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Nanotechnologies — Vocabularies for science, technology and innovation indicators

Nanotechnologies — Vocabulaires pour la science, la technologie et les indicateurs d'innovation

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Contents

Page

Foreword

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The committee responsible for this document is ISO/TC 229, *Nanotechnologies*.

Introduction

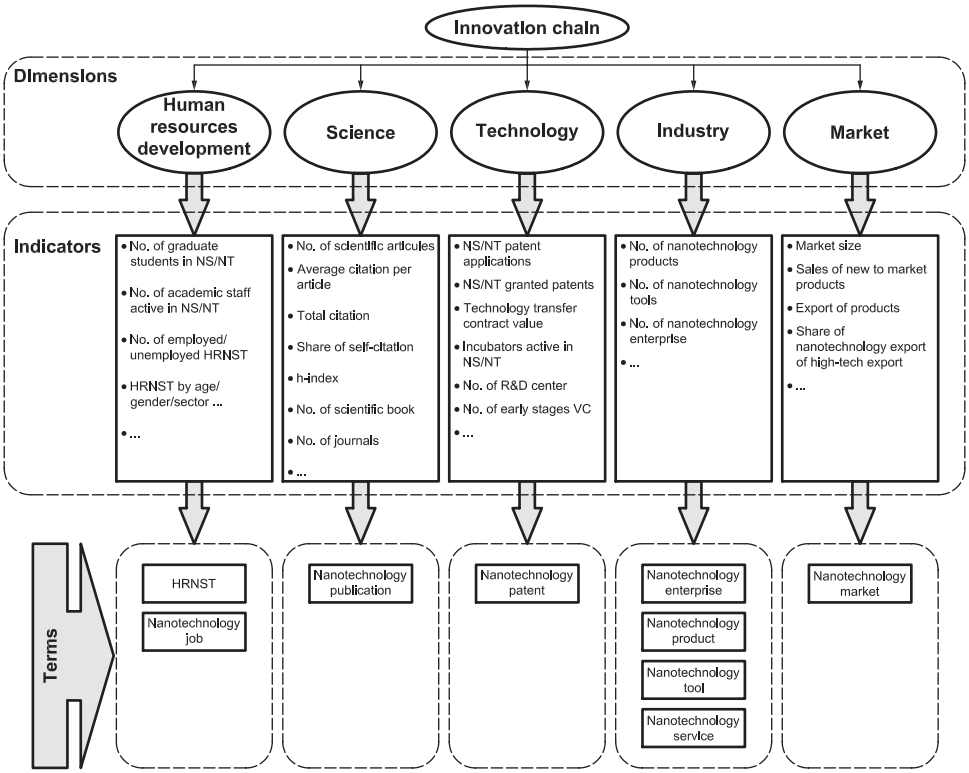
Emerging nanotechnologies are moving towards commercialization and will in future create extensive economic benefits in various industrial sectors. In this field, monitoring trends and the rate of changes in science, technology and industry at global, regional and domestic levels is an important consideration. Due to the high levels of investment by the private, public and industrial sectors and the substantial increase in nanotechnology-based publications, inventions and products, a unified approach is required to evaluate the impact of these investments, as well as the overall progress and impact of nanotechnology.

Understanding the socio-economic impacts of nanotechnology is important among communities. Investors, for example, require the assessment of scientific and technological advancements, while policy makers are interested in the assessment of results and impacts of their policies and programs.

The basic efforts of ISO/TC 229 for the standardization of nanotechnology-related terms were an important step towards the creation of a common language to inform people of nanotechnology development worldwide. Most of the terminology projects have focused on the development of scientific and technological vocabularies and terms. The creation of terms and core terms for science, technology and innovation indicators are of great interest, especially where existing indicators are inadequate for applications relating to nanotechnology. Such terms would help transparent and trustworthy comparison of international activities in this area. Unfortunately, due to the lack of such globally agreed vocabularies/definitions, the released economic, scientific and innovation statistics should be considered with caution.

Figure 1 typically demonstrates the major dimensions of the nanotechnology innovation chain as human resources development, science, technology, industry and market. For each of these dimensions, there are several relevant indicators, which are utilized to varying degrees in some analytical reports related to nanotechnology.

Generic indicators that are descriptive of innovation dimensions are already well defined; however, the bounds of these indicators as they relate to nanotechnology need to be defined and harmonized to ensure consistent reporting.



Key

NS nanoscience

NT nanotechnology

NOTE Adopted from References [15] and [28].

Figure 1 — Demonstration of innovation chain dimensions, indicators and defined terms

Nanotechnologies — Vocabularies for science, technology and innovation indicators

1 Scope

This Technical Specification aims to provide the necessary definitions that specify the bounds of key innovation indicators as they relate to nanotechnology, in order to facilitate and unify the global assessment of nanotechnology activities in different areas.

The availability of these terms can help the measurement and comparison of various indicators in this field. This Technical Specification does not intend to redefine terms that are already defined in other ISO documents. Furthermore, there is no intention to show how the indicators can be used as an assessment tool.

2 Terms and definitions from ISO 14040, ISO 14041 and ISO/TS 80004-1

The terms and definitions in this Clause are from ISO 14040, ISO 14041, and ISO/TS 80004-1. They are reproduced here for context and better understanding.

