatented inventions.
 - Licences (linked to know-how).
 - Know-how.
- 2) Transfers of designs (sales, licences, franchises), trademarks and patterns.
- 3) Provision of technical services, comprising:
 - Technical and engineering studies (project design and implementation).
 - Technical assistance.
- 4) Provision of industrial R&D (performed abroad or financed from abroad).

122. Measures based on these concepts can be used as key references for technology diffusion measurement. Further details on the topic are provided in the *OECD Handbook on Economic Globalisation Indicators, 2005*.

123. Questions on linkages can refer to all types combined depending on co-operation side (enterprises, R&D institutions, Universities, public institutions, etc.), and formulated a binary scale (*i.e.* yes/no) or an ordinal scale to ask respondents whether they have used the source and, if so, its importance.

124. Spillovers are external effects (not necessarily mediated through markets) of R&D, technology or innovation activity that affect those who are not directly involved in the processes of technology development and direct use. Firms and organisations can be significantly impacted (positively and negatively) by technological developments in other organisations.

125. The measurement of spillovers presents numerous challenges. Technology-related data provides some indirect approaches for identifying the direction and intensity of knowledge flows which can ultimately support the identification of spillovers across sectoral and spatial domains. Information on the number of grants and contracts (see extramural R&D expenditure, p.4.1.2.) awarded or their share in technology R&D can also be used as a source of technology spillover identification.

126. Some key **measures** may include:

- **Citation patterns and co-authorship:** scientific articles in scientific and patent literature.
- **Research mobility:** number of researchers that completed an internship at universities and research organisations in different sectors or countries, changes in author's affiliations over time.
- **Collaborative agreements:** number of agreements made by two authors seeking to work together on a project/creative work related to development and/or use of technologies.

127. Key measures for technology commercialisation are licensing and patent activities. Patent analysis could be based on the patent statistics based on the information provided by international databases and measurement of patent activity of the firm. The further approach allows for measuring the inventiveness of countries, regions, firms or individual inventors, under the assumption that patents reflect inventive output and that more patents mean more inventions. The use of patent data for the analysis of technology growth described in section 3 and could be developed on the basis of approach presented in the OECD Patent Statistical Manual (2009).

128. Technology commercialisation measured through firms' activities could be operationalised with the following types of activity:

- **Inventions and co-inventions:** patent applications (patents granted) in a selected areas of S&T submitted (obtained) independently or jointly with co-inventors located in other countries
- **Technology transfer:** technology exports/imports in a selected areas of S&T between different countries
- **High-tech trade:** high-technology exports in a selected areas of S&T by product group
- **Start-up establishment:** number of start-ups in a reference year established in a selected S&T areas
- **Costs of commercialization:** specialized equipment and support services (*e.g.*, intellectual property protection, market studies, business plan development, counselling and mentoring, technology evaluation) required for technology protection and use.

129. Technology use is proposed to be measured in terms of newly introduced or advanced manufacturing processes and outputs. The choice between the measures depends on the purpose of study, available information and other factors.

Technology outputs are considered as goods and services produced with the use of specific technologies (technology-enabled products) within a producer unit and that become available for use outside the unit.

130. For measuring technology output the following measures within the firm activities are proposed:

- Number of new products, based on selected technologies introduced to the market
- Sales of technology-enabled products/ innovative technology-enabled products
- Stage of product development
- Level of technology integration (first used year, extent of used potential, principal aims of utilisation)
- Types of processes including use of new technologies
- Cost of development by stage
- Technology development times/durations
- Barriers and opportunities affecting development
- Co-products

131. Other issues such as reasons for adopting technologies and the benefits that resulted from this can be also addressed. Related questions concern the impacts of technologies.

132. A number of issues related to the processes of technology development, diffusion and use could also be addressed in a form of specialised surveys or indicators in accordance with the national priorities in S&T, specifics of technology use in particular sectors of performance (e.g. energy, space, etc.), development goals and other societal issues. Measurement of technology impacts is a subject for a special discussion.

5. Survey procedures

133. Planning a the introduction of technology related questions in existing surveys or designing new technology-related surveys requires careful consideration of statistical units, research population, sources of information and data collection strategies.

5.1. Population

134. A research population is generally a large collection of objects that is the main focus of a statistical query. Due to the fuzzy boundaries of emerging and enabling technologies statisticians are likely to struggle to identify a tightly defined group of units from which broader inferences can be extracted. A target population is needed to be identified as well as the method by which those populations can be systematically identified and contacted.

135. Since technology growth includes a variety of actors a relatively new population across the different sectors of economy existing classification systems provide lack evidence for identification entities developing and using new technologies that are subjects of research interest. Somehow, these classifications could be helpful for sampling at least because they represent structure of the national economy. Methods for constructing custom lists on the basis of existing knowledge on technology area, sampling, keyword searches and involvement of experts can be used to identify target populations. The adoption of technology, end users and the possible impacts are areas that may warrant future inclusion as technology enters different areas of the economy and society.

136. The survey frame population could be identified with the use of scanning questionnaires including indicators on technology development and application that can be used with core questionnaires of regular surveys to identify key players in the given S&T field. Scanning can be a fast and accurate method for framing the research population, though it is limited by the coverage of the entire survey it is applied to.

137. By definition, several statistical populations can be involved in this kind of surveys, at least *business enterprises, universities, public institutions* and *households*. It has to be stressed that, beyond the use of a common definition, each single population is to be surveyed by using its relevant methodologies and classifications (according to the international standards). The institutional approach described in the *Frascati Manual* is relevant for focusing on the key properties of the performing or funding institutions. For the business enterprise sector, for instance, relevant breakdowns may also include those by industry (ISIC/NACE) and size. More in general, the consistency with official statistics as to the identification of the reference population, the availability of a sampling frame, a standard sampling strategy and a consistent statistical unit should be assured for every survey.

Recommendation 12. The results of national surveys on “emerging technologies” should be representative, in statistical terms, of the respective target populations. An appropriate sample methodology should be applied at least that the target population would not be extremely small.

138. In order to produce statistics which would be comparable with the official statistics made available by national statistical offices, surveys on “emerging technologies” should be based on official statistical infrastructures, like the business registers, and use standard methodologies. In principle, all the results should be comparable with similar datasets from other official economic or social surveys.

5.2. *Statistical units*

139. According to the OECD, statistical units are “the entities for which information is sought and for which statistics are ultimately compiled. These units can, in turn, be divided into observation units and analytical units”.

Source: OECD Glossary of Statistical Terms, 2008, p. 513.

140. Within the EEGPT Framework statistical units are taken in line with the International Standard Industrial Classification (ISIC) Rev. 3 and comprise the:

- enterprise;
- enterprise group;
- kind-of-activity unit (KAU);
- local unit;
- establishment;
- homogeneous unit of production.

Source: ISIC Rev. 3, paras. 63, 76.

141. This definition is chosen for benefits of international comparability of data. Somehow, national statistical offices may prefer to specify statistical units on the basis of national standards and criteria. It should be noted that statistical units, may differ according to the sector. In the model surveys one should take into account the issue mentioned and the sector.

142. Taking into account social and economic nature of technologies, it is reasonable to consider new statistical units (e.g. research teams, user groups, social networks, etc.) for data collection efforts in the

relevant fields along with traditional ones (business enterprises, HEIs, non-profit organisations, individuals/households, etc.). These units somehow require using a combination of information sources and research techniques. For example, network analysis could be based on bibliometric data (for detecting extended research networks and groups in both national and a global contexts) as well as on information collected within national databases and registers (for R&D institutions, business enterprises or individuals, etc.). Choose of reporting unit is finally based on various factors like research agenda, institutional structures, legal framework for data collection, available resources.

5.3. *Data sources*

143. The development of new definitions and classifications cannot ignore practical approaches to data collection. The OECD Working Party on Nanotechnology (WPN) provided an outline of different information sources on nanotechnology ([DSTI/STP/NANO\(2008\)2](#)) that are adopted and proposed to be taken as a guidance for general framework for technology measurement and provided below.

