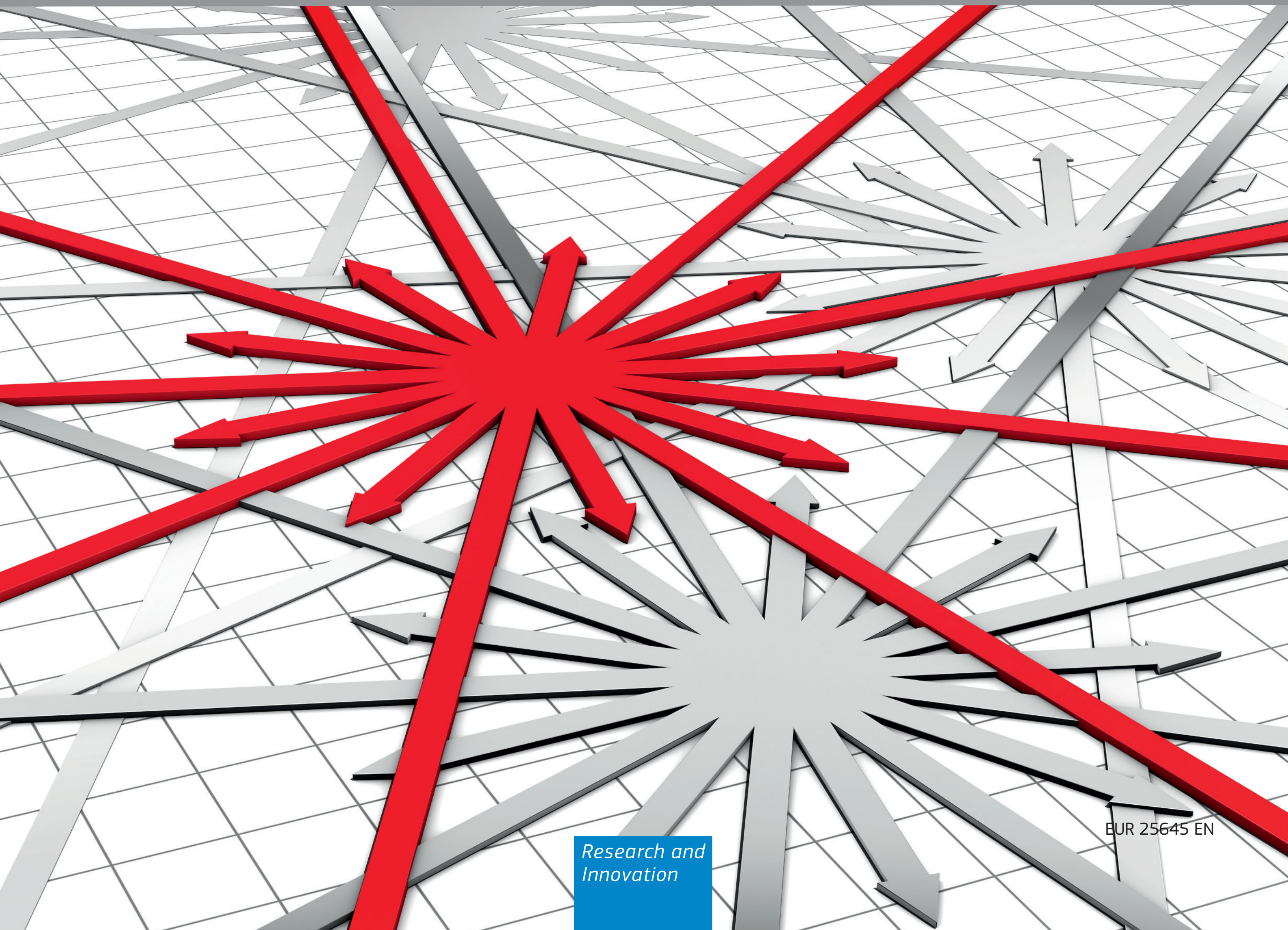
European Commission

Nanometrics

A Technometric and Socio-Economic Analysis System to Support the Development of the European Nanotechnology Strategy Options

Part I: Monitoring System



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NANOMETRICS

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Part I: Monitoring System

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LIST OF ABBREVIATIONS

CIP	Competitiveness and Innovation Framework Programme
COSME	Programme for the Competitiveness of enterprises and SMEs
EHS	Environment, health, and safety
EC	European Commission
EU	European Union
FP7	EU's 7th Framework Programme for Research, Technological Development and Demonstration 2007-2013
Horizon 2020	The EU Framework Programme for Research and Innovation 2014-2020
NACE	Statistical Classification of Economic Activities in the European Community
NMP	Nanoscience, Nanotechnologies, Materials and New production Technologies
NST	Nanoscience and technology
OECD	The Organisation for Economic Co-operation and Development
R&D	Research and development
STI	Science, technology and Innovation
US	The United States
WoS	Web of Science

1. INTRODUCTION

There is discrepancy between, on the one hand, a strong policy dedication to Nanoscience and technology (NST) ([1]) research and development (R&D) investments and, on the other hand, a lack of indicators and data. This situation is paradoxical in view of an increasing emphasis on evidence-based policies. The absence of reliable indicators and monitoring systems will complicate the monitoring of the recent developments within NST and make it more difficult to identify and nurture emerging research and commercially promising innovation trajectories.

The lack of reliable indicators will also make it harder to assess the impacts of R&D investments and can become a barrier for proactive policy-making and organisational and institutional adaptation; e.g. the development of human and other resources, facilitation of technology transfer, environment, health, and safety (EHS) standards and other regulations to support the industrial uptake and diffusion of NST.

The European Union (EU) ([2]) and the OECD have undertaken numerous studies which provide valuable information. However, one shortcoming of these studies is their one-off nature which limits their usability for continual monitoring of developments. Further, indicators used in these studies mainly point to differences in activity levels across countries and regions while falling short of analysing underlying dynamics in science, technology and innovation (S&T&I) and of indicating in which applications fields R&D investments are having most impacts.

One of the main problems in the indicator work, related to NST is the lack of commonly agreed definitions of nanotechnology as well as methodologies for data collection, which could level the playing field for future data collection on a continual basis. The OECD has taken an initiative to develop a framework for NST indicators and statistics. However this work is still unfinished and therefore the situation without standardised and harmonised definitions and data collection methods still exists. ([3]).

At the same time the European Commission (EC) has a pressing need for reliable indicators to enable it to monitor the development of NST and impact of policies related to NST ([4]). The EC has observed that there are a number of factors which may cause Europe to fall short of meeting its goals for NST; these include barriers to commercialisation, shortages of industrial and venture capital investment, and concerns about the environment, health and safety issues ([5]).

This report is organised as follows. In the second chapter a short introduction to the work on nanotechnologies is presented and discussed. In the third chapter a general proposed monitoring frameworks is presented. The individual monitoring areas as well as individual indicators are presented in chapters four to seven. For each proposed indicator, a short indicator fiche is presented, describing the key issues related to the indicator. Also examples of data collection, use and analysis are shown for each indicator. In the final chapters specific methodological issues concerning the data collection and analysis are discussed.

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[1] NST typically refers to research, development and manufacturing at the atomic, molecular or macromolecular levels, in the length scale of approximately 1-100 nanometers. Nanotechnologies cover a wide range of scientific fields from chemistry, physics and biology to medicine, engineering and electronics. As a result several different (and often overlapping) sub-categories can be identified, such as nanomaterials; nanometrology; electronics, optoelectronics and information and communication technology; bio-nanotechnology; nanomedicine; nanotools, nanoinstruments; nanodevices etc. In this way our approach is much broader than e.g. the recent definition of nanomaterials proposed in the EC recommendation (2011/696/EU).

[2] e.g. EURONANO: Nanotechnology in Europe and studies undertaken by ObservatoryNANO and Nanoforum

[3] According to our sources the OECD project on "Statistical Framework for Nanotechnology" has developed quite slow. The latest information from the OECD WPN is that the project is currently on hold.

[4] Nanotechnologies are one of the Key Enabling Technologies that receive specific attention under Horizon 2020.

[5] See e.g. OECD (2010): The Impacts of Nanotechnology on Companies; Friedrichs S. & Schulte (2007): Environmental, health and safety aspects of nanotechnology— implications for the R&D in (small) companies.

2. THE STUDY OF RELIABLE INDICATORS

Previous studies ([6]) indicate that the field of nanotechnology indicators is sporadic and the list of reliable indicators rather small. The situation has not changed radically from 2006 when Angela Hullmann noted in her study ([7]) about economic indicators in nanotechnology that "*Empirical analyses of nanotechnology have to suffer from the limited access to reliable and comparable data and its complex nature*" and that "*official statistics do not identify nanotechnologies at all, or link it to various different categories where it cannot be identified correctly, or the definition is at least questionable*". There still is a need to gather data on nanotechnology activities since all typical data used to analyse research, development and commercialisation activities in established industries is not widely available for NST. On top of that, some trade-offs need to be made in terms of data reliability and consistency.

The most complete studies in measuring the impact of nanotechnologies by public organisations are the EC study by Hullmann (2006) and further updates by the EC and the work carried out by the OECD Working Party for Nanotechnology (WPN).

At OECD, a review of nanotechnology developments based on indicators and statistics was prepared in 2008 and published e.g. in the report "*Nanotechnology: An Overview Based on Indicators and Statistics*" (OECD, 2009). It is the most complete review of nanotechnology development in science and industry and gives an insight in the indicators that were available in 2008. The review incorporates information about the evolution of nanotechnologies, highlights current definitions of nanotechnology, and assesses the significance of nanotechnologies from expected socio-economic impacts as seen in market and job forecasts, company activity and emerging products. The report also uses investment data to review the volume, nature and distribution of R&D activities and employs publication and patent data in tracing developments over time, across technologies and countries and patents to monitor developments across nanotechnology sub-areas and application fields. On top of this, it assesses the position and specialisation of countries. It also reports company survey findings indicating how companies are addressing nanotechnologies and some of the challenges they are experiencing. The OECD project was mostly based on available statistics and indicator data from public sources.

The OECD Working Party on Nanotechnology (WPN) has also collected some further information on nanotechnology national policy development as well as available national indicators (OECD, 2008). From the point of view of the Nanometrics project, the nanotechnology policy study is especially interesting since it contains a policy survey that also includes questions on public R&D funding and human resources. A modified version of this survey has been used as a template for collecting data on public investments in the Nanometrics monitoring system

Various individual projects have also gathered data on nanotechnology activities, such as EURONANO (Nanotechnology in Europe) ([8]) and ObservatoryNano ([9]). These projects provide a good source for studying data collection related to NST activities. However, the information provided by those projects is mostly not usable for the proposed NST monitoring system since they do not cover all sectors or all countries and are one-off exercises.

There is also work carried out by researchers to study nanotechnologies and particularly nanosciences. Several studies have been carried out by various research teams and progress has been made especially in the use of bibliometrics and patent data ([10]).

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[6] See e.g. OECD (2009) Nanotechnology: an overview based on indicators and statistics; Sargent (2008) Nanotechnology and U.S. Competitiveness: Issues and Options; OECD (2007) Science, Technology and Innovation Indicators in a Changing World.

[7] Hullmann (2006) The economic development of nanotechnology – An indicator based analysis.

[8] Meyer et. al. (2008) Nanotechnology in Europe: assessment of the current state, opportunities, challenges and socio-economic impact.