2.1
engineered nanomaterial
nanomaterial (2.8) designed for a specific purpose or function

[SOURCE: ISO/TS 80004-1:2015, 2.8]

2.2
final product
product which requires no additional transformation prior to its use

[SOURCE: ISO 14041:1998, 3.6]

2.3
intermediate product
output from a unit process that is input to other unit processes that require further transformation within the system

[SOURCE: ISO 14040:2006, 3.23]

2.4
manufactured nanomaterial
nanomaterial (2.8) intentionally produced to have selected properties or composition

[SOURCE: ISO/TS 80004-1:2015, 2.9]

2.5
nano-enabled
exhibiting function or performance only possible with *nanotechnology* (2.13)

[SOURCE: ISO/TS 80004-1:2015, 2.15]

2.6
nano-enhanced
exhibiting function or performance intensified or improved by *nanotechnology* (2.13)

[SOURCE: ISO/TS 80004-1:2015, 2.16]

2.7
nanomanufacturing process
ensemble of activities to intentionally synthesize, generate or control *nanomaterials* (2.8), or fabrication steps in the *nanoscale* (2.9), for commercial purpose

[SOURCE: ISO/TS 80004-1:2015, 2.12]

2.8
nanomaterial
material with any external dimension in the *nanoscale* (2.9) or having internal structure or surface structure in the nanoscale

Note 1 to entry: This generic term is inclusive of nano-object and nanostructured material.

Note 2 to entry: See also *engineered nanomaterial* (2.1), *manufactured nanomaterial* (2.4) and incidental nanomaterial.

[SOURCE: ISO/TS 80004-1:2015, 2.4]

2.9
nanoscale
length range approximately from 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from larger sizes are predominantly exhibited in this length range.

[SOURCE: ISO/TS 80004-1:2015, 2.1]

2.10
nanoscale phenomenon
effect attributable to the presence of nano-objects or *nanoscale* (2.9) regions

[SOURCE: ISO/TS 80004-1:2015, 2.13]

2.11
nanoscale property
characteristic of a nano-object or *nanoscale* (2.9) region

[SOURCE: ISO/TS 80004-1:2015, 2.14]

2.12
nanoscience
study, discovery and understanding of matter where size- and structure-dependent properties and phenomena manifest, predominantly in the *nanoscale* (2.9), distinct from those associated with individual atoms or molecules, or extrapolation from larger sizes of the same material

[SOURCE: ISO/TS 80004-1:2015, 2.2]

2.13
nanotechnology
application of scientific knowledge to manipulate and control matter predominantly in the *nanoscale* (2.9) to make use of size- and structure-dependent properties and phenomena distinct from those associated with individual atoms or molecules, or extrapolation from larger sizes of the same material

Note 1 to entry: Manipulation and control includes material synthesis.

[SOURCE: ISO/TS 80004-1:2015, 2.3]

3 Terms and definitions for science, technology and innovation indicators

Further information relating to definitions in this Clause can be found in informative Annexes A to G.

3.1
human resources for nanoscience and nanotechnology
HRNST
people who have:

a) successfully completed education at the university level in *nanoscience* (2.12) (NS) or *nanotechnology* (2.13) (NT) majors, or

b) successfully graduated in majors other than NS/NT majors, but completed a requirement of the major in the field of NS/NT, or

c) not formally qualified as above, but are employed in a *nanotechnology job* (3.2)

3.2
nanotechnology job
job whose main tasks and duties use *nanotechnology* (2.13)

Note 1 to entry: Regarding the potential of nanotechnology to establish new enterprises and facilities, an indicator may be measured as "*job created by nanotechnology*". This indicator includes nanotechnology jobs as well as other job opportunities in these establishments which do not necessarily use nanotechnology.

3.3
nanotechnology publication
science-based publication that publishes information about *nanotechnology* (2.13), its applications and implications

Note 1 to entry: Those publications may also include socio-economic aspects of nanotechnology.

3.4
nanotechnology patent
any patent related to *nanotechnology* (2.13)

Note 1 to entry: Such patents include *nanotechnology product* (3.5), *nanotechnology tool* (3.6), production process of nanotechnology product and *nanomanufacturing process* (2.7).

Note 2 to entry: Such patents would be considered under the IPC/CPC classes and related subclasses, such as B82, or contain at least one claim related to *nanotechnology* (2.13).

3.5
nanotechnology product
one or more of:

a) *manufactured nanomaterial* (2.4) or *engineered nanomaterial* (2.1)

b) *nano-enhanced* (2.6)/*nano-enabled* (2.5) *intermediate product* (2.3)

c) *nano-enhanced* (2.6)/*nano-enabled* (2.5) *final product* (2.2)

Note 1 to entry: Within supply chains, an intermediate product may be considered as a final product, however, process intermediates are excluded.

Note 2 to entry: Final products which are assembled with one or a number of nanotechnology final products as components or parts should not be considered as nanotechnology products. This exclusion prevents multiple counting of nanotechnology final products in a product value chain.

3.6
nanotechnology tool
means for analysis, manipulation or fabrication of *nanomaterial* (2.8) or *nanotechnology product* (3.5)

Note 1 to entry: Analysis of nanomaterial includes studying and measuring *nanoscale phenomena* (2.10) and *nanoscale properties* (2.11).