Surveys

144. Survey data can provide insight into the activities and environment of firms involved in technology development and use. Questionnaires can probe the intricacies of topics such as raising capital, human resources and which is the very nature of technology domain under observation. The technology sector is a rare population with potential respondents found in numerous sectors of the economy, raising the challenge of accurately and completely developing a survey frame. Technology area describes both products and processes used to create a product. These issues pose challenges to accurate measurement. Surveys compete with each other for the limited time and attention from managers and suitable respondents. Respondent burden becomes an issue for most surveys since they rely on the participation of the firms involved in the technology sector that requires time and resources of the respondent, who often times are providing sensitive information. Questions are subject to interpretation by respondents, who also often self-identify for participation in surveys of this nature.

145. Surveys can also be addressed to governments to gain information on technology. They can question both the government's internal research and development activities and government's funding of external nanotechnology use, complementing database searches and analysis. They could also address broader issues related to science, technology and innovation policies in the context of technology under development or use, public perception, environmental, health and safety concerns etc. Surveys could include central and sub-national authorities.

National Foresight studies

146. The meaning of national Foresight studies goes far beyond studies to explore trends in specifically defined scientific and technology fields, as often carried out at regional level. These studies undoubtedly play a role in the context of a national Foresight study nevertheless they have to be expanded to include other general aspects particularly with regard to societal development. Looking into the future is a complex process of analysing uncertainties. On the one hand a wide variety of subjects and approaches (e.g. bibliometric methods – see Raan, 1996) have to be considered and on the other hand various stakeholders have to be involved in the implementation of Foresight studies. This helps to bring together participants from science, industry, government, administration and other areas of society in order to identify and evaluate long-term developments in science, technology, industry and society.

Data bases and registers (administrative, patent, publication)

147. Database methodologies (including publication and patent records) can be a useful tool for understanding the evolution of technology domain and analysis of technology trends in member countries. Funding databases for research granting entities can be quite extensive with detailed information such as titles, keywords and in some cases abstracts as well as the names of research leaders, teams and institutions. As such they can provide consistent, comparable data over time. Data capture, analysis, and quality control, however, pose a number of challenges. First and foremost existing databases are not specifically designed with the intention of capturing technology spending. Given the multidisciplinary nature of the emerging or enabling technology area, key words, and terminology can differ from discipline to discipline. Database searches by keyword often require a review by a subject area expert to ensure consistency. However, they can provide insight into the linkage between government-sponsored funding programs and industrial application of technologies.

Case studies

148. Case studies can provide the detailed insight that might be absent in databases and survey data. For example, in-depth analysis of firms can lead to a better understanding of the firms' activities and environment than can surveys. Investigators can pursue lines of questioning impossible for a questionnaire to explore with accuracy. The face to face nature of the case study leads to discussion that reveals new topics and interviewers can then explore those topics. Case studies tend to be topical and current and usually involve a willing respondent who is eager to talk about their organisation/

Model Surveys

149. A model survey could be developed to test definition, classifications, and concepts and could address for example the following issues:

- Development of nanotechnologies - products and processes
- R&D spending
- Revenues
- Human resources
- Capital
- Collaborative Arrangements and Alliances

150. The content of model surveys is dependent on the identified priorities of policy makers and can inform whether those priorities are accurate.

5.4. *Survey strategies*

151. Nonetheless, the experience accumulated in decades of data collection about R&D and other S&T phenomena should be used in this field as well. For this reason, the Task Force recommends two basic models of data collection on technologies:

- a. Introducing new variables into regular statistical exercises like scanning techniques allows for identifying, mapping and scaling relevant technological areas and population of organisations involved in technology development vis-à-vis standard economic activities (*e.g.* in terms of R&D, innovation, and sales of products/services). Thus regular surveys may be amended to include questions about the use of particular techniques or technologies. For example the Labour Force Survey has been used as a vehicle to carry enquiries about employee use of new ICTs, and

categories reflecting new ICT consumer goods have been added into household expenditure surveys, etc.

- b. Designing specialised statistical surveys is a strategy to address case-specific measurement issues (for example, R&D results, technology transfer, barriers, etc.), with a strong emphasis on the measurement of social and economic impacts of technologies. Therefore specialised regular surveys are better for more established technology domains, such as ICT or biotechnology.
- c. Mixed strategies are the combination of the abovementioned strategies and using other techniques and information sources (*e.g.* administrative databases, case studies, Foresight, etc.). They can be helpful in monitoring key patterns of technological change and used for provision of an integrated picture of technology lifecycle.

152. In this regard, a harmonised model approach to design a survey questionnaire for data collection on application and impact of technologies should be established. Subsequent national pilot surveys will provide a feedback for improving methodology and statistical tools. Integration with regular statistics may be accomplished for some technology domains to the extent that survey length allows and the technology phenomena is of sufficient relevance to a significant proportion of the overall population covered in regular statistics.

6. Presentation of results

153. Presentation of data collection results is one of the most important issues obtained from a statistical activity to users. There are now special recommendations beyond the relevance and objectiveness of statistical data. Each data release needs to be presented in a user friendly manner to effectively communicate with the interested audiences. Forms of release may vary depending on the target group of interest and include articles, databases and databooks, analytical reports, publications, meta- or microdata disseminated according to the standard practices accepted in the OECD member countries and special requests from users. Results of the particular surveys could be also presented in a form of public speech, presentation or television or radio interview.

7. Concluding remarks

154. Technology development, dissemination and diffusion across economy have been described as part of social and economic processes including the interaction of different actors along the technology lifecycle. Taking into account the increasing expansion and complex multidisciplinary character of growing technology areas, no single indicator, method or data source will likely be sufficient to measure or monitor technologies and their changes over time.

155. However a variety of methods, including database analysis, survey data, case studies, Foresight, Internet searches and their mixture can be utilized to provide complex understanding of the technology phenomenon. The nature of measurement needs in this area is such that it requires a systematic approach that examines and considers all perspectives on technology, ranging from R&D, commercialization, adoption by industry to its eventual entry into the users and markets.

156. There is a clear need for a common language to describe technology lifecycle in a standardized form. There is a strong case for integrating different methodologies into a systemic approach. Good policymaking requires good evidence, based on regularly updated, accurate, reliable, and complete information. A comprehensive statistical program is to be developed as a significant component of any further strategic approach to technology regulation.

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ANNEXE 1 - AVAILABILITY OF TECHNOLOGY-RELATED DEFINITIONS IN OECD MANUALS

Technology. A frequently stated objective of measuring productivity growth is to trace technical change. Technology has been described as “the currently known ways of converting resources into outputs desired by the economy” (Griliches, 1987) and appears either in its disembodied form (such as new blueprints, scientific results, new organisational techniques) or embodied in new products (advances in the design and quality of new vintages of capital goods and intermediate inputs). In spite of the frequent explicit or implicit association of productivity measures with technical change, the link is not straightforward.

Source: OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth. OECD, Paris, March 2001, p. 11.

Technology refers to the state of knowledge concerning ways of converting resources into outputs

Source: OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth, OECD, Paris, March 2001, Annex 1 – Glossary

Technology is a “stock of (physical or managerial) knowledge which makes it possible to make new products or new processes” (Mansfield), implying the constant addition of new knowledge to existing knowledge that may make the existing knowledge totally or partially obsolete.

Source: OECD Handbook on Economic Globalisation Indicators. OECD Paris, 2005, p. 166

Acquisition of technology and knowledge involves the purchase of external knowledge and technology without active co operation with the source. This external knowledge can be embodied in machinery or equipment that incorporates this knowledge. It can also include the hiring of employees who possess the new knowledge, or the use of contract research and consulting services. Disembodied technology or knowledge also includes other know-how, patents, licences, trademarks and software.

Source: OECD, 2005, “The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, Third Edition” prepared by the Working Party of National Experts on Scientific and Technology Indicators, OECD, Paris, para. 269

Advanced manufacturing technology is defined as computer-controlled or micro-electronics-based equipment used in the design, manufacture or handling of a product.