[9] http://www.observatorynano.eu/

[10] E.g. Bassecoulard et. al. (2007) Mapping nanosciences by citation flows: A preliminary analysis; Leydesdorff & Zhou (2008) Nanotechnology as a field of science: Its delineation in terms of journals and patents; Dang et. al. (2010) Trends in worldwide nanotechnology patent applications: 1991 to 2008. Motoyama & Eisler (2011) Bibliometry and Nanotechnology: A Meta Analysis.

Typical STI-indicator sets are heavily biased towards input indicators (R&D funding, human resources etc.), since there is much information available on these issues and these can be fairly easily analysed based on commonly agreed definitions of the indicators. However, in NST the situation is even more problematic as many of the traditional statistical indicators do not differentiate NST. The reasons are many. NST does not fall in any one existing scientific or sectoral classification, such as the Statistical Classification of Economic Activities in the European Community (NACE), and at the same time the use of NST is sometimes difficult to differentiate since, being an enabling technology, the use of nanotechnology is embedded in products and manufacturing processes. Therefore the R&D information on nano has to be collected from many sources and as a result the compatibility of data is questionable ([11]).

The publication and citation databases are widely used for analysing nanotechnology research. Although the currently popular databases, such as Web of Science ([12]) and Scopus ([13]), favour publications published in English, they nevertheless give a good and fairly reliable picture of NST research activity.

In terms of patents, Eurostat has introduced a tagging system as a tool for identifying nanotechnology patents ([14]). This tagging is further divided to six sub-classes according to technology and/or applications. Additional data can also be collected from widely used patent databases, such as PATSTAT ([15]).

Based on the experience of the previous studies ([16]) using an indicator based approach to nanotechnology developments, it can be concluded that the only genuinely reliable indicators with the EU-level coverage are publications and patents. However, publications and patents only cover a part of the value chains in nanotechnologies. The EC faces an equally important need for information of other aspects of NST, such as nanotechnologies' contribution to growth and jobs and to the societal challenges that Europe is facing today. Therefore other indicators are also needed, even though from a purely statistical point of view, a more careful approach might be needed in their analysis due to the fact that there may be some compromises in the definition of the indicators or data collection. The set of indicators with satisfactory reliability is presented in the next chapter that describes the tentative monitoring system for NST.

[11] Hullmann (2006)
[12] http://thomsonreuters.com/products_services/science/science_products/a-z/web_of_science/
[13] http://www.scopus.com/home.url
[14] Eurostat (2010) Science, technology and innovation in Europe.
[15] http://www.epo.org/searching/subscription/raw/product-14-24.html
[16] Hullmann (2006); OECD (2009)

3. DESCRIPTION OF THE MONITORING SYSTEM

The proposed Nanometrics monitoring system consists of four different areas, which are commonly used in the STI evaluation frameworks. These include inputs, activities, outputs and outcomes/impact.

In our approach, the impact of NST is limited to mainly economic impact of nanotechnology research and commercialisation ([17]) (as opposed to e.g. environmental impact).

The monitoring system focuses on developing a few indicators which are relevant and comparable across time and countries, and which are suited for continuous monitoring in real time. The

system aims to be a dynamic entity, where new indicators can be added whenever relevant or mature and existing ones can be left out when no longer relevant. The monitoring system related to NST research and commercialisation is described in the Figure 1 below.

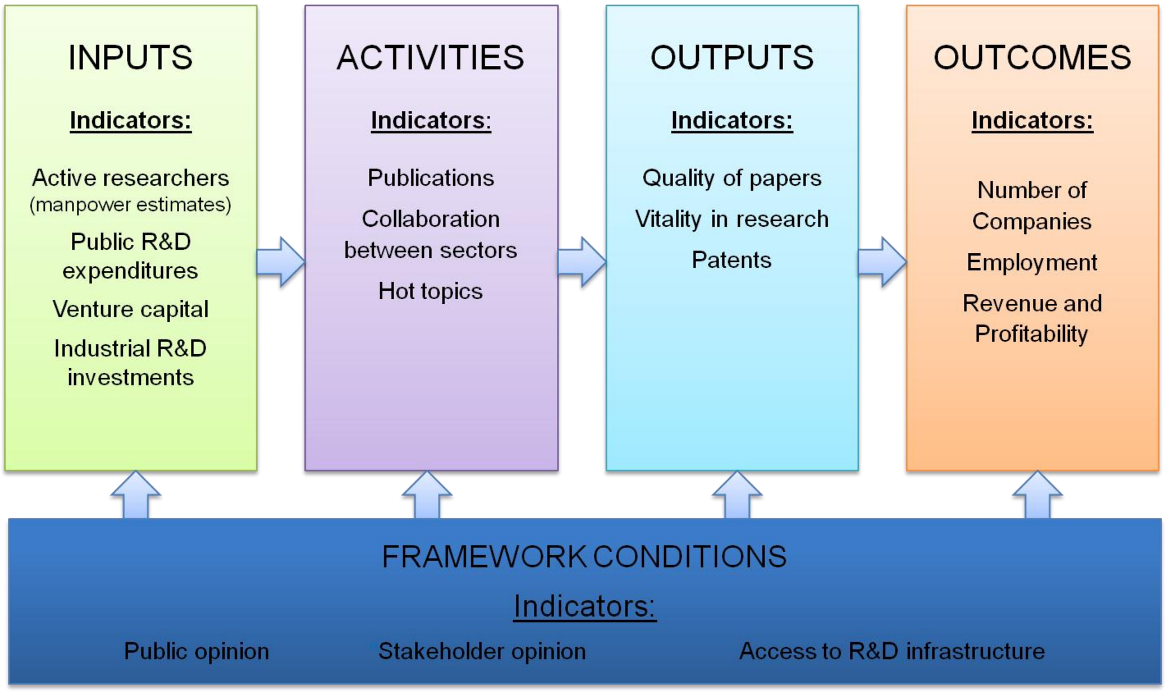

Figure 1. Description of the NST research and commercialisation monitoring system

The proposed indicators for the monitoring system are presented in Chapters 4-7. A description of the indicator template elements is presented in Supplement 1.

The final monitoring system is the result of an assessment of several indicators. Only a part of the original list of indicators has ended up in the final framework. The list of other potential indicators that were not included in the framework is presented in the Supplement 4.

[17] The approach is based on the project objectives to analyse and synthesise data to a policy relevant monitoring system of indicators related to nanotechnology research activities, products, businesses and markets from scientific and economic viewpoint.

4. INPUT INDICATORS

The inputs for R&D typically cover people, information, ideas, equipment and funds needed for research, development and innovation activities. R&D investments are a very good input proxy for nanotechnology since it is a science-driven field. Traditional statistics on R&D investments do not cover incremental or non-technological innovations but this problem is less problematic in NST than in some other fields, since the field of NST is relatively science-driven compared with many other industries, such as machinery.

For the input indicators, the main problem is not the definition of the right indicators but the lack of nanotechnology-related data available for these indicators. General R&D data is widely available and primarily collected by official national statistical agencies based on indicators, methodologies and model questions proposed by the OECD Frascati Manuals. The national agencies conduct surveys that extend to both companies and public sector organisations. Results from these surveys enable breakdowns by source and performance, also at the sectoral level (e.g. product groups and industries).

Readily available data on nanotechnology R&D expenditures is problematic since nanotechnologies lack a jointly agreed statistical definition. The lack of definition means that nanotechnology related data is not widely collected. The lack of dedicated questions on NST in official surveys implies that indicators and data on R&D expenditures or investments are not readily available for all countries concerned. For public R&D investments, information can be synthesised at national level based on reports and publications which contain data on the volume on NST programmes and initiatives. However, these data will not be comparable across countries in a strict sense due to the different definitions of NST that are used ([18]). Further, NST may also be funded outside dedicated programmes and initiatives. Finally, some countries may not use the NST label at all in their funding schemes while many schemes may only be identifiable at the provincial/regional/local level in countries.

For private sector R&D investments, the lack of data is even clearer. Currently some consultancies (e.g. LuxResearch) provide this information, based on proprietary data. However, it is not always clear which methodologies have been used and how reliable they are. Much of this information is based on qualitative interviews, the findings of which have been extrapolated to sectoral and country level. While valuable in its own right, this type of data will not lend itself to a monitoring system which should provide continuous and real time information.

Given the poor availability of input data on nanotechnologies related R&D investments, it was finally concluded that the use of survey instruments needs to be continued to feed the Nanometrics monitoring system.

For the public funding of NST R&D, the Nanotechnologies Unit of the Directorate General for Research & Innovation (European Commission) has conducted a policy survey of public funding of nanotechnologies in Member and Associated States in 2007 and 2009. Also funding information related to the Framework Programmes and other relevant programmes and schemes have been collected. Apart from the EC sources, this data has been obtained from the Member and Associated States themselves. This methodology will be continued to collect this type of data.

In the industrial survey, companies will be asked how much they are currently investing in NST R&D and what rate of increase/decrease they anticipate over the next five years. The data from this industrial survey will also be used for the indicators on outcomes (see chapter 7)

There is also a need for indicators that can estimate the amount of "manpower" per country, i.e. the number of personnel dedicated to nanotech research. The R&D personnel working with NST is again a difficult topic to cover with traditional indicators systems. The statistics on *Human Resources for Science & Technology (HRST)* and the *number of Researchers ([19])* do not allow the

[18] For a summary of different definitions of NST see OECD (2009) Nanotechnology: an overview based on indicators and statistics.
[19] See Eurostat

differentiation of nanotechnology related sectors even if we could agree on the definitions (e.g. industry classifications, fields).

It is, however, possible to use the above mentioned more general (i.e. not NST specific) indicators as a proxy of "potential" human resources capable of participating in nanotechnology research. In the same way it might be possible to use R&D personnel data collected in other projects such as the NMP Scoreboard. A third approach could be collecting human resources information through the policy survey, collecting data on public R&D funding. A fourth, more novel way to approach this is to search for NST researchers through publications. A methodology for manpower estimation using publication data was introduced during 1980s by the so-called 'Budapest team'[20]. The theory is elegant, although theoretically advanced, and uses the distribution of publications over published authors to estimate the full set of "potential authors", including those who have not published during the given time period. While *number of papers* is a product of manpower and productivity, manpower estimates only adjust the publication number and account for differences in productivity. Since countries can be expected to have different publication productivity, the number of published papers will not give a comparable estimate of the countries manpower. However, with the use of the statistical methods proposed by the Budapest team, this is made possible. This is basically the methodology that will be used in the Nanometrics monitoring system as well.

4.1 Public funding for nanotechnology R&D

4.1.1 Description of the Indicator

Public funding for nanotechnology R&D	
Type	Quantitative input indicator
Description	Public R&D expenditure (together with private investments) is the single most important indicator measuring the financial inputs dedicated to NST research and development. It shows the emphasis of public policy to NST. The indicator measures the financial investments in nanotechnologies by the public sector. It estimates the public R&D funding based on the funding data obtained from the EU funding instruments as well as from national sources.
Policy relevance	It is important to have a clear view on public R&D investments so that policymakers can estimate the results compared to the investments i.e. value for money as well as if the level of investments are sufficient compared with the possibilities offered by NST as well as to benchmark the emphasis on NST compared to other countries and regions. The indicator is easy to understand and policymakers are familiar with it.
Variables	Single indicator
Source of data (and identification of needs for new/better data generation)	Funding data (EU and national funding instruments) collected from various sources (EC officials working with Framework Programmes as well as national contact points) through a web survey (more detailed information on data collection described in the section below)
Methodology for the compilation of the reliable indicator	• Further elaborating and validating the survey questionnaire by the Commission staff (the proposed questionnaire is presented in Supplement 2).