Note 2 to entry: In some instances fabrication may include *nanomanufacturing processes* (2.7).

3.7
nanotechnology enterprise
enterprise with at least one of the following:

— production of a *nanotechnology product* (3.5), or *nanotechnology tool* (3.6)

— provision of a *nanotechnology service* (3.8)

Note 1 to entry: Some nanotechnology enterprises may have a small share of total economic activity related to nanotechnology, while some are dedicated nanotechnology enterprises of which nanotechnology is their principal activity.

3.8
nanotechnology service
technical service that needs knowledge of *nanoscience* (2.12) and *nanotechnology* (2.13)

Note 1 to entry: Includes performance of R&D in the field of *nanotechnology* (2.13).

3.9
nanotechnology market
market including:

— *nanotechnology products* (3.5),

— *nanotechnology tools* (3.6), and

— *nanotechnology services* (3.8)

Annex A
(informative)

Human resources for nanoscience and nanotechnology (HRNST) and nanotechnology job

A.1 General

A number of important indicators related to NS/NT can be classified under the category "Human resources". In this respect, the terms "human resources for nanoscience and nanotechnology (HRNST)" and "nanotechnology job" need to be defined.

It should be mentioned that the term "human resources devoted to science and technology (HRST)" has previously been defined in the OECD manual known as the "Canberra Manual"[20]. This manual was developed collaboratively among the OECD, Eurostat of the European Commission, UNESCO, and the International Labour Organization (ILO). Here, in this work, the term "HRNST" has also been defined in close harmony with the already mentioned definition of "HRST".

The Canberra Manual introduces its classification by qualification and occupation. The basic ideas are described as follows:

"In order to obtain a complete picture of both supply and demand for HRST, the definition is based on two dimensions, qualification and occupation. The qualification axis tells us about the supply of HRST, i.e. the number of people who are currently or potentially available to work at a certain level. The demand for HRST, i.e. the number of people who are actually required in S&T activities at a certain level, is related to the occupation dimension. Because demand does not always match supply and because skills can be obtained outside the formal education system, the following combined definition is proposed.

HRST are people who fulfil one or other of the following conditions:

a) Successfully completed education at the third level in a S&T field of study;

b) Not formally qualified as above, but employed in a S&T occupation where the above qualifications are normally required."

A.2 Description of the term HRNST

In harmony with the Canberra Manual, both approaches can be utilized to define HRNST.

A.2.1 Identification by qualification

In some countries, highly focused NS/NT specific curricula are provided by universities/research institutes. People who graduated in these majors are recognized in those countries as HRNST [category a) in the abovementioned definition].

In addition, in many countries, there are people who graduated in majors other than NS/NT majors, but completed their dissertation or any other main requirement in the field of NS/NT. They may be acknowledged as HRNST, since they normally have appropriate knowledge and skills for scientific and technological activities in the field of NS/NT. The inclusion of these two categories is justified by the level of quality of the trained people in this field, since highly skilled educated human resource is a major requisite for future development of NS/NT.

Nonetheless, people who have attended a few days' workshop, a brief training or passed a few intermittent courses in the field of NS/NT are not recognized as HRNST. On one hand, such people have

insufficient skills for scientific and technological activities in the field of nanotechnology. On the other hand, to be an easily measurable indicator, HRNST could not include this group of people.

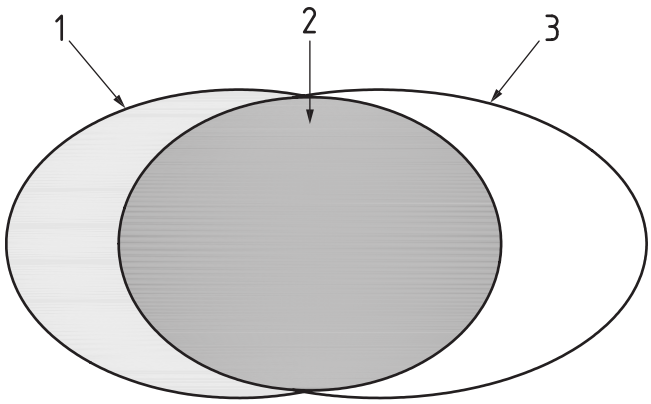
A.2.2 Identification by occupation

On the demand side of human resources, people who are not formally qualified as mentioned in Clause A.1, but employed in an occupation related to nanotechnology, are recognized as HRNST.

The ILO has introduced a definition for occupation in the International Standard of Classification Occupation (ISCO) standard.[9] According to ISCO-08 the definition of occupation is as follows:

"Occupation refers to the kind of work performed in a job. The concept of occupation is defined as a set of jobs whose main tasks and duties are characterized by a high degree of similarity."

It is worth mentioning that one cannot ignore the possible overlap between HRNST by qualification and occupation as shown in Figure A.1.



Key

1 HRNST by Occupation but not by Qualification

2 HRNST by both Qualification and Occupation

3 HRNST by Qualification but not by Occupation

NOTE Reproduced with permission from *Canberra Manual*,[20] page 17, Figure 3.1 with minor modifications.