Source: OECD Frascati Manual, Fifth edition, 1993, Annex 2, para. 35, page 117

Best available technology. The term is taken to mean the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges.

Source: United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank, 2005, Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003, Studies in Methods, Series F, No.61, Rev.1, Glossary, United Nations, New York, para. 9.42

ANNEX 2 - KEY FINDINGS FROM THE STOCKTAKING EXERCISE ON NATIONAL EXPERIENCES IN TECHNOLOGY MEASUREMENT

The stocktaking exercise was launched among NESTI delegates in cooperation with the Secretariat and was carried out in two rounds. The first round (April-May 2011) covered 11 OECD and observer countries, providing a first overview of national experiences in technology (mainly EEGPT) measurement. The second round (October-November 2011) included responses from 14 more countries, thus providing a wider overview of existing methodologies and practices.

The questionnaire asked about the key characteristics of national approaches to STI statistics with the focus on EEGPT issues, including definitions and classification used, technology areas covered, issues addressed, types of survey and survey strategies, main problems in data collection and key indicators.

Basic definitions of EEGPT used in the stocktaking were adopted from [DSTI/EAS/STP/NESTI\(2010\)25](#) with further expert discussions. The results of the exercise demonstrate these propositions as acceptable by representatives of most countries in order to start with the development of a common measurement framework. The exercise revealed that among the features of EEGPT technologies taken into consideration in national statistical activities, the following three are especially relevant:

1. its novelty (in comparison with existing technologies),
2. its potential influence on the applicability of other technologies (e.g. the use of scanners in materials engineering and medicine), and
3. its direct and indirect economic and societal impacts.

One of the highly important issues, noted by Japan, is drawing borders between technologies and (1) developments, (2) inventions, and (3) innovations. Related question has already been raised before within the discussion on the revision of Oslo Manual (further see: OECD/ Eurostat, 1997; Gimel, 2003: 4; OECD, 2005: § 35), but final decision is not taken yet. Within the Framework we are following approach elaborated in the *OECD Handbook on Economic Globalisation Indicators*. According to the proposed methodology that technology could be measured in their embodied form of tangible and intangible goods (equipment, software, etc.) and incorporated in patents, licences, know-how or technical assistance, external databases (Internet), published research findings, knowledge acquired through mergers and acquisitions, or through cooperation with other firms or sectors (OECD, 2005a: § 525). That makes categories of development inventions and innovations a kind of reference points, but technologies themselves are not reduced to these categories.

Definitions of EEGPTs were complemented with distinctive features drawn on the basis of the findings from scientific literature and stocktaking results are formulated as follows:

- *Emerging Technologies* focus our attention on developments that: (a) result from contemporary advances in a given field of knowledge, (b) are rapidly evolving, and (c) have high potential to result in inventions and innovations with significant societal and economic impacts. A set of technologies, or a growing technology area, is involved, with novel ways of applying scientific or technical knowledge for practical purposes to transform energy, matter,

or data. (For example, microelectronic technologies allowed for much more powerful and small scale devices as compared to those based on thermionic valves.) The new transformations, or ways of transforming things, that they offer, are such as to be of considerable potential influence on the applicability of other, even well established technologies. (For example, the use of scanners in materials engineering and medicine radically augments existing systems such as X-rays). Finally, these potentials are liable to produce direct and indirect – economic and societal impacts of the emerging technologies on final users over the long-term.

- *Enabling technologies* are described as already-available inventions or innovations that are likely to be applied in a foreseeable period of time to drive radical change in the capabilities of a user in its use of other technologies. That means bringing into discussion on the irreversibilities that emerged in the on-going activities of researchers, policy makers and organisations a need for the agenda building processes (Van Merkerk & van Lente, 2005), when spontaneous and open socio-cognitive patterns are to be limited by user needs and expectations, policy issues and national interests. Examples are EU Key enabling technologies,⁷ and official lists of S&T priority areas in countries like the Russian Federation and the United States. It should be noted, that some enabling technologies may not be emerging, in the sense that they involve upgrading and more fully exploiting a known technology, but many of them experience considerable challenges in reaching a commercialisation stage.
- *General purpose technology (GPT)* are enabling technologies with confirmed or potential ability to be widely used across the entire economy. They are characterised by a more sustainable relations between various actor-networks involved to share beliefs that the GPT is spawning innovations in multiple technological areas. Previous research (Helpman & Trajtenberg, 1994; Lipsey, Bekar & Carlaw, 1998) has suggested that a GPT must have at least four attributes: (1) pervasiveness, (2) an innovation spawning effect, (3) scope for improvement, and (4) wide dissemination. Taking these criteria as a reference point researchers (Yotie et al., 2008) show that new and growing areas such as bio-, and nanotechnologies have a chance to be followed by a sequence of events in which a major technological innovation is preceded by a number of smaller inventions that expand the range of applicability of the core technology bringing them to the group of GPTs such as electricity, information and communications technology (ICT), and others that have been previously documented as major breakthroughs.

As it was almost impossible to distinguish between different technologies at the early stage of their life cycle (at least, with the use of traditional statistical surveys), the questionnaire was requesting to complement standard definitions of the most common technological domains with particular examples or cases, representing nationally relevant technology areas or particular technologies that should be included among the technologies under consideration, at least for a certain reference period. Examples are EU Key

7. According to the EU definition, key enabling technologies (KET) are knowledge and capital-intensive technologies associated with research and development (R&D) intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. Their influence is pervasive, enabling process, product and service innovation throughout the economy. They are of systemic relevance, multidisciplinary and trans-sectorial, cutting across many technology areas with a trend towards convergence, technology integration and the potential to induce structural change. KETs can assist technological leaders in other fields to capitalise on their research efforts. These KETs are nanotechnology, micro and nanoelectronics, advanced materials, photonics, biotechnology, along with advanced manufacturing technologies as a cross-cutting application (European Commission 2009).

enabling technologies used by Switzerland, and official lists of S&T priority areas in Japan, Russia and the US. References for prioritisations in S&T sector were also found in responses from Norway and Spain.

In most cases technology measurements at national level are usually limited to mainly three broad technological domains – namely ICT, biotechnology, and more recently nanotechnology (though not that widely spread and yet without international harmonisation) – adopting standard OECD and Eurostat definitions and methodological guidelines. Several countries apply a specification of technology-related activities (like Switzerland and Korea for nanotechnology or New Zealand for biotechnology) or additional lists of technological domains (like Japan, Russia and the US for the above-mentioned S&T priority areas and top critical technologies or Norway for new materials beyond nanotechnologies) to obtain technology-specific breakdowns of R&D expenditure, covered by statistical surveys at the national level. Such lists/single technologies are usually defined with the use of bibliometric and patent analyses or Foresight studies and included to the national strategic S&T policy documents.

Along with regular statistical surveys, government agencies, research institutions and private organisations have undertaken various initiatives to measure technology or EEGPT-related issues, by using different data collection tools. These activities are commonly based on the integration of a set of indicators (questions) into regular surveys. They allow, on the one hand, to identify a population of organisations engaged in technological development and, on the other hand, to exploit the potential of existing measurement frameworks. Specialised regular surveys of more established technology domains, such as ICTs, are under development in several countries. In a few cases similar projects were started with the aim of an in-depth analysis of biotechnology (*e.g.* Austria, Belgium, Iceland, Italy, New Zealand, Spain and Switzerland). Some ad-hoc surveys were addressed to the distinct technology areas (*e.g.* the specialised survey on clean-tech carried out by Switzerland in 2009 or nanotechnology ad-hoc survey by Korea).

In some cases statistical data is complemented with the information from specialised registers of organisations or data bases. Registers are mostly used to summarise and systemise information on the general population of firms engaged in development and use of certain technologies (*e.g.* biotechnology-related organisations register in Spain). National registers could also be helpful in selecting relevant statistical units for surveying. Specialised data bases are used to identify S&T areas relevant for statistical measurement and can provide useful information on their definitions and distinctive features. For example, Japan uses international citation and patent databases to figure out “Science Map” helpful in capturing recent trends in science and technology and selecting research fronts without further specification. This information becomes a basis for further prioritisation of national S&T development. Similar strategies complemented with expert opinion polls and findings from Foresight studies are used in Russia and USA.