[20] Braun, T., W. Glänzel and A. Schubert (1990)

	• Updating the list of contacts in Member and Associated States and in the Commission for data collection. This includes:
	    ○ Updating the list of respondents in the Commission responsible for various instruments in FP7 (later Horizon 2020)
	    ○ Updating list of respondents in other European instruments (ERC, CIP (later COSME))
	    ○ Updating the list of national respondents (national contact points)
	    ○ Compiling a list of respondents
	
	• Preparing a web-based survey (using an web survey tool ([21]))
	    ○ Forwarding information to the respondents
	    ○ Publishing the survey
	    ○ Follow-up-contacting to make sure that information is received
	    ○ Collecting the data
	
	• Analysing the data
	    ○ Analysing the information from each country (with comments on the data availability and reported potential challenges with the data reliability). The result will be a spread sheet with summary information
	    ○ Analysing the information from the EU funding instruments.
	    ○ Compiling data with additional information to a spread sheet
	
	• Reporting the data

Scope and coverage	EU, Member States and Associated States
Unit	Euro
Data-update interval	Suggestion is to collect data on an annual basis. Since most of the funding instruments last for 3 to 7 years, annual averages are used to estimate the volume of funding for these instruments
Interpretation of the data	We get information of the absolute investments and the relative share of investments in NST. We also get the data on the EU funding for nanotechnology. Since the data is based on an estimate (with some margin of error) the data should be used as an indication of investments and not a definite figure. As the funding may fluctuate annually (e.g. individual calls for applications) it may bay safe to use the average of at least 2-3 years when looking at the long term developments of public funding.

[21] There are several web survey tools available. See e.g. the Interactive Policy Making (IPM) of the EC (http://ec.europa.eu/ipg/services/interactive_services/surveys/index_en.htm)

Pitfalls in interpretation	Lack of consistent definitions of NST and challenges in extracting funding data on NST from the research programme funding data may cause some inaccuracies in the results.
Rating: complexity[22]	2
Rating: labour intensity / cost	4 (to set up) 2 (to repeat)
Estimated resources to collect and analyse data	Policy survey, duration two months: 2 man-days to design the survey (1st round) + 3 man-days of work to identify the survey respondents + 2 man-days of work for analysis and reporting.
Overall assessment	Very important although labour intensive and dependant on the quality of survey data. Caution is needed to interpret the data since it may not be complete and depend on the quality of the primary data sources.

4.1.2 Example of using the indicator

This section gives an example of using the indicator and presenting the information with a sample real world data. Below is an example of public nanotechnologies R&D funding based on the 2004 data ([23])

Table 1. Estimated funding for nanotechnology R&D in 2004.

Country	Funding (€ m)	Country	Funding (€ m)
Austria	13.1	Portugal	0.5
Belgium	60.0	Slovenia	0.5
Bulgaria	--	Romania	3.1
Czech Republic	0.4	Spain	12.5
Denmark	8.6	Sweden	15.0
Finland	14.5	United Kingdom	133.0
France	223.9	EU-25 Total	915
Germany	293.1		
Greece	1.2	EC	370
Ireland	33.0	Total EU and MS	1288
Italy	60.0		
Latvia	0.2	Russia	-
Lithuania	1.0	P R China	83.3
Luxembourg	0.8	South Korea	173.3
Netherlands	42.3	Switzerland	18.5
Poland	1.0	USA	1243.3

4.2 Manpower estimates

4.2.1 Description of the Indicator

Manpower estimates	
Type	Quantitative input indicator
Description	This indicator estimates the number of researchers that

[22] See Supplement 1 for description of the rating.
[23] European Commission (2005): Some Figures about Nanotechnology R&D in Europe and Beyond.; OECD has more recent data but full data covering all EU member states is not available at the moment.

	could potentially publish nanotechnology research papers.
Policy relevance	From the policy perspective actual manpower devoted to NST is more interesting than the number of publications. Partly, because manpower is easier to translate into research budgets, partly because publication production figures differs between areas. This indicator provides identically measured manpower estimates for each country, all based on the same field delimitation. The estimates will therefore provide results which can be compared between countries (or other entities as regions or universities).
Variables	Publications per author in the data sample
Source of data (and identification of needs for new/better data generation)	Web of Science (WOS) or SCOPUS[24]
Methodology for the compilation of the reliable indicator	1) Compile all papers from each analysed country, published during selected years; 2) Harmonise and differentiate author names to indentify unique authors in the data set; 3) Determine number of papers per unique author; 4) Delimit and compile a set of nanotechnology devoted authors; 5) For each country, compile a nanotechnology author publication frequency distribution and use the distributions to estimate the "manpower" – i.e. the estimate number of nanotechnology researchers – by following the steps below[25]: Estimation procedure: a) Extract the stepwise left truncated sample mean: calculate the mean of the full country sample and then remove all one-frequencies (authors with one publication). Subsequently, calculate the one-truncated sample mean, the two-frequencies removed and so on. The result is a set of data points where the x-axis range from one (zero-truncated) to the maximum value of the distribution, and the y-axis present increasing values (the calculated means). b) Fit a straight line: Plot the data points and fit a straight line through the points using weighted least square regression. Use weights presented in Telcs et al. (1985). The intercept of the fitted line is an estimate of the mean of the non-truncated distribution c) Divide the total number of papers in the country sample with the estimated mean to get an estimate of "manpower". Note: we recommend not counting all authorships of the papers when determining the number of paper per unique

[24] Web of Science (WOS) or SCOPUS are database sources to which a subscription is needed. Cost is usually more than 50,000 Euro per year. E.g. see http://thomsonreuters.com/products_services/science/academic/

[25] See A. Telcs, W. Glänzel & A. Schubert (1985): Characterization and statistical test using truncated expectations for a class of skew distributions. Mathematical Social Sciences, 10, 2, 169-178.

	author, but instead to only count one randomly chosen author from each paper[26]
Scope and coverage	Global coverage. EU figures available from the WOS database or SCOPUS.
Unit	Researchers (actual and potential authors)
Data-update interval	Annually
Interpretation of the data	The metric is an estimate of the total number of researchers that could potentially publish nanotechnology research papers. A high number can be interpreted as high investments in NST. Comparability can be achieved by using country inhabitants as reference.
Pitfalls in interpretation	The estimates are to some extent uncertain as it is difficult to determine what exactly "a researcher that could potentially publish nanotechnology research papers" would include. Therefore, the estimates should primarily be used to show the relative differences between countries.
Rating: complexity	4
Rating: labour intensity / cost	4 (to set up) + 4 (to repeat)
Estimated resources to collect and analyse data	High, 2-3 man-days per country
Overall assessment	Although labour intensive, this indicator can provide important figures for comparisons between countries.

4.2.2 Example of using the indicator

The following example of using the indicator is applied to papers registered in Web of Science, published 2008-2010, with at least one address from Sweden, Norway, Finland or Denmark. Unique authors having nanotechnology related terms (Selection 2, as defined in chapter Bibliometric Indicators) in at least 1/3 of their papers have been selected as nanotechnology dedicated authors. The table below provides manpower estimates based on the publication frequency distributions of the selected authors from each Nordic country.

Table 2. Table A: Manpower estimates for the Nordic countries and related figures

	Inhabitants (million)	P	Frac P	Estimated P/Author	Potential Authors	Per mille
Denmark	5,6	1 797	1 081,5	0,936	1 156	0,228
Finland	5,4	1 851	1 185,7	0,992	1 195	0,203
Norway	4,9	851	507,7	0,927	548	0,112
Sweden	9,3	3 530	2 111,1	0,993	2 124	0,206

Note: P=number of papers, Frac P=fractionalised papers.
Source: Web of Science, 2008-2010 and Wikipedia for inhabitants per country.

Table 2 indicates that Norway has a lower investment in NST related research than the other Nordic countries. The number of NST active researchers per million inhabitants is only half of what is the figure for Sweden, Denmark and Finland. The potential author method gives an indication of the number of researchers that are working in the area, and from that it is possible

[26] See Koski, Sandström & Sandström, Estimating Research Productivity from a Zero-Truncated Distribution, ISSI 2011

to draw a conclusion about the amount of resources spent on NST research. Standard error estimates and confidence intervals can be obtained using bootstrap procedures.[27]
The differences in productivity between Denmark, Finland, Norway and Sweden are small – as can be expected for countries where the scientific infrastructure and the relations of production are rather homogenous. If we were to include other European countries we would probably find another pattern of productivity differences between countries. In effect, the relative differences between the countries' activity indicators (P and Frac P), on the one hand, and the manpower estimates (Potential Authors), on the other hand, would also be greater. Under such circumstances, the importance of the Potential Author estimates would increase, since the activity indicators cannot be used as proxies for the countries' relative manpower volumes (which may, as Table 2 indicate, be the case when comparing Denmark, Finland, Norway and Sweden).

The Per mille values of Table 2 indicate that Norway has a relatively low investment in NST. The same result has earlier been presented by Unit G4 Nanosciences and Nanotechnologies in 2004,[28] and is also underlined by the analysis of the Research Council of Norway (RCN) in their report on NST.[29]

4.3 Venture Capital

4.3.1 Description of the Indicator

Venture Capital Investments in Nanotechnology	
Type	Quantitative input indicator
Description	This indicator measures the total number and value of capital investments made into nanotechnology firms. This indicates both the availability of investment to help companies develop or expand and the extent to which investors view the attractiveness of nanotechnology. The overall level of venture capital investment is derived by the total of individual investments. For each investment it will be possible to derive the date, amount, investors, and the demographic data about the company receiving the investment.
Policy relevance	The Innovation Union Communication ([30]) identifies difficulties in accessing risk capital as a major barrier to innovation in Europe. Tracking the level of venture capital investment will indicate to what extent this barrier exists for nanotechnologies.
Variables	The value of nanotechnology Venture Capital Investments
Source of data (and identification of needs for new/better data generation)	Sources of data include companies themselves via a survey. In the longer term, the European Venture Capital Association (EVCA) may also be a source of data, although it does not currently define nanotechnologies as an investment sector in its surveys.
Methodology for the compilation of the reliable indicator	In the short term, the venture capital indicator would be developed using data from the companies themselves. The company survey can be used to ask companies whether they have received investment, and for amounts and dates. This is likely to capture more data than using other sources monitoring alone, as some deals may not be disclosed at the time that they are completed. This question would be asked in the

[27] Koski, T., Sandström, E. & Sandström, U. (2011) Estimating Research Productivity from a Zero-Truncated Distribution. Paper to the ISSI 2011 Conference in Durban, South Africa
[28] European Commission, Some figures about Nanotechnology R&D in Europe and Beyond, 2005. [N.B! put this into the reference section]
[29] Forskningsrådet, Programplan 2007-2016 NANOMAT. Oslo, 2007.
[30] European Commission (2010), http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=keydocs

	following way: • Has your company received venture capital investment within the last five years? • If you have answered yes to the previous question, please indicate the amount and date of investment? Gathering and analysing this data would not require additional time beyond that required to conduct and analyse the survey. In the longer term, the EC could partner with the European Venture Capital Association (EVCA) to gather this data. EVCA carries out quarterly surveys[31] of its members in an effort to track venture capital in Europe. The survey covers deal size, stage and industry sector, but does not include specific technology areas. This data is released publicly in an aggregate form. A long term solution to the challenge of monitoring venture capital investment would be to ask EVCA to include a question in their survey about the key enabling technologies used by each company receiving investment: data about Nanotechnologies, Micro- and nano-electronics, Photonics, Biotechnology, Advanced Materials and Advanced manufacturing systems could be collected with the same effort. This would need to be associated with some clear instructions for investors – who are likely to be non-technical - to help them determine which category their investment falls into.
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Data gathered from the company survey would provide data that could be broken down by country, sector, and investment round.
Unit	Euro invested per quarter
Data-update interval	Monitoring-based data can be collected on a quarterly basis, with an annual rebalancing based on information from the company survey
Interpretation of the data	Venture capital, defined here as capital investments into a firm in return for a share of equity, is an important indicator of the development stage of nanotechnology and its sub-sectors. Taken in isolation, increasing levels of venture capital investment would indicate that private investors have a more positive view of the sectors, with an expectation of high returns in the short to mid-term. Low levels or shortages of venture capital are an indication that the sector is not expected to provide returns which fit venture capital's investment criteria.
Pitfalls in interpretation	The overall amount does not in itself measure shortfalls in investment; this would need to be combined with an attitudinal question in the company survey.
Rating: complexity	Company survey method: 1 EVCA method: 1
Rating: labour intensity / cost	Company survey method: 3 EVCA method: 2 (but more difficult to set up)

[31] The survey is carried out for EVCA by PEREP Analytics, a non-commercial research firm supported by EVCA member organisations. The contact person at PEREP Analytics is Dan Magirescu, Statistics Manager, (dan.magirescu@perepanalytics.eu, +40-21-301.23.66).