Figure A.1 — Three main categories of HRNST

A.3 Description of the term *nanotechnology job*

Job creation as a direct socio-economic outcome of nanotechnology commercialization is an important indicator for the effectiveness of nanotechnology policies.

The ISCO standard defines the term "*job*" as follows:

"A job is a set of tasks and duties performed, or meant to be performed, by one person, including for an employer or in self-employment."

Jobs, whose tasks and duties use some special technical skill related to nanotechnology, should be considered as nanotechnology jobs. As an example, in a nanomaterial production workplace, a safety specialist must be aware of safety aspects of nanomaterials and be able to apply appropriate measures and procedures. Therefore, his/her job is a nanotechnology job.

Besides nanotechnology job, many job opportunities are created in institutions related to nanotechnology which do not necessarily need technical skills in the field of NS/NT. These jobs are important from an economical perspective and show the potential of nanotechnology in creating

new jobs. In this respect, the indicator "Job created by nanotechnology" may be measured. A similar indicator has been utilized by OECD in the field of biotechnology as "Total employment".[25]

A.4 Some examples

Consider a nanotechnology product manufacturing enterprise.

— The R&D expert who has graduated in nanomaterial engineering can be both considered as HRNST by qualification and by occupation and has a nanotechnology job.

— The AFM operator in the R&D section who has graduated in physics and has obtained expertise to characterize nanomaterial samples is considered as HRNST by occupation and has a nanotechnology job.

— The support staff person with a diploma of literature can be considered neither as HRNST by qualification nor by occupation because he or she does not need any specific NS/NT skill for performing his/her job. This job is considered as a job created by nanotechnology.

Annex B
(informative)

Nanotechnology patent and nanotechnology publication

B.1 General

Some indicators for evaluating the results and outputs of R&D activities are related to publications and patents. For instance, some indicators such as "Academic Science and Engineering Article Output per 1 000 S&E Doctorate Holders in Academia" and "Academic Patents Awarded per 1 000 Science and Engineering Doctorate Holders in Academia" have been reported annually by US. National Science Foundation.[17]

An integrated and comprehensive definition of publications and patents in the field of NS/NT has not been provided in international and scientific communities so far. Therefore, given the importance of nanotechnology and science evaluation at the national and international levels, providing definitions of these words seems quite necessary. This Technical Specification does not intend to redefine publication and patent terms, but rather provides guidance on determining which publications and patents fall within the scope of nanotechnology.

B.2 Nanotechnology publication

There are different types of publications which are indexed in scientific databases and resources. For instance, more than 30 types of documents have been introduced as publications in the Web of Science database including article, book review, meeting abstract, review, etc.[36] Usage of each item depends on the scope of the related indicator. For example, if publications are considered as an indicator for assessing knowledge generation, peer reviewed articles can be chosen and analysed. The main question raised here is which publications fall within the nanotechnology scope. Due to the interdisciplinary nature of nanotechnology, relevant articles are published by many scientific journals in different scientific fields, so there is a need for a clear definition to identify such articles.

Even the Web of Science database has introduced a new classification of journals titled "nanoscience and nanotechnology" comprising journals with nanotechnology as their scope. Many articles unrelated to nanotechnology have been published in that classification, while many nanotechnology-related articles are published in other journals. In addition, many journals do not follow the standard definition of "nanotechnology" from ISO/TC 229. Therefore, there is a need to distinguish nanotechnology publications by a clear definition.

Most published nanotechnology-related articles are about scientific and technical aspects of nanotechnology or the application of nanotechnologies for manufacturing and fabrication of devices and systems. Other publications discuss issues beyond scientific and technical aspects like economic and societal debates in nanotechnology. Considering the high importance of these issues for nanotechnology development in the world, such publications in the field of nanotechnology cannot be ignored. Thus, in this Technical Specification, nanotechnology publications refer to publications related to nanoscience and nanotechnology and their applications, as well as the socio-economic aspects of nanotechnology. Table B.1 shows some examples of the mentioned kinds of nanotechnology publications.

Table B.1 — Some examples of different nanotechnology publications

Topic	Examples
Nanotechnology	• Studying electrical conductivity of CNTs • Modelling and simulation of Boron Nitride nanotubes • Production of carbon nanotubes by PECVD method • Surface coating technology using nanoparticles
Application of nanotechnology	• Using nanosilica as an additive in cement manufacturing • Application of nanofiltration for removal of pesticides, nitrate and hardness from ground water
Socio-economic aspects	• Bibliometric approach to the assessment of nanoscience policy • International strategy for nanotechnology research and development • Commercializing nanotechnology products • Nanotechnology challenges: implications for philosophy, ethics and society • Market estimation of nano-based cosmetic products

B.3 Nanotechnology patent

Based on the World Intellectual Property Organization (WIPO) definition, patent is an exclusive right granted for an invention for a limited period. A patent may be for a new product or process. By definition[33] a patent shall:

— have novelty,

— benefit from an inventive step/be non-obvious,

— have industrial application/be useful,

— lead to full and transparent disclosure of the invention.