The development of technology (or EEGPT) measurements within the existing statistical frameworks was based, in most cases, on internationally harmonised classifications such as FOS (for research areas), NACE (for areas of applications), ISCO (for human resources), etc. For certain technology areas (*e.g.* bio- and nanotechnologies) some countries use national ad-hoc classifications (*e.g.* technology areas, types of products and services, organisations etc.) and lists of technology domains.

The most relevant problems countries encountering collecting data on EEGPT and reported within the stocktaking are related to methodological issues, in particular:

- 1) identification of technology area or lists of technologies in terms of relevance for statistical measurement;
- 2) the selection of a proper level of aggregation (a single technology, a (intermediate) technology domain, or a larger technology area);
- 3) formulating operational definition of selected technology areas;

- 4) the scope of technology-related practices and recognition of statistical units for sampling (core groups) caused by their various activities and continuous evolvement;
- 5) understanding by respondents and achieving a relevant response rate;
- 6) limited access to existing bibliometric, patent or other databases (*e.g.* Web of Science, Scopus, PATSTAT) for gathering information on S&T frontiers and disciplinary structure.

Among the other reported problems, the most important issue is how to increase attention and support from policy makers, national business or professional associations to the statistical measurement of technologies. This raises series of important methodological requirements, balancing methodological recommendations, initially proposed in Japanese response:

- 1) The database or survey should cover all technology area as a whole without being confined to specific technologies. It is commonly noted that inter-/multi-disciplinary area is getting important in the development of science and technology.
- 2) The measurement of EEGPT should be objective. The process of making the list of EEGPTs should be based on the common principles, though priority setting would vary across countries depending on the role of the technologies in the context of national STI policy.
- 3) The methodology should be sustainable. Time series analysis is needed to assess the changing nature of science and technologies, thus the measurement should be sustainable in both methodologically and economically.

All the countries responded to the stocktaking questionnaire expressed their interest for further elaboration of an integrated statistical framework for EEGPT indicators. It was suggested that, among the main measurement tasks, particular focus should be made on the identification of the initial population of organisations engaged in technology development, dissemination and use. In order to capture the recent trends in S&T technology creation, measurement issues should include R&D intensity in selected areas (primarily in terms of different types of resources allocated), technology commercialisation and usage, human resources and competencies for new/emerging technological areas, learning and career pathways, various impact indicators.

Groups of EEGPT indicators already used by countries depend on the type and the scope of a certain study. To describe a selected technology area some countries (*e.g.* Italy, Spain, and Switzerland) combine indicators resulted from different surveys. Beyond the Frascati input/ output indicators that are widely applied in regular R&D surveys (such as R&D expenditure, personnel, etc.) a number of metrics characterising intensity and impacts of EEGPT are used as well. Measuring R&D collaboration, patenting and IPR protection is becoming a common practice for describing technology development processes. A few countries pay special attention to commercialisation barriers (Belgium and New Zealand), employment in technology-related sectors beyond R&D (Czech Republic, Korea, Russia and Spain) and technology transfer (Australia, Czech Republic, Norway, Russia, Spain and USA). There are few examples (Russia, Spain and Switzerland) of measuring public awareness of science and technology that could be regarded as one of the metrics for social acceptance of EEGPT.

In the Annex 3, an essential overview of the major statistical activities undertaken by respondent countries in the area of technology statistics is provided. A wide range of data collection tools and sources of information (national registers and data-bases, statistical surveys, expert polls and interviews, etc.) are used. Basically, regular and/or specialized surveys are still selected as the main means to address the issue of collecting technology-related data.

In the Annex 4, some examples of national definitions and criteria for EEGPT identification are demonstrated. It should be pointed out that, in several cases, as an alternative to develop a complex and flexible indicators system, selected definitions and classifications originally developed for policy making, have been adopted to the statistical needs.

Stocktaking results demonstrate high level of interest from the delegates to measuring technology development, diffusion and use for general purpose as well as the various characters of national strategies of data collection depending on sustainable practices and existing priorities, driven by policy issues. Therefore further development of the Framework should be recommendatory and apply variety of principles applicable within the different economic and political environments.

ANNEX 3 - SUMMARY OF INVENTORY OF AVAILABLE TECHNOLOGY INDICATORS AND STATISTICS

| Country | Agency | Technology areas covered | Survey type | Survey strategies | Periodicity/Frequency | Sources of definitions | Classification used | Participation in OECD/ UN/ EUROSTAT surveys | Indicators used |
|---------|---------------------------------|--------------------------|--|-------------------|-----------------------|------------------------------------|---|---|--|
| AU | AUSTRALIAN BUREAU OF STATISTICS | ICT | R&D Technology transfer Innovation Business / Manufacturing Internet activity | Specialised | annually | OECD | Standard Institutional Sector Classification of Australia (SISCA), Australian and New Zealand Standard Industrial Classification (ANZSIC), 2006 edition (cat. no. 1292.0). | NO | R&D expenditure Innovation expenditure R&D personnel Number of collaborations in R&D Number of publications Number of patent applications/patents registered Barriers to commercialisation Imports/exports of goods and services |
| AT | STATISTICS AUSTRIA | ICT | Business enterprise Households | Specialised | annually | OECD, Eurostat | N/A | YES | N/A |
| | | BIO | R&D | Integrated | 2006 | National biotechnology association | N/A | NO | R&D expenditure R&D personnel |
| BE | BELGIAN SCIENCE POLICY OFFICE | BIO | R&D | Specialised | 2010 | OECD | Technology areas Areas of application | YES | R&D expenditure Venture capital investments R&D personnel Researchers Business angels, public funding, equity credit line, subordinated loans Number of collaborations in R&D Types of collaboration: for which kind of activities, results of the collaboration Expenditure on technology commercialization Barriers to commercialization Manufacturing of goods and services Income generated by means of grants, royalties and licenses |
| FI | STATISTICS | NO | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

| Country | Agency | Technology areas covered | Survey type | Survey strategies | Periodicity/Frequency | Sources of definitions | Classification used | Participation in OECD/ UN/ EUROSTAT surveys | Indicators used | |
|------------|---|----------------------------|---|---|-----------------------|------------------------|--|---|---|-----------------|
| | FINLAND | | | | | | | | | |
| EE | STATISTICS ESTONIA | NO | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| CZ | CZECH STATISTICAL OFFICE | ICT | R&D Technology transfer Business/ Manufacturing Human resources Households Patent statistics Annual National Accounts ICT infrastructure | Integrated Specialised | annually | OECD, Eurostat | Technology areas Organisations Products/services | YES | R&D expenditure R&D direct government support Number of patent applications/patents registered Technology imports/exports Manufacturing of goods and services Employment in technology-related manufacturing of goods and services Imports/exports of goods and services Use by population | |
| | | BIO | R&D | Integrated | annually | OECD | Technology areas | YES | Number of patent applications/patents registered R&D direct government support R&D expenditure | |
| | | NANO | R&D | Integrated | annually | N/A | N/A | NO | R&D direct government support R&D expenditure | |
| CL | MINISTRY OF ECONOMY OF CHILI | NO | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| JP | STATISTICS BUREAU, MINISTRY OF INTERNAL AFFAIRS AND COMMUNICATIONS OF JAPAN | Life sciences | R&D | Integrated, NISTEP 'Science map' database | annually (R&D survey) | National Survey | R&D | Fields of S&T | NO | R&D expenditure |
| | | ICT | | | | | | | | |
| | | Environmental technologies | | | | | | | | |
| | | Materials | | | | | | | | |
| | | NANO | | | | | | | | |
| | | Energy | | | | | | | | |
| | | Space exploration | | | | | | | | |
| Oceanology | | | | | | | | | | |
| HU | HUNGARIAN CENTRAL STATISTICAL OFFICE | NO | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| IS | THE ICELANDIC CENTRE FOR RESEARCH (RANNIS) | BIO | R&D Human resources | Specialised | 2003 | OECD | OECD FOS Technology areas Organisations | N/A | R&D expenditure R&D personnel Researchers | |
| IR | CENTRAL STATISTICS OFFICE IRELAND | NO | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| IT | ITALIAN | ICT | ICT usage (business | Integrated | annually | Eurostat | NACE, ICT-related | YES | Broadband penetration rate, E-government | |