Estimated resources to collect and analyse data	Company survey: approx. 3 man-days per quarter for data gathering and analysis. EVCA method: 5 days to establish, 2 days per quarter to analyse data.
Overall assessment	Venture capital investment is a strong indicator of the expectation of above average investment returns in the short and medium term. Increases in investment would indicate developments in the market readiness of nanotechnology. Given the importance of this indicator and the moderate level of difficulty involved in collecting data, this would be an important indicator to include.

4.4 Industrial Investment

4.4.1 Description of the Indicator

Industrial Investment	
Type of indicators	Quantitative input indicator
Description	This indicator measures industrial investment in nanotechnology-related R&D, product development or production facilities.
Policy relevance	The aim of increasing European investment in R&D to 3% of GDP requires public investment to leverage even larger amounts of private investment. This indicator measures the extent to which firms are investing in nanotechnology-related activities.
Variables	Investment in Euro at each technology readiness level
Source of data (and identification of needs for new/better data generation)	Overall data on industrial investment in R&D can often be obtained by looking at the annual reports of publicly listed companies. However for private companies, and particularly for obtaining a breakdown of spending on nanotechnology-specific activities, this can only be obtained by surveying companies directly.
Methodology for the compilation of the reliable indicator	This indicator will be obtained by including a question in the company survey (see survey methodology, chapter 10). This would be framed as “Please indicate your firm’s annual investment – expressed as a proportion of turnover- in nanotechnology-related activities at the relevant technology readiness levels”. Collecting the data in this ways presents two difficulties. Firstly, respondents may be unwilling to disclose this information as it would have some value to competitors – the information that a graphene producer is spending 10 million Euro on a production facility is likely to be of interest to rival firms. This must be overcome with strong confidentiality guarantees such as those included with the model survey. The second challenge is that individuals within the firm may not know the answer to this question – or they may know a partial answer but not the firm-wide position. This could be overcome by targeting sufficiently senior respondents, such as the firms' CEO or CTO.
Scope and coverage (Possible reliable sub-	Comparing this indicator with demographic data about the firms themselves would enable a breakdown of this

indicators and/or breakdowns)	figure by country, sector, firm size and age.
Unit	Euro
Data-update interval	Data would be collected in an annual company survey
Interpretation of the data	This metric is both a measure of firm-level confidence in their ability to realise return on investment, as well as an indication of the development stage (R&D, production) of different nanotechnologies.
Pitfalls in interpretation	Absolute investment may be misleading in some cases, e.g. if a new production technology is lower cost than existing solution
Rating: complexity	2
Rating: labour intensity / cost	2
Estimated resources to collect and analyse data	Collection and analysis of this data will be linked to the whole company survey (which will require up to 0,5 man years – see chapter 10)
Overall assessment	The level or industrial investment is an important indicator of the expectation of economic returns from nanotechnology, and is therefore a particularly important indicator to incorporate.

5. ACTIVITY INDICATORS

Regarding the NST activities, our intention is to cover the importance of linkages between science and technology. We propose to use indicators that map the basic *research activities and growth* by using papers as well as collaboration patterns and the so called hot topics (i.e. topics that have become more popular lately). Much of these indicators are based on publication data. Since this data requires a lot of specific methodology, the detailed description of key definitions and methodology is presented in the supplement.

5.1 Publications and fractions of publications

5.1.1 Description of the Indicator

Publications and fractions of publications	
Type	Quantitative activity indicator
Description	This indicator measures the output of NST research papers. Normally, only publications which are classified by Web of Science (WoS) as articles, letters, proceeding papers and reviews are included.
Policy relevance	This is a rudimentary indicator, providing magnitudes of nanotechnology research production output for countries (or other units).
Variables	Number of papers in time period x, using whole (full) counting and fractional counting
Source of data (and identification of needs for new/better data generation)	Web of Science or SCOPUS (cf. Footnote 24). Individual and group analyses can be done through queries using the ISI internet version, Web of Science, though analyses at higher levels of aggregation generally require access to the underlying data.
Methodology for the compilation of the reliable indicator: "country fractionalisation"	1) Delimit and compile nanotechnology related research papers; 2) For each country, determine the total number of papers and the sum of address fractions (where an article with three addresses gives 1/3 fraction for each address etc.) or author fractionalisation (where an article with three addresses gives 1/3 fraction per author etc.). For further discussion on this point, see chapter 9.
Scope and coverage	Global coverage, articles, books, book chapters and conference proceedings per country, institution and by author name for all countries in the world.
Unit	Full papers (P) or fractions of papers (Frac P)
Data-update interval	Annually or twice a year.
Interpretation of the data	The indicator reveals activity in the nanotechnology research area and how the activity develops over time.
Pitfalls in interpretation	Number of papers differs between areas of NST research. While Chemistry and Physics have high numbers areas such as Engineering normally have much lower rates of publication per researcher. This has to be taken into consideration when differences between countries in number of papers are interpreted. Changes in journal coverage produce interpretation difficulties.

Rating: complexity	1
Rating: labour intensity / cost	2 (to set up) 2 (to repeat)
Estimated resources to collect and analyse data	Low, given that a viable definition of NST is available, the collection of data should be 1 man-day of work.
Overall assessment	A fundamental indicator which is necessary for the interpretation of other indicators.

5.1.2 Example of using the indicator

The following example of using the indicator is applied to publications registered in Web of Science, published 2004-2008, in NST journals (Section 9.7). The table below provides publication values per country and year.

Table 3. NST publications (P) full counts per country, 2004-2011.

Country	2004	2005	2006	2007	2008	2009	2010	2011	Total
Belgium	129	121	136	184	207	220	276	265	1 538
England	418	408	463	650	773	768	771	808	5 059
Finland	31	31	62	67	106	112	117	106	632
France	446	408	557	732	876	841	919	1 021	5 800
Germany	712	645	830	1 142	1 240	1 286	1 420	1 495	8 770
Italy	219	215	280	495	528	549	589	805	3 680
Netherlands	132	177	178	262	278	344	359	360	2 090
P R China	676	1 029	1 633	2 365	3 185	3 413	4 015	4 747	21 063
Russia	228	131	180	283	459	411	430	433	2 555
South Korea	381	503	643	954	1 237	1 194	1 385	2 131	8 428
Spain	228	203	255	425	523	541	566	632	3 373
Sweden	95	131	145	197	215	232	266	318	1 599
Switzerland	143	131	224	259	285	311	358	370	2 081
USA	1 967	2 388	2 877	4 013	4 383	4 300	4 981	5 323	30 232
Total	5 048	5 714	7 263	10 375	12 314	12 383	13 823	15 909	82 829

Source: Web of Science, July 2011

Table 4. NST publications, fractional counts (Frac P) based on addresses. Same set as Table 1

Country	2004	2005	2006	2007	2008	2009	2010	2011	Total
Belgium	83,7	81,9	83,1	121,6	129,3	144,2	168,5	163,1	975,4
England	321,3	295,5	334,3	452,5	505,1	508,5	501,9	503,2	3 422,5
Finland	22,3	24,6	44,8	48,4	74,0	78,0	75,9	75,4	443,4
France	323,1	286,3	380,1	501,2	602,3	587,4	635,5	690,4	4 006,3
Germany	532,3	481,0	581,6	792,4	853,8	905,0	962,2	1 012,8	6 121,0
Italy	169,7	166,7	203,9	370,6	397,8	411,4	426,7	611,0	2 757,8
Netherlands	89,6	128,2	130,1	181,9	191,9	244,8	230,7	235,7	1 433,1
P R China	596,8	915,7	1 443,4	2 096,8	2 825,8	2 987,6	3 454,3	4 124,5	18 444,9
Russia	157,1	81,9	123,4	197,9	356,1	305,8	322,4	328,4	1 873,0
South Korea	327,3	442,0	547,6	821,9	1 065,8	1 009,4	1 156,8	1 837,1	7 208,1
Spain	158,4	148,0	183,0	305,4	372,0	389,8	395,7	423,6	2 375,7
Sweden	72,1	97,4	104,6	126,5	135,5	145,9	166,0	195,1	1 043,3

Switzerland	98,8	95,4	157,0	166,8	184,0	203,3	215,4	234,1	1 354,7
USA	1 737,9	2 089,1	2 431,1	3 465,4	3 719,0	3 581,3	4 102,1	4 312,1	25 437,9
Total	4 690,5	5 333,8	6 748,0	9 649,3	11 412,4	11 502,5	12 814,1	14 746,6	76 897,2

Source: Web of Science, July 2011.

Fractional count is the mirror to collaboration between countries. If we were not to correct for collaborations the numbers and the trend would be exaggerated.

Data in Tables 3 and 4 can be further analysed e.g. by transformation to percentage figures per year. It then becomes apparent that while PR China and South Korea are growing quite fast, other countries like USA, Germany, France and England are losing ground or have reached a certain level of saturation. Remember that this data set covers publications in dedicated NST journals and that much more of NST research is published in Medical, Physics and Chemistry journals not assigned as NST journals. Knowing that this is the case, we still might use dedicated NST journals as they can reveal some basic information about trends.

5.2 Collaborations between sectors

5.2.1 Description of the Indicator

Collaboration between sectors	
Type	Quantitative activity indicator
Description	This indicator measures national and international collaboration between sectors (universities, research institutions and corporations) using co-authorship analysis.
Policy relevance	The indicator can illuminate industrial interest in nanotechnology research, international flows of knowledge between countries and sectors, and regional/geographical differences in sector collaboration.
Variables	Co-authorships
Source of data (and identification of needs for new/better data generation)	Web of Science or SCOPUS. (see Footnote 24)
Methodology for the compilation of the reliable indicator	1) Delimit and compile nanotechnology related research papers; 2) Categorise the authors' addresses into different sectors; 3) For each country, determine the number of national and international co-authorships between sectors. Differentiation of collaboration levels depends to a large extent on the amount of 'cleaning' of the raw address data.
Scope and coverage	Global coverage
Unit	Co-authorships
Data-update interval	Annually
Interpretation of the data	The metric is a measure of how well a country collaborates between sectors nationally and internationally. Collaborations reveal knowledge flows within the knowledge system.
Pitfalls in interpretation	The causality of differences in number of co-authorships is open for interpretation (see below).