Patent offices have taken the necessary measures to distinguish nanotechnology inventions. Some of these offices have defined nanotechnology and classified nanotechnology patents even before the establishment of ISO/TC 229. For instance class 977 and class Y01N have been formed by USPTO since 2004[32] and by EPO since 2003[24][3] respectively. In addition, five important patent offices (EPO, JPO, KIPO, SIPO and USPTO) have compiled a unified classification, Cooperative Patent Classification (CPC), which has a special class dedicated to nanotechnology (B82).[34] A standardized definition for nanotechnology patent for usage among patent offices will facilitate the process of assigning a patent into a class or subclass of nanotechnology. Moreover, such definition may be useful for those working on research and analysis of patent information for the purposes of technical usage, policy-making, planning or providing statistics.

Since a patent may be granted to a product or process, generally nanotechnology patents include these two types. As defined in this Technical Specification, nanotechnology products and nanotechnology tools are classified as products in the field of nanotechnology. Additionally, ISO/TS 80004-8 outlines many fabrication and synthesis processes that could be patentable. In addition, for manufacturing intermediates and finished nanotechnology products one may invent a production process that could be also patentable. Hence nanotechnology patents can be classified as illustrated in Figure B.1. Also, Table B.2 shows some examples of nanotechnology patents.

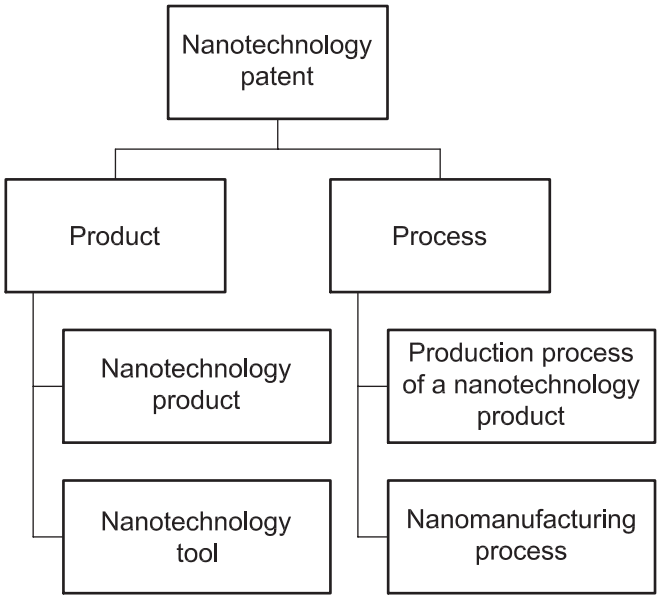


Figure B.1 — Nanotechnology Patent classification

Table B.2 — Some examples of nanotechnology patents

Nanotechnology products	• Nano-carbon sensor and method of making a sensor (EP2426487) • Nano-Phosphor And Nano-Phosphor Composite (EP1995293A1)
Nanotechnology tools	• AFM probe with variable stiffness (US 7,958,566) • Piezomotor connector (US D639737)
Nanomanufacturing process	• Method for making carbon nanotube structure • (US 8,414,859) • Method And Catalyst Reactor For Producing Nano-Carbon (JP2006290682)
Production process of nanotechnology products	• Radiation Method for Fabrication of Nano-sized Compound Antibacterial Fabric Textile (US20090092645) • Method of fabricating nano-silver fibres (US 7,410,650) • Process for the production of nano-fibrillar cellulose gels (EP2236545A1)

B.4 Size matter in nanotechnology patents

It is common for a patent applicant to claim a size range which can generally cause a problem for nanotechnology patents because the nanoscale size range might be a sub-range of a prior art. For instance, if in a granted patent for a micro-structured material, a size range of below 10 μm has been claimed, the new patent application with size range of 20 nanometres to 40 nanometres faces a problem in terms of novelty or having an inventive step. Fortunately considering patent registration rules (unexpected result), the same new material can be patented if the exhibited properties in the claimed size range are different from those in the larger sizes. On the other hand, new patent applications related to nanotechnology are patentable if their size range is claimed narrowly and miniaturization is to be performed for getting the improved properties or new ones that are common at the nanoscale where size-dependent or structure-dependent properties emerge.

Annex C
(informative)

Nanotechnology product

C.1 General

Many indicators related to NS/NT can be classified under the category “Industry”. In this respect, the term “nanotechnology product” needs to be defined. It should be mentioned that the terms “product” and “production” have previously been defined in the System of National Accounts (SNA) by UN.[30] In addition, OECD and EuroStat in *Guidelines for Collecting and Interpreting Innovation Data (Oslo Manual)* categorized products innovation.[21]

C.2 Description of the term’s definition

United Nation’s System of National Account (SNA) defines “product” and “production” as follows.

“Products, inclusive of goods and services, are the result of production. They are exchanged and used for various purposes; as inputs in the production of other goods and services, as final consumption or for investment”.

“Production is an activity, carried out under the responsibility, control and management of an institutional unit that uses inputs of labour, capital, and goods and services to produce outputs of goods and services”.

NOTE According to SNA, paragraph 4.2, an institutional unit is an economic entity that is capable, in its own right, of owning assets, incurring liabilities and engaging in economic activities and in transactions with other entities.