| Country | Agency | Technology areas covered | Survey type | Survey strategies | Periodicity/Frequency | Sources of definitions | Classification used | Participation in OECD/ UN/ EUROSTAT surveys | Indicators used |
|---------|--|--------------------------|---|---|-------------------------------------|--|--|---|--|
| | STATISTICAL INSTITUTE (ISTAT) | | sector, public sector, households) | | | | classifications | | usage by enterprises, E-commerce, Level of Internet access, etc. |
| | | BIO | R&D (business sector) | Integrated | annually | OECD | NACE, OECD biotech classification | YES | R&D biotech expenditure in the business sector |
| | | BIO | R&D (public sector) | Integrated | annually | OECD | NACE, OECD biotech classification | YES | R&D biotech expenditure in the business sector |
| | | NANO | R&D | Integrated | annually | National/OECD | NACE, areas of application | N/A | R&D nanotech expenditure in the business sector |
| | ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT (ENEA) | BIO | Application of biotechnologies in the business sector | Specialised | annually | OECD | NACE, OECD biotech classification, areas of application | YES | Areas of application of biotechnologies, main features of biotech enterprises. |
| KR | NATIONAL NANOTECHNOLOGY POLICY CENTER | NANO | Survey of nanotechnology-related organisations | Specialised | Ad-hoc sample survey (year n/a) | Nanotechnology Promotion Act | Technology areas Organisations Areas of application Products/ services | YES | Researchers Number of collaborations in R&D Employment in technology-related manufacturing of goods and services |
| NL | <i>STATISTICS NETHERLANDS</i> | NO | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| NZ | STATISTICS NEW ZEALAND | BIO | Bioscience survey | Specialised | N/A | Statistics NZ (based on OECD) | Fields of Science Areas of application Constraints to work Intellectual property rights | YES | R&D expenditure Source of funds Income from exports Provisional patent applications Full spec patent applications Plant breeder rights Copyright, trademark or trade secrets |
| NO | NORDIC INSTITUTE FOR STUDIES IN INNOVATION, RESEARCH AND EDUCATION STATISTICS NORWAY | BIO | R&D | Integrated (R&D) Specialised in HE, GOV, and NPI sectors | Annually (R&D) N/A (specialised) | OECD and white papers to the <i>Storting</i> | Technology areas | NO | R&D expenditure Funding sources R&D personnel Researchers Number of collaborations in R&D Number of publications Number of patent applications Number of patents registered Number of notifications to technology transfer organisations |
| | | NANO | | Integrated | annually | | | NO | R&D expenditure |
| | | ICT | | | | | | YES | R&D expenditure |

| Country | Agency | Technology areas covered | Survey type | Survey strategies | Periodicity/Frequency | Sources of definitions | Classification used | Participation in OECD/ UN/ EUROSTAT surveys | Indicators used |
|---------|---|-----------------------------|---|---------------------------|-----------------------|------------------------|---|---|--|
| | | New materials (except NANO) | | | | | | NO | R&D expenditure |
| PL | STATISTICAL OFFICE OF THE REPUBLIC OF POLAND | BIO | R&D Technology transfer Innovation Business/ Manufacturing | Integrated Specialised | N/A | OECD | Fields of Science Organisations Areas of application | YES | R&D expenditure Innovation expenditure |
| | | NANO | R&D | Integrated Specialised | N/A | OECD | Technology areas Organisations | YES | N/A |
| | | ICT | Business/ Manufacturing (based on main SBS assumptions) | Integrated Specialised | N/A | Eurostat | Organisations Socio-economic objectives National classification of economic activities | YES | N/A |
| RU | NATIONAL RESEARCH UNIVERSITY "HIGHER SCHOOL OF ECONOMICS" (methodology, pilot and ad hoc surveys) and FEDERAL STATISTICAL SERVICE (data collection) | ICT | R&D Technology transfer Innovation Business/ Manufacturing Structural Business Survey Human resources Households ICT infrastructure | Integrated Specialised | annually | OECD, Eurostat | Organisations Areas of application Products/services Occupations Special applications software Types of ICT Types of ICT expenditures ICT related services | UNCTAD, ITU | Innovation expenditure Venture capital investments R&D personnel Researchers Number of collaborations in R&D Number of publications Public awareness Social impact e-government e-commerce e-skills |
| | | NANO | R&D Technology transfer Innovation Business/ Manufacturing Human resources | Integrated Specialised | 2008- 2010 | ISO | Nanotechnology areas Types of nano-enabled products /services Organisations Forms of ownership Legal Forms Socio-economic objectives Administrative regions Areas of applications Occupations Sectors of R&D performance | NO | R&D expenditure R&D personnel Researchers Number of patent applications/patents registered Manufacturing of goods and services Employment in technology-related manufacturing of goods and services Imports/exports of goods and services Public awareness Technology creation and usage Nanotechnology-related personnel employed/required (by occupation) |
| | | S&T priority areas | R&D | Integrated | 2008-2010 | N/A | National list of S&T priority areas | NO | R&D expenditure |

| Country | Agency | Technology areas covered | Survey type | Survey strategies | Periodicity/Frequency | Sources of definitions | Classification used | Participation in OECD/ UN/ EUROSTAT surveys | Indicators used |
|---------|---|--------------------------|---|--|-----------------------|------------------------|---|---|--|
| SK | STATISTICAL OFFICE OF THE SLOVAK REPUBLIC | ICT | R&D Technology transfer Business/ Manufacturing Human resources | Integrated Specialised | annually | OECD | SK NACE Rev.2 CPA 2008, HS (SITC) ISCO | N/A | R&D expenditure Direct government support of R&D Manufacturing of goods and services Employment in technology-related manufacturing of goods and services Imports/exports of goods and services |
| | | BIO | R&D | Integrated | annually | OECD | N/A | N/A | R&D expenditure Direct government support of R&D |
| | | NANO | R&D | Integrated | annually | OECD | N/A | N/A | R&D expenditure Direct government support of R&D |
| SL | STATISTICAL OFFICE OF THE REPUBLIC OF SLOVENIA | BIO | R&D | Integrated | annually | OECD, Eurostat | NACE FOS | N/A | R&D expenditure Number of R&D active firms Total employment R&D personnel Researchers FTE and HC |
| | | NANO | | | | | | | |
| | | ICT | | | | | | | |
| ES | SPANISH NATIONAL INSTITUTE OF STATISTICS (INE) OBSERVATORY OF INDUSTRIAL TECHNOLOGY FORESIGHT (OPTI) GENOMA SPAIN | BIO | R&D Business/ Manufacturing | Specialised National register of organisations | annually | INE | Areas of application Types of economic activities Regional | NO | R&D expenditure R&D personnel |
| | | NANO | R&D | | annually | OPTI | N/A | NO | N/A |
| | | ICT | R&D Innovation Business/ Manufacturing Human resources | | annually | INE | Technology areas Areas of application | YES | R&D expenditure Innovation expenditure Venture capital investments R&D personnel Researchers Number of collaborations in R&D Number of publications Number of patent applications/patents registered Technology imports/exports Employment in technology-related manufacturing of goods & services Public awareness Social impact |
| SE | STATISTICS SWEDEN | ICT | R&D Innovation | N/A | N/A | N/A | N/A | BERD surveys | N/A |
| CH | FEDERAL | BIO | R&D | Integrated | annually | OECD | NACE | NO | R&D expenditure |