Rating: complexity	1
Rating: labour intensity / cost	3 (to set up) + 3 (to repeat)
Estimated resources to collect and analyse data	Moderate, estimated number of man-days is 5 in order to categorise each institutional address.
Overall assessment	An indicator with a high potential for policy relevant interpretations as collaboration within the system of innovation is important.

5.2.2 Example of using the indicator

The following example of using the indicator is applied to papers registered in Web of Science, published 2005-2008, and papers including nanotechnology related terms (Selection 2, as defined in chapter "Bibliometric Indicators", see section 9.7). Table 5 below presents the pattern of sector collaboration, on national and international level. To the left, in rows, is a sample of ten countries with figures per sector.

Their respective collaborations are found in the columns to the right. For Belgian universities, accounting for almost 90% of publications from that country, we find that 4,2% of their publications are a result of collaborative work with international business corporations. Collaborations with domestic corporations are 2,4%. More than half of Belgium university publications (52,3%) are collaborations with international university researchers. While university publications in countries like Italy, Germany and France have considerably smaller shares of international corporative collaborations, university publications in countries like Sweden, England, Belgium and Switzerland have larger shares. Sweden is, actually, the country with the highest amount of collaboration (9,3%) with industrial corporations. The lowest frequency is found in Russia and Spain.

Table 5. Sector collaborations per country, 2005-2008.

								National			International			National			International		
Country	Sector	P	Frac P	SCS	Top 5%	Vitality	% of Frac P	C	I	U	C	I	U	C	I	U	C	I	U
Belgium		2 878	1 778,4	0,13	5,2%	1,03													
	C	141	58,2	-0,05	4,4%		3,3%		10	63	25	25	58		7,1%	44,7%	17,7%	17,7%	41,1%
	I	344	137,2	0,10	8,1%		7,7%	10		219	23	79	144	2,9%		63,7%	6,7%	23,0%	41,9%
	U	2 679	1 583,0	0,14	5,0%		89,0%	63	219		113	767	1 401	2,4%	8,2%		4,2%	28,6%	52,3%
England		12 988	8 561,6	0,13	6,3%	1,04													
	C	926	389,1	0,08	5,7%		4,5%		34	621	84	148	346		3,7%	67,1%	9,1%	16,0%	37,4%
	I	837	372,2	0,21	7,9%		4,3%	34		382	33	268	406	4,1%		45,6%	3,9%	32,0%	48,5%
	U	12 229	7 794,3	0,13	6,3%		91,0%	621	382		468	2 822	5 753	5,1%	3,1%		3,8%	23,1%	47,0%
France		15 248	10 358,6	0,02	4,4%	0,99													
	C	541	209,2	-0,06	4,3%		2,0%		276	265	45	64	161		51,0%	49,0%	8,3%	11,8%	29,8%
	I	8 145	4 150,8	0,06	5,1%		40,1%	276		3 355	239	1 910	3 704	3,4%		41,2%	2,9%	23,4%	45,5%
	U	10 332	5 993,6	0,00	4,0%		57,9%	265	3 355		227	1 942	4 483	2,6%	32,5%		2,2%	18,8%	43,4%
Germany		23 836	16 541,0	0,10	5,7%	1,02													
	C	1 435	605,1	-0,11	4,5%		3,7%		367	721	132	272	536		25,6%	50,2%	9,2%	19,0%	37,4%
	I	9 241	4 828,2	0,17	7,0%		29,2%	367		3 355	218	2 331	4 004	4,0%		36,3%	2,4%	25,2%	43,3%
	U	17 396	11 061,6	0,09	5,2%		66,9%	721	3 355		378	3 562	7 110	4,1%	19,3%		2,2%	20,5%	40,9%
Italy		9 692	7 231,1	-0,07	2,9%	0,98													
	C	265	100,2	-0,25	0,9%		1,4%		97	191	14	29	52		36,6%	72,1%	5,3%	10,9%	19,6%
	I	3 926	1 755,3	-0,08	2,8%		24,3%	97		2 595	85	820	1 476	2,5%		66,1%	2,2%	20,9%	37,6%
	U	8 242	5 254,7	-0,06	2,9%		72,7%	191	2 595		183	1 404	3 052	2,3%	31,5%		2,2%	17,0%	37,0%
Netherlands		4 466	2 945,8	0,30	8,9%	1,05													
	C	364	154,7	0,21	8,8%		5,3%		29	182	45	70	169		8,0%	50,0%	12,4%	19,2%	46,4%
	I	646	264,7	0,41	11,6%		9,0%	29		386	31	149	296	4,5%		59,8%	4,8%	23,1%	45,8%
	U	3 990	2 496,9	0,29	8,6%		84,8%	182	386		159	796	1 881	4,6%	9,7%		4,0%	19,9%	47,1%
Russia		8 687	6 447,8	-0,94	0,7%	0,86													
	C	78	31,1	-0,95	0,0%		0,5%		46	33	7	6	21		59,0%	42,3%	9,0%	7,7%	26,9%
	I	6 744	4 394,9	-0,92	0,7%		68,2%	46		1 459	173	1 366	2 460	0,7%		21,6%	2,6%	20,3%	36,5%
	U	3 361	1 994,4	-1,01	0,6%		30,9%	33	1 459		59	493	1 122	1,0%	43,4%		1,8%	14,7%	33,4%
Spain		8 650	6 076,1	0,02	3,6%	1,00													
	C	51	29,4	-0,68	1,9%		0,5%		13	19	2	8	8		25,5%	37,3%	3,9%	15,7%	15,7%
	I	3 030	1 530,4	0,06	4,8%		25,2%	13		1 268	52	736	1 320	0,4%		41,8%	1,7%	24,3%	43,6%
	U	6 763	4 368,7	0,01	3,2%		71,9%	19	1 268		145	1 314	2 803	0,3%	18,7%		2,1%	19,4%	41,4%
Sweden		4 001	2 558,5	0,06	5,1%	0,99													
	C	256	95,8	0,04	5,9%		3,7%		16	198	19	59	80		6,3%	77,3%	7,4%	23,0%	31,3%
	I	213	93,4	0,03	3,8%		3,6%	16		150	11	43	69	7,5%		70,4%	5,2%	20,2%	32,4%
	U	3 877	2 365,5	0,06	5,1%		92,5%	198	150		164	945	1 952	5,1%	3,9%		4,2%	24,4%	50,3%
Switzerland		4 656	2 928,9	0,30	8,5%	1,06													
	C	379	175,9	0,31	8,1%		6,0%		25	148	49	75	173		6,6%	39,1%	12,9%	19,8%	45,6%
	I	808	352,8	0,14	5,5%		12,0%	25		289	40	281	441	3,1%		35,8%	5,0%	34,8%	54,6%
	U	3 866	2 348,4	0,33	9,0%		80,2%	148	289		154	978	1 903	3,8%	7,5%		4,0%	25,3%	49,2%

Note: C=Corporations; I=Research Institutes and U=Universities.
P=number of publications; Frac P= number of publications (fractional counting).
National and international percentages relate to P.

As revealed in Table 5 universities with larger shares of corporative collaborations are, in most cases, associated with higher citation rates, but these correlations can be interpreted in at least two different ways (see Figure 2). One interpretation could be that companies search for excellence and align with institutions producing good results, or collaboration between sectors in itself might produce good results. These questions will have to be further investigated e.g. by looking closer at actual collaborations. Exactly what are the driving forces and which factors (geographical proximity etc.) have to be taken into consideration?

Table 6. Quality of papers and international collaboration for universities per country, 2005-2008.

						International		
Country	Sector	P	Frac P	SCS	Top 5%	C	I	U
Belgium	U	2 679	1 583,0	0,14	5,0%	4,2%	28,6%	52,3%
England	U	12 229	7 794,3	0,13	6,3%	3,8%	23,1%	47,0%
France	U	10 332	5 993,6	0,00	4,0%	2,2%	18,8%	43,4%
Germany	U	17 396	11 061,6	0,09	5,2%	2,2%	20,5%	40,9%
Italy	U	8 242	5 254,7	-0,06	2,9%	2,2%	17,0%	37,0%
Netherlands	U	3 990	2 496,9	0,29	8,6%	4,0%	19,9%	47,1%
Russia	U	3 361	1 994,4	-1,01	0,6%	1,8%	14,7%	33,4%
Spain	U	6 763	4 368,7	0,01	3,2%	2,1%	19,4%	41,4%
Sweden	U	3 877	2 365,5	0,06	5,1%	4,2%	24,4%	50,3%
Switzerland	U	3 866	2 348,4	0,33	9,0%	4,0%	25,3%	49,2%
		Correlation with Top 5%(RKV):				0,56	0,36	0,54

Note: C=Corporations; I=Research Institutes and U=Universities.
P=Number of publications; Frac P= Number of publications (fractional counting).
SCS=Standardized Citation Score[32] (Quality Indicator); Top 5%=Percentage of papers cited above the 95th percentile[33] (Quality Indicator). International percentages relate to P.

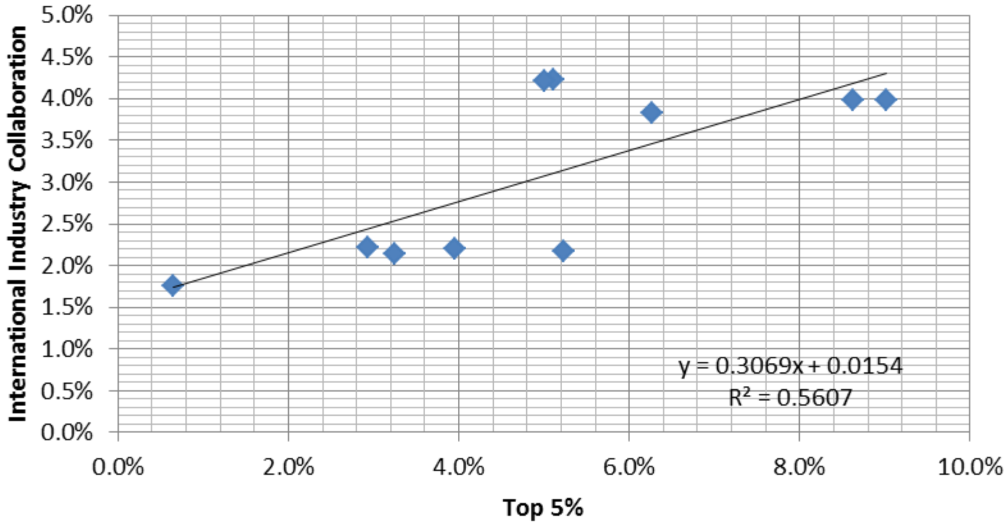

Figure 2. Correlation between university-industry collaboration per country and quality of papers per country measured as percentage of papers cited above the 95th percentile (Top5%).

[32] See section 6.1.1. for definition of this indicator.
[33] Ibidem.