It should be noted that according to the above mentioned definitions, a clear distinction should be made between goods and services in the field of nanotechnology. However, in almost all related publications, the term “nanotechnology product” is more common and regarded as equivalent to goods produced utilizing nanotechnology. Whereas here it is focused on goods, “nanotechnology services” needs to be defined separately.

In addition to nanomaterials (including engineered and manufactured) as primary nanotechnology products, depending on the effect of nanotechnology on the performance and functionalities of a product, two categories of nano-enhanced and nano-enabled products may be identified. This is in harmony with innovation perspective which has been elaborated in Oslo Manual[21] as follows:

“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.”

On the other hand, in a product value chain, different elements can be observed as materials, intermediate products and final product. The distinction of these elements leads to more transparency in development of the related indicators.

Overall, inclusion of the above mentioned categorizations in the definition of nanotechnology product provides enough options for measuring different indicators related to nanotechnology products.

It is worth mentioning that products which are produced in a process that uses nanotechnology but do not contain any nanoscale component should not be considered as nanotechnology products. Water purified by a nanofiltration system or petrol produced using nanocatalysts are two examples of such products.

Complex products like nanorobots and NEMS, of which all components or the main components are at nanoscale, are considered as nanotechnology products. In addition, electrical components like 30 nm chips which are composed of nanoscale components are also considered as nanotechnology products. However, for complex pre-existing products of which only some parts are nanotechnology products, e.g. cars which have nanostructured anti-stain glasses, the issue of double-counting should be considered.

Annex D
(informative)

Nanotechnology tool

D.1 General

"Nanotechnology tool" should be considered as an important term related to "industry" and "market" indicators. Considering the immense impact of such tools on the advancement of nanotechnology and their huge market, the definition of such a term is justified. It is worth mentioning that these tools are utilized in R&D activities as well as manufacturing nanomaterials.

D.2 Description of the term

Existing tools and instruments which are being used in nanotechnology related activities mainly are targeting two functions, namely analysis and production. Common tools for analysis function are described in D.3 and D.4.

D.3 Characterization and measurement tools

Tools used for reproducible measurements and determination of nanomaterial properties and characteristics with established accuracy and precision based on scientific grounds.

D.4 Simulation and modelling tools

Tools providing the possibility of prediction and assessment of nanoscale phenomena based on some scientific basis governing nanomaterial behaviours. Quantum-based software is an example of tools for the assessment of nanoscale phenomena which utilize molecular dynamics method.[8][16]

Tools used for production are elaborated as in D.4.1 and D.4.2.

D.4.1 Manipulation tools

Tools utilized for the manipulation of nanomaterial in laboratory/industrial scale based on reproducible/controllable and reliable process.

D.4.2 Manufacturing tools

Tools used to manufacture different types of nanotechnology products based on reproducible/controllable and reliable process.

Figure D.1 highlights categorization of nanotechnology tools.

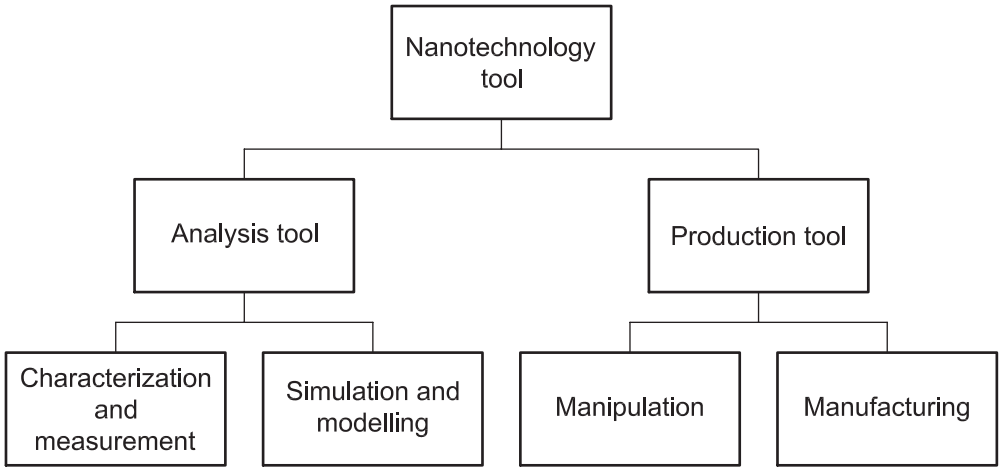


Figure D.1 — Classification of nanotechnology tools

Some relevant tools are demonstrated in Table D.1.

Table D.1 — Examples of different categories of Nanotechnology Tools

Category	Examples
Characterization and measurement tools	Scanning Probe Microscope (SPM), Electron Microscopes (EM), Surface Area Measurement tools (e.g. BET), Dynamic Light Scattering (DLS), X-ray Photoelectron Spectroscopy (XPS)
Manipulation and manufacturing tools	Nanomanipulator, Focused Ion Beam (FIB), Nanolithography Instruments e.g. Electron Beam Lithography), Molecular Beam Epitaxy (MBE), Atomic Layer deposition (ALD), Deep Reactive Ion Etching (DRIE), Physical Vapour Deposition Instruments, Electrospinning,
Modelling and simulation tools	Quantum mechanical tools such as CASTEP and DMOL, …

Generally, tools are not exclusively built to study or measure nanoscale phenomena and properties or nanomanufacturing, so we have to consider all tools that can be used for studying, measuring or manufacturing at nanoscale, while such tools are used for larger scales as well.