| Country | Agency | Technology areas covered | Survey type | Survey strategies | Periodicity/Frequency | Sources of definitions | Classification used | Participation in OECD/ UN/ EUROSTAT surveys | Indicators used |
|---------|---|------------------------------------|--|---|-------------------------|--------------------------------|---|---|--|
| | STATISTICAL OFFICE OF SWITZERLAND | | Innovation Technology transfer Business/ Manufacturing Human resources | Specialised | | | | | Venture capital investments Number of patent applications/patents registered Public awareness |
| | | NANO | R&D | Specialised | annually | National FSO | NACE | | R&D expenditure Number of patent applications/patents registered |
| | | Software | R&D | Specialised | annually | OECD | NACE | | R&D |
| | | White biotech | R&D Human resources Business/ Manufacturing | Specialised (Swiss Biotech Association survey) | 2009, 2010 | OECD | Technology areas Organisations Areas of application Products/services | | R&D expenditure Venture capital investments Number of publications Number of patent applications/patents registered |
| | | Cleantech | N/A | Specialised (the Federal Department of Economic Affairs and the Federal Department of the Environment, Transport, Energy and Communications) | 2009 | The Swiss Cleantech Masterplan | NACE | | N/A |
| | | ICT | Household Innovation | Integrated Specialised | 2005,2008, 2010 | OECD, Eurostat | NACE | | ICT Usage |
| US | NATIONAL CENTER FOR SCIENCE AND ENGINEERING STATISTICS/ NSF | Critical technologies (list based) | Business, R&D and Innovation (BRDIS) Human resources Advanced Technology Program | Integrated Specialised | BRDIS: 2010 HR: 1995 | NSF | Classification system for internationally traded products that embody new or leading-edge technologies (US Census Bureau) | NO | Innovation expenditure (BRIDS) Number of collaborations in R&D (1995 human resources surveys only) Number of patent applications/patents registered (USPTO) Technology imports/exports (Trade in high-tech or advanced tech products) |
| ZA | CENTRE FOR SCIENCE, TECHNOLOGY AND INNOVATION INDICATORS, HUMAN SCIENCES RESEARCH COUNCIL | NANO | R&D | Integrated | annually | OECD | Types of organisations (corresponding to FM sectors of R&D performance) | NO | R&D expenditure |
| | | BIO | R&D National biotechnology survey | Integrated Specialised | 2008/09 | OECD | | | R&D expenditure R&D personnel Researchers |
| | | Open source software | R&D | Integrated (Business enterprise R&D) | annually | N/A | | | R&D expenditure |

| Country | Agency | Technology areas covered | Survey type | Survey strategies | Periodicity/ Frequency | Sources of definitions | Classification used | Participation in OECD/ UN/ EUROSTAT surveys | Indicators used |
|---------|--------|--------------------------|-------------|---|---------------------------|------------------------|---------------------|---|-----------------|
| | | | | survey) | | | | | |
| | | New materials | R&D | Integrated (Business enterprise R&D survey) | annually | OECD | | | |

ANNEX 4 - SUMMARY OF INVENTORY OF DEFINITIONS USED IN NATIONAL S&T STATISTICAL SURVEYS

| Country | Technology areas covered | Definitions used | Source |
|---------|--------------------------|--|--|
| BE | BIO | <p><i>Biotech active firm</i> defined as a firm engaged in key biotechnology activities such as the application of at least one biotechnology technique (as defined in the OECD list-based definition of biotechnology techniques) to produce goods or services and/or the performance of biotechnology R&D.</p> <p><i>Dedicated biotechnology firm</i> (core) defined as a biotechnology active firm whose predominant activity involves the application of biotechnology techniques to produce goods or services and/or the performance of biotechnology R&D. These firms are a subset of the biotech active firms.</p> <p>Biotech R&D active firms includes all firms that perform biotechnology R&D. These firms are captured by R&D surveys. Dedicated biotech R&D active firms are estimated from this data by assuming that firms that have dedicated 75% or more of their total R&D to biotechnology R&D.</p> | OECD, A Framework for Biotechnology Statistics, 2005 |
| CZ | ICT | <p>1) <i>ICT products</i> are defined as products that must primarily be intended to fulfill or enable the function of information processing and communication by electronic means, including transmission and display (OECD).</p> <p>2) <i>ICT industries (sector)</i>: The production (goods and services) of a candidate industry must primarily be intended to fulfill or enable the function of information processing and communication by electronic means, including transmission and display (OECD).</p> <p>3) <i>ICT professionals</i> are defined as persons employed in the national economy, whose principal activity comes within the following two main occupational groups expressed in terms of the current International Standard Classification of Occupations (CZ-ISCO-88 in the Czech Republic):</p> <ol style="list-style-type: none"> 1. CZ-ISCO 213 – Computing professionals conduct research, plan, develop and improve computer based information systems, software and related concepts, develop principles and operational methods as well as maintain data dictionary and management systems of databases to ensure integrity and security of data. a) b) CZ-ISCO 312 – Computer associate professionals provide assistance to users of computers and standard software packages, control and operate computers and peripheral equipment and carry out limited programming tasks connected with the installation and maintenance of computer hardware and software. | Eurostat |
| | BIO | <p><i>Biotech R&D active firms</i> defined as a firm engaged in key biotechnology activities such as the application of at least one biotechnology technique (as defined in the OECD list-based definition of biotechnology techniques) to produce goods or services and/or the performance of biotechnology R&D.</p> | OECD, A Framework for Biotechnology Statistics, 2005 |
| IS | BIO | <p><i>Biotechnology</i> is the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.</p> | OECD, A Framework for Biotechnology Statistics, 2005 |
| IT | ICT | <i>OECD/Eurostat definitions</i> | OECD/Eurostat |
| | BIO | <i>OECD/Eurostat definitions</i> | OECD/Eurostat |
| | NANO | <p><i>List-based definition for nanotechnologies:</i></p> <ul style="list-style-type: none"> - Nano-materials - Nano-materials and application of nanotechnologies to data transmission, data-processing and data storage. - Application of nanotechnologies for health and in scientific life sciences-related fields | National definition agreed between Istat and the Italian Nanotech Industrial Association |

| Country | Technology areas covered | Definitions used | Source |
|---------|--------------------------------------|---|---|
| | | <ul style="list-style-type: none"> - Application of nanotechnologies to electro-chemical processes - Energy-related nanotechnology applications - Development of devices and processes for nanotechnology research - Non oriented research on nanotechnologies. | |
| JP | Life sciences | This refers to research on improvement and development of living by clarifying life related phenomena and various functions and organisms, and by applying the results to a variety of disciplines including medical, agricultural, industrial, environmental protection, energy development and so on. | <p>The questionnaire of R&D Survey</p> <p>Definitions are based on the descriptions of S&T prioritised areas in the "Second Science and Technology Plan" for FY2001–FY2005 adopted by the Cabinet on 30 March 2001.</p> |
| | ICT | In addition to R&D on hardware and software, that for the upgrading of networks and the development of high-speed computing technologies that enable high-speed processing, analysis and storage of massive quantities of information. | |
| | Environmental science and technology | This refers to research concerning the infections of polluted natural environments, life cycle and property, protection of natural environments from pollution and destruction, achievement of non-polluted environments, etc. | |
| | Materials | This means researches on 1) investigation and control of the structure, etc., of substances on the level of atoms and molecules which become the bases of IT, medical sciences, etc., and 2) development of the materials for the high value added energy and environment-related substances that can meet the needs to save energy and natural resources and recycle natural and other resources. | |
| | NANO | R&D for the achievement of functions utilizing nanosize material/substance characteristics. | |
| | Energy | This refers to research relating to exploration, production, conversion, transportation, consumption, safety, etc., in relation to the development and reasonable use of energy resources. | |
| | Space exploration | This includes research on rockets and artificial satellites and also research on tracing or communication stations. | |
| | Oceanology | This means oceanic research and technical development relating to culture of bio-resources, development of mineral resources, research on ocean space, utilization of seawater, etc. | |
| KR | NANO | Nanotechnology is science and technology which is to produce new or improved physical, chemical and biological materials, devices or systems by analyzing, manipulating and controlling materials in the category of nanometer-sized or it is science and technology which is the processing means in the category of micro- or nanometer-sized materials. | Nanotechnology Promotion Act |
| NZ | BIO | <p>Bioscience is the development and application of knowledge of the way plants, animals and humans function for the development of products and services.</p> <p>Bioscience activities may occur in the following areas:</p> <ul style="list-style-type: none"> – Agriculture feedstock and chemicals – Aquaculture, horticulture and forestry – Human and animal therapeutics and diagnostics – Medical devices and equipment – Research testing and medical laboratories – Microbes – Biotechnology | <p>Statistics NZ,</p> <p>Based on OECD Framework for Biotechnology Statistics, 2005</p> |
| NO | BIO | The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services. | <p>OECD and white papers to the Storting:</p> <ul style="list-style-type: none"> - St.meld. nr. 20 (2004–2005) <i>Vilje til forskning</i> - St.meld. nr. 30 (2008–2009) <i>Klima for forskning</i> |
| | NANO | New techniques for synthesis and processing, including moving and rearranging nature's building blocks (atoms, molecules or macromolecules) for intelligent design of functional and structural materials, components and | Based on white papers to the Storting: |