5.3 Hot topics

5.3.1 Description of the Indicator

Hot Topics	
Type	Quantitative activity indicator
Description	This indicator measures the growth of nanotechnology article topic clusters to reveal emerging or escalating nanotechnology topics.
Policy relevance	Monitoring the global development of nanotechnology requires knowledge about trends in nanotechnology research. This indicator provides one dimension of input data for strategic policy decisions by revealing which topics are predominately focused on and which topics are growing.
Variables	Growth of paper production (e.g. linear regression trend line)
Source of data (and identification of needs for new/better data generation)	Web of Science or SCOPUS. (see Footnote 24)
Methodology for the compilation of the reliable indicator	1) Delimit and compile nanotechnology related research papers; 2) Calculate similarities between papers based on bibliographical coupling; 3) Cluster papers based on similarities; 4) Calculate growth of clusters and performance indicators (e.g. citation indicators); 5) Give names to cluster based on ocular inspection or based on keywords or noun phrases from titles and abstracts The bibliographic coupling (BC) between two papers can be defined as $$BC = \frac{F_{ij}}{\sqrt{S_i S_j}}$$ • where Fij is the number of common references of paper i and j and Si is the number of references in paper i, and Sj is the number of papers in j; • In the example below, clustering has been performed using the Multi-level Aggregation Method (MAM);([34])There are many clustering algorithms available.
Scope and coverage	coverage, articles and conference proceedings per country and by institution for all countries in the world
Unit	Papers/year
Data-update interval	Annually
Interpretation of the data	Topic clusters that are growing rapidly and are highly cited could be regarded as “hot topics”, i.e. topics which are in focal point of contemporary nanotechnology

[34] see Blondel, V. D., Guillaume, J. L., Lambiotte, R., & Lefebvre, E. (2008). Fast unfolding of communities in large networks. Journal of Statistical Mechanics: Theory and Experiment, P10008

	research.
Pitfalls in interpretation	The information provided by the indicator is not self-evident and must be carefully interpreted. For example, a lengthy growth of papers could be a sign that the topic will soon peak and decline (rather than continue to grow).
Rating: complexity	4
Rating: labour intensity / cost	4 (to set up) + 4 (to repeat)
Estimated resources to collect and analyse data	Moderate, estimated number of man-days is 5.
Overall assessment	Although not self-evident, this indicator has many potential applications to policy questions as whether EU countries are active within "hot" research lines.

5.3.2 Example of using the indicator

The following example of using the indicator is applied to papers registered in Web of Science, published 2004-2008, from NST journal (selection 1, as defined in Section 9.7). The table below provides paper counts per year and selected (hot) topic clusters (and regression gradients or trend)

Table 7. Hot Topics (based on paper per year) in NST research, 2004-2008

2004	2005	2006	2007	2008	Label	Yearly growth
116	123	191	717	879	Reactive surfaces	212
163	231	355	703	817	Plasmonics	178
44	73	93	364	448	Photocatalysis	110
113	185	238	417	495	Quantum Dots	100
220	338	430	572	594	Microfluids	98
81	127	252	399	420	Magn Nanoparticles	95
298	338	432	610	635	Emission prop CNTs	95
177	296	329	399	573	Mesopouros Silica	90
80	147	227	298	400	Zinc Nanowires	79
118	192	244	363	426	Si Nanowires	79
70	82	139	299	344	Carbon Nanotubres	76
94	125	198	336	366	Li-ion Energy Store	75
76	141	160	285	329	Organic photovoltaics	65

Source: Web of Science

As mentioned above, the trend figure is the slope of the regression line for the data points per year for each topic". Table 7, does not show all topics, as there are 78 research fronts (topics) identified in the full investigation and about 40 of these had at least 100 publications per year. On average there is a growth of about 50 publications per year, and topics with a yearly growth above 70-80 papers can be seen as hot topics. The rate of production in hot topics grows as many researchers are drawn to these topics and expectations are high for new possibilities in that area of research.

6. OUTPUT INDICATORS

While activity indicators measure research activity of both public and private sectors, output indicators aim to measure the results of research activities. The first of the output indicators considered here is the quality of papers, which can be measured by the use of citations. Another important view is the vitality of research. Finally, R&D activities produce results, which may not always be easy to identify. In this context, patenting remains a powerful indicator to capture the intermediate stages of innovation activities.

6.1 Quality of Papers

6.1.1 Description of the Indicator

Quality of Papers	
Type	Quantitative output indicator
Description	These indicators measures citation strength of nanotechnology articles. In other words: how many times one article has been cited by other publications in the database.
Policy relevance	Innovation policies need to focus on quality of research. On a large scale, citation analysis provides a reasonable estimate of the importance and impact of nanotechnology research accomplishments.
Variables	Citations
Source of data (and identification of needs for new/better data generation)	Web of Science or SCOPUS. (see Footnote 24)
Methodology for the compilation of the reliable indicator	1) Delimit and compile nanotechnology related research papers; 2) Determine the number of citations to each paper. *3) Standard citation Score (SCS)*: calculate the average and the standard deviation of the logarithms of the number of citations (plus 0.5 to avoid the value 0) to papers of the same document type, publication year and subject area to determine reference values; use the logarithms of the number of citations and the reference values to calculate a logarithm-based citation z-score for each paper; determine the average z-score for each country. The Standard Citation Score (SCS) of a country is defined as $$SCS = \frac{1}{P}\sum_{i=1}^{P}\frac{ln(c_i + 0{,}5) - [\mu_{f[ln]}]_i}{[\sigma_{f[ln]}]_i}$$ where c_i is the number of citations to paper i, $\mu_{f[ln]}$ is the average of the number of citations (+0.5) to papers of the same document type, publication year and subject area, $\sigma_{f[ln]}$ is the standard deviation of the $\mu_{f[ln]}$ distribution and P is the country's number of papers.[35] [36] *Top 5%:* determine the 95th citation percentile (i.e. the number of citations to the top 5% cited paper) for publications of the same document type, publication year

[35] see McAllister, Narin & Corrigan (1983) Programmatic evaluation and comparison based on standardized citation scores, IEEE Transactions on Engineering Management 30:205-211
[36] *f* tells us that the indicator is normalised to subject areas (field normalised)

	and subject area; determine the share of papers in the top 5% of cited papers for each country. The top 5% of a country is defined as $$Top\ 5\% = \frac{P_{5\%}}{P}$$ Where $P_{5\%}$ is the number of papers cited more than the 95th citation percentile for papers of the same document type, publication year and subject area and P is the total number of papers.
Scope and coverage	Global coverage, articles, letters, proceeding papers and reviews for all countries or organisations in the world."
Unit	z-score / percentage (calculations can be used at different levels – top 1%, top 10%, etc.),
Data-update interval	Annually
Interpretation of the data	If the ratio is above 0.0, or higher than 5 %, the research unit's publications are cited more frequently than average publications in the areas in which the unit is active. Higher citation strength is an indicator of higher levels of impact or quality of research. SCS is probably the most adequate measure for research performance.
Pitfalls in interpretation	Small variations in citation strength need not be significant, especially if the samples are small. Furthermore, absence of citations need not be a sign of absence of quality. Instead, the absence of citations could be the effect of activity in new research fields, yet to be widely adopted. However, on the country level (where samples are large) this would seldom be the case.
Rating: complexity	3
Rating: labour intensity / cost	3 (to set up) + 3 (to repeat)
Estimated resources to collect and analyse data	Moderate, estimated number of man-days is 2.
Overall assessment	Provides a fundamental dimension (impact/quality) to the analysis and is therefore of substantial importance.

6.1.2 Example of using the indicator

This indicator is used to discover whether there are outstanding contributions among a publication set which might otherwise be hidden by the average citation score. The following example of using the indicator is applied to papers registered in Web of Science, published 2005-2008, based on the use of nanotechnology related terms (Selection 2, as defined in section 9.7). The table below provides citations indicators for selected countries. Publication indicators are also provided for reference (see section 5.1 for the indicators publication (P) and fractions of publications (Frac P)).
Table 8 shows that countries like Switzerland and The Netherlands are top performers with a citation score of about 0.30 (world level is 0.0) and their share of publications in the TOP5% is 70% higher than expected. While Germany, Sweden England and Belgium are rather good performers with expected citation levels, countries like France, Spain, Italy and Russia are performing below expected values.

Table 8. Citation indicators for ten countries, 2005-2008

Country	P	Frac P	SCS	Top 5%
Switzerland	4 656	2 928,9	0,30	8%
Netherlands	4 466	2 945,8	0,30	9%
Belgium	2 878	1 778,4	0,13	5%
England	12 988	8 561,6	0,13	6%
Germany	23 836	16 541,0	0,10	6%
Sweden	4 001	2 558,5	0,06	5%
France	15 248	10 358,6	0,02	4%
Spain	8 650	6 076,1	0,02	4%
Italy	9 692	7 231,1	-0,07	3%
Russia	8 687	6 447,8	-0,94	1%

(N.B! Table is organised according to the SCS indicator)
P=number of publications; Frac P=country fractions of papers; SCS=standardised citation score (quality indicator); Top5%=share papers above the 95th percentile of most cited publications.
Source: Web of Science

6.2 Vitality of research

6.2.1 Description of the Indicator

Vitality of research	
Type	Quantitative output indicator
Description	This indicator measures the "vitality" of research article references, measured as the average age of all cited references from the papers.
Policy relevance	Vitality indicates researcher's willingness to attack new problems with new measures and can therefore function as an estimate for diversity and dynamics within the research and innovation system.
Variables	Vitality
Source of data (and identification of needs for new/better data generation)	Web of Science or SCOPUS (see Footnote 24)
Methodology for the compilation of the reliable indicator	1) Delimit and compile nanotechnology related research papers; 2) Determine the age of all cited references from the papers (the number of years between publication of paper and the cited paper). 3) Calculate the average age of all cited references from papers of the same document type, publication year and subject area to determine reference values; 4) Use average age of each papers cited references and the reference values to calculate the vitality for each paper; 5) Determine the average Vitality for each country. The Vitality for a country is defined as $$Vitality = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{a_i+1}$$ where *n* is the number of references from the country's papers, and a_i is the age of reference *i* in year move to

	footnote please)
Scope and coverage	Global coverage, articles, letters, proceeding papers and reviews for all countries or organisations in the world.
Unit	Relative recency of references
Data-update interval	Annually
Interpretation of the data	High Vitality is an indication of ability to build upon recent discoveries in a field. Those successful in this perspective can exercise a thought leadership and the unsuccessful will be followers to those that change and reorganise the research front.
Pitfalls in interpretation	The correlation between Vitality and "thought leadership" is still speculative since there are not enough studies on the subject yet. However, the case study report shows that Vitality is an important indicator and that a region or a country that want to be leader in NST research has to have a high Vitality score.
Rating: complexity	2
Rating: labour intensity / cost	2 (to set up) + 2 (to repeat)
Estimated resources to collect and analyse data	Low, approximately 1-2 mandays.
Overall assessment	The indicator is still untested on a policy level and needs to be handled with caution. The indicator should primarily be seen as a supplementary indicator to other output indicators.

6.2.2 Example of using the indicator

The following example of using the indicator is applied to papers registered in Web of Science, published 2004-2008, from nanotechnology journals (Selection 1, as defined in Section 9.7). The table 9 below provides Vitality figures for selected areas of nanotechnology research (combinations of "topic clusters"; see section on Hot topics in 5.3). High figures indicate that authors have used the latest papers. While United States-Canada has a leading position in six out of eight areas, EU is at the forefront of research in Energy, Manufacturing and Instruments. Asia is close to the global average, which is always 1.0 as figures are field normalized, but Russia and Latin America are well below international standards.