It should be added that in many texts and documents, the term "nanodevice" has been used. It is useful to clarify the distinction between the term "nanodevice" and "nanotechnology tool" to prevent any probable confusion. A "nanodevice" is a nanoscale part or machine capable of performing a certain function. [1] Nanosensors, nanorobots and NEMS are examples of nanodevices. According to the definition and categorization of nanotechnology products introduced in 3.5 and Annex C, nanodevices are considered as nanotechnology products, not as nanotechnology tools. Some categories of nanodevices accompanied by nanosystems are mentioned in ISO/TR 12802 without trying to define them.

Annex E
(informative)

Nanotechnology enterprise

E.1 General

Many economic indicators related to industry and market measure the number and economic effects of institutional units, so it is necessary to identify the active institutional units in a specific area. The following examples show some indicators in different sources:

— number of new businesses registered[35]

— number of biotechnology firms[26]

— population of active enterprises[7]

— share of parent companies in R&D expenditure and the number of researchers.[22]

In the area of nanotechnology some indicators related to the quantity, job creation and market volume of enterprises are reported. A comprehensive and standardized definition is essential for analysing and comparing the statistical reports. On the other hand, the multidisciplinary nature and the diffusion of nanotechnology in various industrial sectors demand to have transparent criteria to distinguish nanotechnology enterprises. In other words, it should be clarified whether an enterprise producing or using a nanotechnology product or a nanotechnology service could be considered as a nanotechnology enterprise. How can an enterprise in the field of cosmetics or the automotive industry which is applying nanotechnology in one or a few of its products also be identified as a nanotechnology enterprise?

Generally speaking, various terms such as company, firm, enterprise, corporation and business are used in different statistical resources. Considering the definition and application of the term "enterprise" in OECD, SNA, ISIC, Eurostat, and also considering common usage of this term in business-related indicators like small and medium-sized enterprises,[4] in this Technical Specification the term "enterprise" is used. Table E.1 shows the definition of this term in some sources.

Table E.1 — The definition of "enterprise" in different sources

Definition	Source
The enterprise is the smallest combination of legal units that is an organizational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more locations. An enterprise may be a sole legal unit.	Reference[5]
An institutional unit in its capacity as a producer of goods and services is known as an enterprise. An enterprise is an economic transactor with autonomy in respect of financial and investment decision-making, as well as authority and responsibility for allocating resources for the production of goods and services. It may be engaged in one or more productive activities. An enterprise may be a corporation (or quasi-corporation), a non-profit institution or an unincorporated enterprise.	Reference[31]
An enterprise is an institutional unit in its capacity as a producer of goods and services; an enterprise may be a corporation, a quasi- corporation, a non-profit institution, or an unincorporated enterprise.	Reference[30]

Table E.1 shows that all definitions emphasize goods or services production. Nanotechnology products and nanotechnology tools are goods in the field of nanotechnology.

It should be mentioned that enterprises utilizing a nanotechnology product or service are not necessarily themselves considered as a nanotechnology enterprise. Also it is worth mentioning that

some nanotechnology enterprises could be considered as dedicated nanotechnology enterprises. In these enterprises, nanotechnology is the principal activity while there are many enterprises that have just a part of activities related to nanotechnology. This is a distinguishing criterion that clarifies the statistical data gathered for nanotechnology enterprises. Table E.2 shows some examples of nanotechnology enterprises in terms of the type of activity.

Table E.2 — Examples of "nanotechnology enterprise"

Type of activity	Examples
Production of a nanotechnology product	• Manufacturing nanomaterials • Producing antibacterial textiles
Production of a nanotechnology tool	• AFM Production • Electrospinning instrument production for producing nanofiltration systems
Performance of R&D in the field of nanotechnology	• An enterprise that develops nanotechnologies and transfer to industry • Developing a nanotechnology product/process
Provision of a nanotechnology service	• Maintenance and repair services • Technical consultancy • An enterprise that designs and establishes a production line for nanomaterial

In this definition, some terms are taken from internationally accepted sources; for instance, "principal activity" and other related terms have been defined in ISIC (Table E.3).

Table E.3 — The ISIC definitions of "principal activity", "secondary activity" and "ancillary activities"[31]

Principal activity	In ISIC, the expression "activity" is used to identify productive activities. The principal activity of an economic entity is the activity that contributes most to the value added of the entity. It is not necessary that the principal activity account for 50 per cent or more of the total value added of an entity or even that its generated value added exceed that of all other activities carried out by the unit, although in practice it will do so in the majority of cases. Products resulting from a principal activity are either principal products or by-products.
Secondary activity	A secondary activity is each separate activity that produces products eventually for third parties and that is not the principal activity of the entity in question. The outputs of secondary activities are secondary products. Most economic entities produce at least some secondary products.
Ancillary activities	Principal and secondary activities cannot be carried out without the support of a number of ancillary activities, such as bookkeeping, transportation, storage, purchasing, sales promotion, cleaning, repair and maintenance, security etc. At least some of these activities are found in every economic entity. Thus, ancillary activities are those that are undertaken to support the main productive activities of an entity by providing goods or services entirely or primarily for the use of that entity.