| Country | Technology areas covered | Definitions used | Source |
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| | | systems which offer attractive features and functions, and where dimensions and tolerances in the range 0.1 to 100 nm play a critical role. Materials whose properties have been intentionally altered using nanotechnology. Ethical, legal, social and health / environmental / safety aspects of nanotechnology. | - St.meld. nr. 20 (2004–2005) <i>Vilje til forskning</i> - St.meld. nr. 30 (2008–2009) <i>Klima for forskning</i> |
| | New materials (except NANO) | Functional materials (materials with specific chemical, physical or biological properties). Materials, whose particular features have been changed using nanotechnology, will be included in nanotechnology. | |
| | ICT | Development and use of telecommunications and computer systems. Digital information and communication systems. Hardware, software, web-based technologies. E-science and wireless technologies. Social issues related to ICT. | |
| PL | BIO | <i>Biotechnology</i> is the application of S&T to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services. List: DNA, proteins and molecules, cell and tissue culture and engineering, process biotechnologies, sub-cellular organisms, bioinformatics, nanobiotechnology, other | OECD, A Framework for Biotechnology Statistics, 2005 |
| | NANO | <i>Nanotechnology</i> is the set of technologies that enables the manipulation, study or exploitation of very small (typically less than 100 nanometres) structures and systems. Nanotechnology contributes to novel materials, devices and products that have qualitatively different properties. Its advances have the potential to affect virtually every area of economic activity and aspect of daily life. | OECD |
| | ICT | <i>Information and Communications Technologies</i> (content : computer and Internet use; automatic and electronic data exchange (e-business), e-commerce, e-skills, e-health, green technologies) | Eurostat |
| RU | ICT | <p>1) <i>Information and communications technology (ICT)</i> is understood as the types of technologies using microelectronics for collection, storage, processing, retrieval, transmission, and presentation of data, texts, images, and sounds.</p> <p>2) <i>The ICT sector</i> comprises enterprises whose main economic activity is production of goods or provision of services which meet at least one of the following requirements: production of goods which:</p> <ul style="list-style-type: none"> - are designed for telecommunications or processing of information, including its transfer and display; or - use electronics to detect, measure and/or record physical phenomena, or control physical processes; or - are individual components intended primarily for use within products described above; <p>provision of services which:</p> <ul style="list-style-type: none"> - allow to process and transfer information by means of electronic devices; or - are connected with sales or leasing of hardware and/or software; or - directly create new information technologies or support implementation, adaptation and/or use of existing ones. <p>3) <i>ICT professionals</i> – groups of employees according to the certain codes of the Russian Classification of Occupations (RU-ISCO-88 in the Russian Federation):</p> <ol style="list-style-type: none"> a) RU-ISCO 2131 – Designers and analysts of computer systems. b) RU-ISCO 2132 – Programmers. c) RU-ISCO 2139 – Other computer related professionals. d) RU-ISCO 2144 – Electronics, communication and instrument engineers. e) RU-ISCO 3114 – Electronics and telecommunications technicians. f) RU-ISCO 3121 – Computer maintenance technicians and operators. g) RU-ISCO 3122 – Computer devices and peripherals maintenance technicians and operators. h) RU-ISCO 3123 – Industrial robots maintenance technicians and operators. i) RU-ISCO 3132 – Radio, television and telecommunications hardware | OECD/ Eurostat Information Society Statistics in the Russian Federation: Harmonisation with International Standards/ Ed. by L. Gokhberg and P. Boegh-Nielsen. Moscow: State University – Higher School of Economics, 2007. |

| Country | Technology areas covered | Definitions used | Source |
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| | | technicians and operators. 4) <i>Employees with ICT user skills</i> – users of computers, other office equipment and global networks who have basic software user skills (other than ICT professionals). | |
| | NANO | Nanotechnologies – a set of methods and techniques, related to analysis & control of elemental composition of the matter and processes at the nanoscale level (100 nm or less by one or several dimensions) and providing new properties of the matter to create improved materials, devices or systems which utilize those new properties | National Research University “Higher School of Economics” and Russian Corporation of Nanotechnologies, in line with ISO working definition |
| | S&T priority areas | S&T priority areas include: <ul style="list-style-type: none"> • Information and telecommunication systems; • Nanosystems industry and materials; • Living systems; • Rational nature utilization; • Power engineering and energy saving; • Transport, aviation and space systems. | Ministry of Education and Science of the Russian Federation |
| SK | ICT | <p>1) ICT products are defined as products that must primarily be intended to fulfill or enable the function of information processing and communication by electronic means, including transmission and display (OECD).</p> <p>2) ICT industries (sector): The production (goods and services) of a candidate industry must primarily be intended to fulfill or enable the function of information processing and communication by electronic means, including transmission and display (OECD).</p> <p>3) ICT professionals are defined as persons employed in the national economy, whose principal activity comes within the following main occupational groups expressed in terms of the current International Standard Classification of Occupations (ISCO-08 in the Slovak Republic):</p> <p><i>a) 251 Software and applications developers and analysts</i> <i>b) 252 Database and network professionals</i> <i>c) 351 Information and communications technology operations and support technicians</i></p> | OECD/ Eurostat |
| | BIO | Biotech R&D active firms —defined as a firm engaged in key biotechnology activities such as the application of at least one biotechnology technique (as defined in the OECD list-based definition of biotechnology techniques) to produce goods or services and/or the performance of biotechnology R&D. | OECD |
| ES | BIO | Biotechnology is the application of science and technology to living organisms as well as parts, products and models, to alter living or inert material in order of producing knowledge, goods and / or services. | Spanish National Institute of Statistics |
| | NANO | Nanosciences and nanotechnologies include a set of disciplines and techniques oriented to the study and the manipulation of the scale of atoms, molecules and molecular structures. | Observatory of Industrial Technology Foresight |
| | ICT | <p>The ICT sector consists of the manufacturing or service industries whose main activity is linked to the development, production, marketing and intensive use of information technology and communications.</p> <p>For statistical purposes, the definition of the ICT sector is done through an exhaustive list of the industries of ICT companies (sector approach) and ICT products (product approach).</p> <p>To determine the list of activities and products of the ICT sector, the INE uses the methodological work carried out by the OECD in this area.</p> | Spanish National Institute of Statistics |
| CH | BIO | <p><i>Biotechnology</i> is the application of S&T to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.</p> <p>Examples of biotechnology-related activities:</p> <ul style="list-style-type: none"> • DNA (coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering. | OECD, A Framework for Biotechnology Statistics, 2005 |