Table 9. Vitality applied to fields of NST research (fields from Hot Topics) per World region, 2004-2008

	US-Canada	Asia	EU	Latin	Russia	All regions
Electronics	1.12	1.03	1.10	0.88	0.94	1.02
Energy	1.14	1.08	1.15	0.92	0.91	1.04
Environment	1.10	1.04	1.06	1.00	0.95	1.03
Health	1.09	0.99	1.04	0.95	0.90	0.99
Manufacturing	1.04	0.90	1.04	0.74	0.75	0.89
Materials	0.98	0.89	0.94	0.81	0.92	0.91
Photonics	1.09	0.95	1.01	0.83	0.92	0.96
Instruments	1.04	0.90	1.07	0.81	0.80	0.92
All topics	1.07	0.97	1.05	0.89	0.89	0.97

Source: Web of Science
Note: All countries are not included in "regions".

6.3 Nanotechnology patents

6.3.1 Definition of the indicator

Number of nanotechnology patents	
Type of indicator	Quantitative output indicator
Description	Absolute and relative share of nanotechnology patents by the European Patent Office (EPO). Gives general information on nanotechnology patenting and therefore an estimate of technologies ready for commercialisation.
Policy relevance	Patent data captures the intermediate stages of innovation activities and are thus especially relevant for analysing R&D outputs of emerging technologies, such as nanotechnology
Variables	Number of nanotechnology patents (total, sectoral scores) Patents per capita Patent to publication ratio
Source of data (and identification of needs for new/better data generation)	Eurostat, Science, technology and innovation, Nanotechnology patent applications to the EPO by priority year at the national level (pat_ep_nnano). EPO Worldwide Patent Statistical Database (PATSTAT) is needed for analysing sectoral data[37].
Methodology for the compilation of the reliable indicator	The data collection takes place by gathering the basic statistical data by searching the indicator "Nanotechnology patent applications to the EPO by priority year at the national level [pat_ep_nnano]" from the Eurostat database. The data can then be moved into a spread sheet where country data and time series as well as (basic) sectoral data can be captured. The basic classification of the indicator is: • Nanobiotechnology • Nanotechnology for information processing, storage and transmission • Nanotechnology for materials and surface science • Nanotechnology for interacting, sensing or actuating • Nano optics • Nanomagnetics The strength of using the readily available categories is that they are relatively reliable as they are based on expert tagging. If specific sectoral data (e.g. from environment or energy sectors) is needed, there is a need to access the nanotechnology database and classify the patents to each sector based on keywords. This methodology has been used in e.g. ObservatoryNano Report 2010 on Statistical Patent Analysis ([38]). To gain additional sectoral

[37] The annual subscription of the database costs around 1100€.
[38] http://www.observatorynano.eu/project/filesystem/files/WP2_Report_Patents_March_2010.pdf

	information, additional data needs to be collected of the EPO´s "Worldwide Patent Statistical database" (PATSTAT). In PATSTAT, a keyword search needs to be applied to all patent documents that have been tagged with "Y01N"-code (nano) of the European Classification System ECLA to limit the search to nanotechnology relevant patent applications. For this sub-set of sector specific patent data a specific search query string based on keywords needs to be prepared by experts. When doing a keyword analysis it has to be kept in mind that they are always compromised in a way how keywords are selected and overlap other application areas, i.e. same patents may be included in several sectors. There is a principle trade-off between covering a large keyword area, resulting in large hit numbers with only little relevance to the desired sector and sharply focused keywords, resulting in reduced numbers but increasing the probability to miss relevant documents (ObservatoryNano, 2010). Also the statistical handling of applicant names is a challenge for the patent data as the names may deviate from document to document For the latter different approaches have been described, based on e.g. priority countries, applicant countries or inventors countries. For this reason, the selection needs to be defined separately but a good rule is to use both priority and applicant data to get the full results. Since the string may vary according to expert opinion and may also change during time (as additional search words are added) the absolute numbers are not comparable across time.
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Nanotechnology patents in sub-sectors: • Nanobiotechnology • Nanotechnology for information processing, storage and transmission • Nanotechnology for materials and surface science • Nanotechnology for interacting, sensing or actuating • Nano optics • Nanomagnetics Number of patents in other sub-sectors can be estimated by using keywords (with the need of external experts).
Unit	Number of patent applications by priority year
Data-update interval	Every 6 months.
Interpretation of the data	The absolute number of patents is an estimate for the volume of research based innovations. The relative share of patents is an estimate for the relative strength of nanotechnology innovation If the relative share of nanotechnology patenting in a country is greater than in other countries, then the country is strong in producing potential innovations. If patenting in a country is relatively more prominent in

	comparison with publications/investments, it indicates that the process from research to innovation may be a relative strength in a country. Likewise, if patenting is less frequent in comparison with other countries compared with investments and research, this is an indicator that the creation of innovation and commercialisation may be challenges.
Pitfalls in interpretation	The utility of individual patents vary significantly - many patents have no industrial application whereas a few are of substantial value commercially and/or to the society. Many inventions are not patented so the indicator only gives a partial picture; moreover the propensity to patent differs across countries as well as the patent regulations. This makes it difficult to make cross-country analyses.
Rating: complexity	1: the basic nanotechnology statistics based on sub-classes are readily available from Eurostat 4: the data collection for sectoral data requires the creation of keyword lists as well as access and use of PATSTAT (or similar) database. This requires some methodological skills.
Rating: labour intensity / cost	1: Basic statistics collection is easy 4: The definition of keywords is time-consuming as well as information collection from the database. Alternatively an external researcher may be hired to do the data collection, or the readily available classification may be used although it fails to capture more refined sectoral classifications.
Estimated resources to collect and analyse data	The basic statistics takes around 1 man-day to analyse, the sectoral data based on key-word analysis takes from 10 to 20 man-days
Overall assessment	A very useful core indicator that captures a specific stage in the innovation chain. The sectoral data is also useful to assess differences.

6.3.2 Example of using the indicator

This section gives an example of using the indicator and presenting the information with a sample real world data:

The example is from the energy sector derived from the 2010 ObervatoryNano report (see above). Since Energy is not readily available as a classification in the patent statistics, a keyword search was carried out. The keywords were:

"energy conversion" OR "fuel cell*" OR "fossil fuel" OR "hydrogen oxidation" OR "oxygen reduction" OR "MEMS" OR "nuclear fission" OR "nuclear fusion" OR "renewable energ*"
OR photovoltaic* OR "photo voltaic*" OR "solar cell*" OR "solar energ*" OR "thermo electr*" OR thermoelectr* OR seebeck OR "energy harvest*" OR "energy scaveng*" OR "micro power*" OR "energy saving" OR "therm* insulation" OR "lighting" OR "energy storag*" OR "hydrogen storag*" OR "gas storag*" OR batter* OR electrode* OR anode* OR cathode* OR "lithium ion" OR "Li ion" OR supercapacitor* OR "super capacitor*" OR "super cap*" OR ultracapacitor* OR "ultra capacitor*" OR "ultra cap*"

Some example results are shown below:

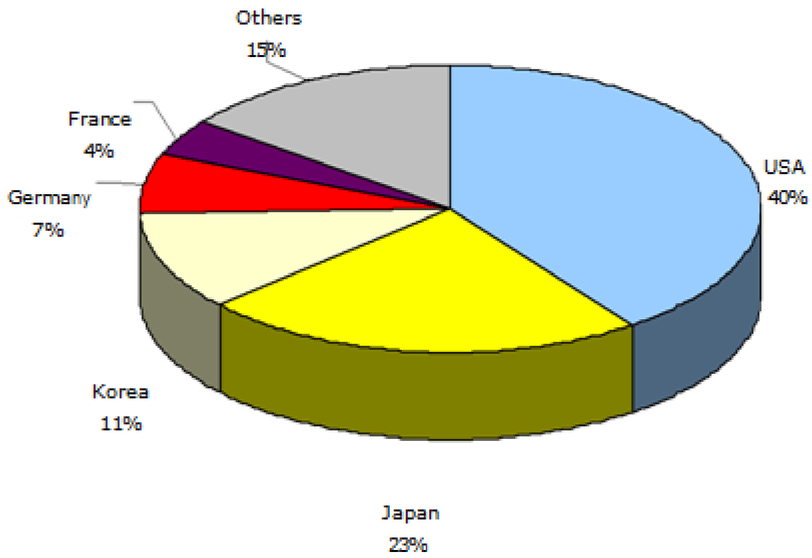

Figure 3. Number of energy patent applications for the major countries between 1987 and 2008 (2859 in total) (Source: ObservatoryNano Report 2010 on Statistical Patent Analysis)

7. OUTCOME INDICATORS

Analysis of R&D investments (inputs), publications (activities) and patents (outputs) goes some way towards understanding NST development, but to gather data about the industrial impact of NST it will be necessary to approach companies as the main carriers of NST to the market.

The impact indicators that will be proposed for the monitoring system and developed in this project are indicators that have been tested previously in a national setting ([39]). Moreover, two additional new indicators are introduced: value chain penetration and competitive advantage of nanotechnology. The former aims to analyse the use of nanotechnology at various parts of the value chain. The latter concentrates to analyse the advantages of using nanotechnology. The main source of data for these indicators is a European wide survey.

7.1 Number of Companies

7.1.1 Description of the indicator

Number of Companies using nanotechnology	
Type of indicator	Quantitative Outcome Indicator
Description	This indicator gives a total number of companies with nanotechnology development activities; defined as those either holding patents in the Y01N class, having author affiliations on publications with nanotechnology keywords in their abstract, or participating in a project involving nanotechnology under Framework Programme 7.
Policy relevance	The indicator measures the extent to which nanotechnology is leading to new firm creation, or is diffusing through industry.
Variables	Composite indicator comprised of patent, publication and project participating statistics
Source of data (and identification of needs for new/better data generation)	Patent information is drawn from the European Patent Office's databases. Publication information can be obtained from Web of Science. Project participants can be drawn from the Cordis database of projects.
Methodology for the compilation of the reliable indicator	The data collection process relies on three sources: • Patent data from the PATSTAT database, available from the European Patent Office ([40]). This database contains 70 million records, and is intended for bibliographic analysis of patents[41]. Analysis of the PATSTAT data requires a relational database server (such as MySQL) and statistical software, so putting the data in a form to be analysed requires some technical expertise. The advantage of this dataset is that it has standardised applicant names, reducing time required for post processing to match entity names. Extracting a list of companies with nanotechnology patents would involve running a query for records with Y01N as the IPC subclass. • Publication data from Web of Science or equivalent. See Publication Data chapter 9. • Information about funded projects under Framework Programme 7. For a non-EC user, this data could be obtained from the Cordis database using the Search Projects interface. A

[39] Nanotech in Finnish Industry. The survey also takes into account the experiences from other similar national surveys (see OECD, 2009)
[40] http://www.epo.org/searching/subscription/raw/product-14-24.html
[41] See Footnote 38 for pricing

	set of nanotechnology-related keywords are used as search terms to identify projects across all funding schemes. The names of participants in these projects could then be manually extracted (which is rather time consuming). It may also be the case that Commission personnel have access to alternative interfaces to this data, making it easier to extract bulk data. The output from each data file could be combined in a single spread sheet. The number of records is likely to be in the 1000s, but not above this number, so that the data could be analysed using Excel.
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Companies can be listed by country. Identification of technology area would be possible with more sophisticated text analysis of patent and publication abstracts.
Unit	Absolute number
Data-update interval	New records are published continuously, so this could be updated every quarter.
Interpretation of the data	The number of companies working with nanotechnology is a critical measure of the breadth and diffusion of the technology. However, simply asking companies whether they use nanotechnology introduces two types of error – companies may inaccurately claim to use nanotechnology to enhance the 'high-tech' image of their firm, and conversely, firms producing consumer products may wish to obscure the fact that they use nanotechnology, fearing the public's response. With this in mind we propose an objective definition of what constitutes a nanotechnology company, using activities such as publications, patents and project participation.
Pitfalls in interpretation	This indicator is likely to undercount company activity, as some developments will not result in patents, publications or projects.
Rating: complexity	3; a simple indicator but complex to produce
Rating: labour intensity / cost	3; gathering the data is a complex process, but subsequently analysing it is quite straightforward
Estimated resources to collect and analyse data	Producing this data would require approximately 30 days to establish, and 10-15 days to repeat annually. Time consuming elements include defining keywords for publication analysis, plus identification and cleaning of duplicate records.
Overall assessment	Despite its complexity, this indicator is worthwhile – not least because additional analysis and indicators are possible when the company population has been developed.