Annex F
(informative)

Nanotechnology service

F.1 General

As a credible source, SNA defines and describes service as follows:[30]

“Services are the result of a production activity that changes the conditions of the consuming units, or facilitates the exchange of products or financial assets.

These types of service may be described as change-effecting services and margin services respectively. Change-effecting services are not separate entities over which ownership rights can be established. They cannot be traded separately from their production. By the time their production is completed, they must have been provided to the consumers.

The changes that consumers of services engage the producers to bring about can take a variety of different forms as follows:

a) changes in the condition of the consumer’s goods like transporting, cleaning, repairing or otherwise transforming them;

b) changes in the physical condition of persons like medical or surgical treatments, etc.;

c) changes in the mental condition of persons with education, information, advice, entertainment or similar services in a face to face manner.

In general, the changes may be presumed to be improvements, as services are produced at the demand of the consumers. Such improvements cannot be held in inventories by the producer or traded separately from their production.

Margin services result when one institutional unit facilitates the change of ownership of goods, knowledge-capturing products, some services or financial assets between two other institutional units.”

As new sciences and technologies emerge, new services are also developed based on new methods and applications which are substantially different to previous technical and general services. Moreover, for provision of these services, new technical processes are used or a minimum level of speciality in that technology is required. As an example DNA/RNA sequencing can be mentioned which is a new technical service based on biotechnology.

Several descriptions have been provided for the term technical or technological service in various documents. For instance, the term “Scientific and Technological Services” has been mentioned in a document published by UNESCO in 1984.[29] As another example, OECD in “A Framework for Biotechnology Statistics” refers to firms specialized in biotechnology services as follows:[23]

“Those services firms that use process biotechnology techniques for the purpose of providing a service, for example, waste management or environmental remediation firms.”

F.2 Description of the term

Likewise, parallel to development of nanoscience and nanotechnology, new services based on nanotechnology-related knowledge or processes are developed which can be categorized in two groups:

a) those business to business or business to customer services which make changes to goods by nanomanufacturing processes e.g. nanoscale coating on a drill bit as a service;

b) those services which do not use any nanotechnology-related processes but their provider needs a level of expertise in nanoscience and nanotechnology e.g. installing or repairing AFM cantilever, providing technical consultancy to a nanomaterial producer for controlling size distribution or designing a nanosilica production line.

It is worth mentioning that using nanomanufacturing process in a producer's own production line cannot be considered as a service. In addition, nanotechnology enterprise needed services such as management consultancy, financing, training, marketing, trading, and so forth which do not require nanoscience and nanotechnology expertise would not be considered as nanotechnology services.

Annex G
(informative)

Nanotechnology market

G.1 General

Nanotechnology market features can be considered as important indicators for evaluating the economic impacts of nanotechnology. Market forecast and assessment are two activities aiming at operationalizing this concept. Market forecasts were initiated from the emergence of nanotechnology. For the first time, in 2001, US NSF predicted a market volume of over USD 1 billion for 2015.[18] There was also a study in 2007 projecting a market size of USD 1,5 billion and USD 2,95 billion for 2015, excluding and including electronics and semiconductors respectively.[2] This level of variance in statistics seen in the mentioned examples is rooted in the lack of an international standard definition for "nanotechnology market" while it may also be affected by other factors such as sources of information, methodologies, etc. In a similar manner, inconsistent definitions can lead to undesirable statistical variances in market assessments.

G.2 Description of the term

Similar to several other sources, the "Glossary of Industrial Organisation Economics and Competition Law"[19] defines market as follows:

"A market is where buyers and sellers transact business for the exchange of particular goods and services and where the prices for these goods and services tend towards equality.... Markets may be local, regional, national or international in scope and do not necessarily require buyers and sellers to meet or communicate directly with each other. Business may be transacted through the use of intermediaries as well.

...There are two fundamental dimensions of market definition: (i) the product market, that is, which products to group together and (ii) the geographic market, that is, which geographic areas to group together. ... Market definition generally includes actual and potential sellers, that is, firms that can rapidly alter their production processes to supply substitute products if the price so warrants..."

Generally, in market analysis various indicators are used. Among them, the size of the market is the most important indicator which has been implied by terms such as sales, revenue, market volume market share and market size in different reports and sources. The level of analysis for market size estimation could be at a product, a service, a firm, a sector or a geographic region. It is worth mentioning that the market size can be measured by value or by number. To name a few examples, "the market share of main electricity suppliers"[6] and "share of mobile revenue in total telecommunication revenue"[27] are used as indicators in electricity and telecommunication markets respectively. "Sales by biotechnology firms" is another indicator for the biotechnology market which has been reported in OECD documents.[25]

Market by definition is a place for exchange and sale of goods and services. Variety of goods and services which can be related to the field of nanotechnology makes it viable to define a distinctive market. In this field, products, services, tools and R&D outputs can be supplied and exchanged. R&D outputs can be a service or a good in nature depending on the way it affects buyers' business. By defining "nanotechnology market" it would be possible to measure markets of goods, services, tools and R&D activities totally or individually.

Annex H
(informative)

Alphabetical index

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