| Country | Technology areas covered | Definitions used | Source |
|---------|--------------------------|---|--------------------|
| | | <ul style="list-style-type: none"> • Proteins and molecules (functional blocks): protein/peptide sequencing/synthesis, lipid/protein glyco-engineering, proteomics, hormones and growth factors, cell receptors/ signalling/-pheromones. • Cell and tissue culture and engineering: cell/tissue culture, tissue engineering, hybridisation, cellular fusion, vaccine/immune stimulants, embryo manipulation. • Process biotechnologies: bioreactors, fermentation, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation and biofiltration, biotransformation, enzyme immobilisation. • Sub-cellular organisms: gene therapy, viral vectors. • Analytical techniques: Screening: metabolomics, transcriptomics, proteomics, high throughput screening. | |
| | NANO | <p><i>Nanotechnology</i> refers to research, development and eventually the production of products which use materials engineered at the atomic, molecular or macromolecular levels, in the length scale of approximately 1–100 nanometer range. Nano-science refers to the fundamental understanding of phenomena and materials at the nanoscale. On a larger scale, nanotechnology research and development includes the controlled manipulation of nanoscale structures and their integration into larger material components, systems and architectures.</p> <p>Examples of nanotechnology-related activities:</p> <ul style="list-style-type: none"> – Development of carbon nano tube (CNT) laminates, structures and devices; – Manufacture of high temperature CNT composites; – Low power CNT electronic components; – New materials based on SiC, GaN; – Develop materials for sensing and monitoring structural health; – Design and fabrication of self-healing materials; – Development of multifunctional CNT structures; – Devices using quantum dots; – Pyro-electric micro-thrusters; – Some deployment of super micro-electro mechanical systems (MEMS); – Testing of nano sensors; – Testing and use of nano coating and materials; – Tech transfer of information from Human Genome Project to create biological approaches to nanotechnology; – Assembly of micro-mirror arrays; | Own FSO definition |

| Country | Technology areas covered | Definitions used | Source |
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| | | <ul style="list-style-type: none"> – Quantum navigation sensors; – CNT vibration sensors for propulsion diagnostics. | |
| | Software | <p>For a <i>software development</i> project to be classified as R&D, its completion must be dependent on a scientific and/or technological advance, and the aim of the project must be the systematic resolution of a scientific and/or technological uncertainty. In addition to the software that is part of an overall R&D project, the R&D associated with software as an end product should also be classified as R&D.</p> <p>Examples of R&D fields in software development:</p> <ul style="list-style-type: none"> – R&D producing new theorems and algorithms in the field of theoretical computer science; – Development of information technology at the level of operating systems, programming languages, data management, communications software and software development tools; – Development of internet technology; – Research into methods of designing, developing, deploying or maintaining software; – Software development that produces advances in generic approaches for capturing, transmitting, storing, retrieving, manipulating or displaying information; – Experimental development aimed at filling technology knowledge gaps as necessary to develop a software programme or system; – R&D on software tools or technologies in specialised areas of computing (image processing, geographic data presentation, character recognition, artificial intelligence and other areas). <p>Examples of software-related activities not to be included in R&D:</p> <ul style="list-style-type: none"> • Business application software and information system development using known methods and existing software tools; • Support for existing systems; • Converting and/or translating computer languages; • Adding user functionality to application programmes; • Debugging of systems; • Adaptation of existing software; • Preparation of user documentation. | OECD, Frascati Manual, 2002, § 2.4.1 |
| | White biotechnology | <p>For the purpose of this survey, white biotechnology refers to the following definition: Manufacture of chemical products, liquid fuels, new biomaterials or polymers using enzymes, microorganisms, fermentation or biocatalysis at any stage of production regardless of the type of raw materials used (biomass, fossil fuel-based or inorganic substances) or enzyme/micro-organism development to make white biotech products. White biotechnology DOES NOT include:</p> <ol style="list-style-type: none"> 1. Cell and tissue culturing or Nanobiotechnology. However, this highlights an important distinction for the purpose of this survey: the development of pharmaceuticals using genomics and genetic engineering is not white biotechnology but the synthesis of pharmaceuticals using white biotechnology is included (even if used in combination with conventional chemical processes), as are diagnostic. 2. Any food or feed products, such as beverages for human consumption. However, food flavorings and food/feed ingredients produced using white biotechnology are included. White biotechnology was defined to include products manufactured using enzymes, microorganisms, fermentation or biocatalysis at any stage of the production process. This | OECD Swiss Biotech Association |

| Country | Technology areas covered | Definitions used | Source |
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| | | is consistent with the OECD list-based definition for process biotechnology techniques. | |
| | Cleantech | <p>Cleantech refers to the combination of technologies, industries and services that preserve and maintain natural resources and systems. Cleantech specifically includes new resource-efficient attitudes in all economic branches. Specifically, cleantech includes the following subsectors:</p> <ul style="list-style-type: none"> • Renewable energies, energy efficiency, energy storage; • Renewable materials, efficient use of resources and materials, including waste management and recycling; • Sustainable water management; • Sustainable mobility; • Sustainable agriculture and forestry; • Industrial biotechnology: replaces conventional industrial processes with biological processes, which reduces consumption of raw materials and energy or enables energy to be generated from biomass; • Environmental engineering in the narrow sense such as measurement technology, remediation of contaminated sites, filter technology. | Federal Department of the Environment, Transport, Energy and Communications, Federal Department of Economic Affairs, Masterplan Cleantech (2010) |
| | ICT | <p>In the Swiss Innovation survey ICT includes the following technologies:</p> <ul style="list-style-type: none"> • Digital assistance (organiser, PDA, etc.); • E-mail; • Electronic data exchange; • Homepage; • Internet, computer networks (WWW, etc.), managed by protocol; • Mobile Internet – mobile phones capable of accessing the Internet and electronic data interchange (EDI) via the Internet; • Intranet (internal information networks based on Internet technologies); • Extranet (expansion of the Intranet, allowing external users to access a part of it); • LAN (Local Area Network: computers or telecommunication devices connected together in a very restricted geographical area, e.g. inside a building); • Laptop; • Personal computer (PC), workstations, terminals; • Broadband technology; • WLAN (Wireless Local Area Network). | Own FSO definition |
| US | Critical technologies | <p>Top 10 critical technologies:</p> <ul style="list-style-type: none"> • <i>Advanced materials</i>—the development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies. • <i>Aerospace</i>—the development of aircraft technologies, such as most new military and civil airplanes, helicopters, spacecraft (excluding communications satellites), turbojet aircraft engines, flight simulators, and automatic pilots. • <i>Biotechnology</i>—the medical and industrial application of advanced genetic research to the creation of drugs, hormones, and other therapeutic items for both agricultural and human uses. • <i>Electronics</i>—the development of electronic components (other than optoelectronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components (such as capacitors and resistors) that improve performance and capacity and, in many cases, reduce product size. • <i>Flexible manufacturing</i>—the development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention. | NSF |

| Country | Technology areas covered | Definitions used | Source |
|---------|--------------------------|---|--|
| | | <ul style="list-style-type: none"> • <i>Information and communications</i>—the development of products that process increasing amounts of information in shorter periods of time, including computers, video conferencing, routers, radar apparatus, communications satellites, central processing units, and peripheral units such as disk drives, control units, modems, and computer software. • <i>Life sciences</i>—the application of nonbiological scientific advances to medicine. For example, advances such as nuclear magnetic resonance imaging, echocardiography, and novel chemistry, coupled with new drug manufacturing techniques, have led to new products that help control or eradicate disease. • <i>Optoelectronics</i>—the development of electronics and electronic components that emit or detect light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers. • <i>Nuclear</i>—the development of nuclear production apparatus (other than nuclear medical equipment), including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges. (Nuclear medical apparatus is included in the life sciences rather than this category.) • <i>Weapons</i>—the development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms. | |
| ZA | NANO | Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometres, where unique phenomena enable novel applications. | OECD |
| | BIO | Biotechnology is an application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services. | OECD, A Framework for Biotechnology Statistics, 2005 |
| | Open source software | No specific definition in use | |
| | New materials | New materials pertain to the technology and R&D activities of high-tech companies particularly in the aerospace, construction, electronic, biomedical, renewable energy, environmental remediation, food and packaging, manufacturing and motor car industries. New materials include multi-functional materials, advanced materials, nanomaterials, nanocomposites and nanotechnology. | N/A |