7.1.2 Example of using the indicator

An example of this data collection process was run during the ObservatoryNano project in 2011. This led to the identification of a population of 1453 companies in the European Union and associated countries. The distribution of these companies by country is shown below.

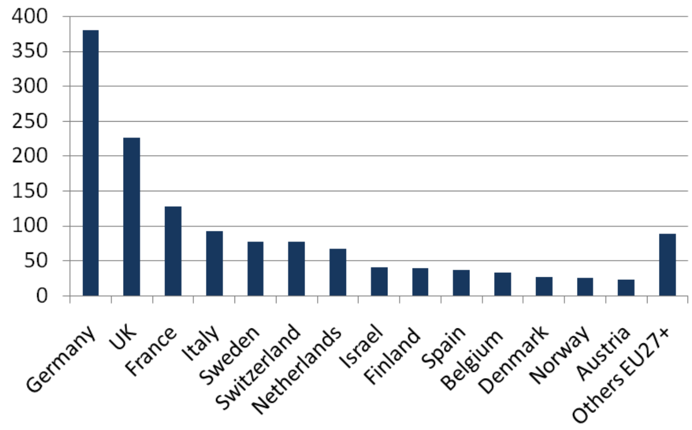

Figure 4. Nanotechnology companies by country (Source: ObservatoryNano 2010)

7.2 Employment

7.2.1 Description of the indicator

Employment	
Type of indicator	Quantitative Outcome Indicator
Description	This indicator measures the extent to which firms using nanotechnology are creating jobs
Policy relevance	Employment is one of the most important impacts that innovation policy should lead to, and therefore it enables a cost/benefit analysis for innovation funding to be performed (i.e. what is the relation of nanotechnology investments to nano related employment)
Variables	These include the absolute level of employment in companies using nanotechnology, as well as change over time.
Source of data (and identification of needs for new/better data generation)	This data would need to be obtained from the company survey. Overall employment figures collected by national statistical agencies generally do not include technology usage as a category.
Methodology for the compilation of the reliable indicator	This indicator would be obtained in the company survey, using two questions; "What percentage of your company's employees work in nanotechnology related roles?" and "How do you expect this to increase in the short to medium term?" This data would then need to be cross-referenced with the question "what is your company's total headcount", which would then give an overall figure for employment. The challenge with this data is similar to that of investment and revenue, in that it may be difficult for some companies to identify which employees are working with nanotechnology, either because of definitional difficulties or because they have limited visibility over other areas of their company.
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Employment numbers would be able to be compared to demographic data about firms or groups of firms, enabling a breakdown by country, sector, age and size.
Unit	Absolute numbers and rates of change.
Data-update interval	This data would be collected in an annual company survey.
Interpretation of the data	The data would enable conclusions to be drawn about the extent to which nanotechnology adoption is having an effect on job creation.
Pitfalls in interpretation	Other factors beyond simply technology usage will also

	affect job creation, including local economic conditions.
Rating: complexity	1
Rating: labour intensity / cost	1; the difficult of gathering this data is minimal once the survey itself is in place.
Estimated resources to collect and analyse data	Company survey as a whole would require 60-120 days to develop fully for the first time. Repeating the survey would require approximately 40 days.
Overall assessment	This is a critical metric that is reasonably simple to include once the survey is in place

7.3 Revenue and Profitability

7.3.1 Description of the indicator

Revenue and Profitability	
Type of indicator	Quantitative Outcome Indicator
Description	This indicator measures the profitability and growth of companies using nanotechnology and compares this to sector averages
Policy relevance	The firm level argument for adopting new technologies is that this will lead to increases in revenue and/or profit, through expanding market share, entering new markets and reducing costs. This metric measures the extent to which this is the case for companies that use nanotechnology.
Variables	Profit, as a percentage of revenue. Growth, expressed as a proportion of previous financial year's revenue.
Source of data (and identification of needs for new/better data generation)	Individual profit and growth rates would be obtained from the companies themselves within the survey.
Methodology for the compilation of the reliable indicator	This information would be obtained by asking the questions "What was your company's annual revenue in 2010?" and "What was your company's operating profit (EBIT[42]) as a percentage of revenue in 2010?". If the same data is collected over time from the same respondents, changes in revenue and profitability can be measured. This could then be cross referenced with sector and 'nanointensity' measurements (percentage of products, employees, sales related to nanotechnology) to give an indication as to whether a company's use of nanotechnology is having an effect on their revenue and profitability.
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Profit and Growth numbers could be compared to demographic data about firms or groups of firms, enabling a breakdown by country, sector, age and size.
Unit	Percentage
Data-update interval	This data would be collected in an annual company survey.
Interpretation of the data	The data would enable conclusions about the extent to which nanotechnology adoption is having an effect on the performance of individual companies, helping in the identification of barriers to successful exploitation of nanotechnologies.
Pitfalls in interpretation	Other factors beyond simply technology usage will also affect revenue and growth, including local economic conditions.

[42] Earnings before interest and taxes

Rating: complexity	1
Rating: labour intensity / cost	1; the difficulty of gathering this data is minimal once the survey itself is in place.
Estimated resources to collect and analyse data	Company survey as a whole would require 60-120 days to develop fully. Repeating the survey would take approximately 40 days.
Overall assessment	This is a useful metric that is reasonably simple to include once the survey is in place

7.4 Confidence

7.4.1 Description of the indicator

Industrial Confidence	
Type of indicator	Qualitative Impact Indicator
Description	This indicator measures the degree of confidence of companies that nanotechnology will have a positive impact on their business. Confidence indicators are commonly used in industry and consumer surveys to assess attitudes of those making investment or purchase decisions. For nanotechnology, an industrial confidence indicator would complement an analysis of barriers to adoption, showing how much effect those barriers have in reality
Policy relevance	This measures the extent to which efforts to support development and remove barriers are strengthening industry's confidence in the technology, and therefore stimulate them to invest in the technology
Variables	Five point confidence scale
Source of data (and identification of needs for new/better data generation)	Data will be obtained from the company survey.
Methodology for the compilation of the reliable indicator	A question in the company survey will be "How much impact do you believe nanotechnology will have on your business in the next year? Strong Negative Impact / Negative Impact / No Impact /Positive Impact /Strong Positive Impact
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Given sufficient survey responses, confidence can be broken down by company size, sector, country and firm age
Unit	Five point confidence scale
Data-update interval	This data would be collected in an annual survey
Interpretation of the data	This data can be interpreted as a measure of the extent to which companies intend to invest in and deploy nanotechnologies
Pitfalls in interpretation	Confidence may be affected by firm and industry-specific factors, as well as the technology itself.
Rating: complexity	1
Rating: labour intensity / cost	2; monitoring process is rather time consuming
Estimated resources to collect and analyse data	Company survey as a whole would require 60-120 days to develop fully. Repeating the survey would take approximately 40 days.
Overall assessment	A confidence indicator is a useful measurement of industrial sentiment, and would be simple to produce once the survey procedure is in place.

7.4.2 Example of using the indicator

An example of a confidence indicator can be derived from the European Commission's Public Online Consultation towards a Strategic Nanotechnology Action Plan 2010-2015 ([43]), which found that over 50% of industrial respondents had high expectations, and 40% described themselves as reasonably optimistic about nanotechnology.

[43] http://ec.europa.eu/research/consultations/snap/report_en.pdf

8. FRAMEWORK INDICATORS

8.1 Public opinion on nanotechnology

8.1.1 Definition of the indicator

Public opinion on nanotechnology	
Type of indicator	Quantitative and Qualitative Framework Indicator
Description	Public opinion indicator contains some core questions on nanotechnology. Cross-national public opinion would be collected by interviews as part of Eurobarometer survey. The idea is that these questions would remain unchanged in forthcoming barometers, which enables time-trend studies. It would be useful to have same questions that the General Social Survey (GSS) in the USA ([44]) is using for the comparison.
Policy relevance	The public opinion on nanotechnology is important for understanding the challenges posed by the public awareness of and attitudes towards nanotechnology commercialisation.
Variables	The variable are: How much respondents have heard about nanotechnology: • A lot • Some • Just a little • Nothing at all • Don't know Benefits and harms of nanotechnology: three options • Benefits will outweigh harmful result • "Benefits will be about equal to harmful results" • "Harmful results will outweigh benefits" The data can be cross-tabulated on various variables, such as age, sex, education etc.
Source of data (and identification of needs for new/better data generation)	Data can be collected as part of the European Commission's Eurobarometer. The questions would be based on the experience of similar questions in the US General Social Survey (GSS) since 2008[45]
Methodology for the compilation of the reliable indicator	In the US public knowledge on nanotechnology and public opinion on nanotechnology has been studied as part of the GSS ([46]). The GSS contains a standard 'core' of demographic, behavioural and attitudinal questions, plus topics of special interest. The questions presented in the survey (2008) are as follows ([47]): • How much have you heard about nanotechnology? Have you heard a lot, some, just a little, or nothing at all? (1-4) • Nanotechnology involves manipulating extremely small units of matter, such as individual atoms, in order to produce better materials (True or False)

[44] GSS conducts basic scientific research on the structure and development of American society with a data-collection program designed to both monitor societal change within the United States and to compare the United States to other nations (see http://www.norc.uchicago.edu/GSS+Website/).
[45] Science and Engineering Indicators: 2010, Chapter 7 (http://www.nsf.gov/statistics/seind10/c7/c7s.htm)
[46] See Footnote 45.
[47] More detailed information on the methodology, questions, and categories for answers can be found from: http://www.norc.uchicago.edu/GSS+Website/Publications/GSS+Questionnaires/

	• The properties of nanoscale materials often differ fundamentally and unexpectedly from the properties of the same materials at larger scales. (True or False) • Nanotechnology works at the molecular level atom by atom to build new structures, materials, and machines. People have frequently noted that new technologies have produced both benefits and harmful results. Do you think the benefits of nanotechnology will outweigh the harmful results or the harmful results will outweigh the benefits? (1-3) • If the benefits are greater (previous question): Would you say that the balance will be strongly in favour of the benefits, or only slightly? • If harmful results are greater (previous question), would you say that the balance will be strongly in favour of the harmful results, or only slightly? The suggestion is that the questionnaire used in the GSS study (with the permission of the National Opinion Research Center) could be adapted e.g. in the Eurobarometer Study. This would provide not only information on the knowledge and attitudes on nanotechnology but would also provide comparable information with the US. This view is also shared in the 2004 communication "Towards a European strategy for nanotechnology"[48], where it is suggested that in support of the dialogue with the stakeholders concerning nanosciences and nanotechnology, "special Eurobarometer (EB) surveys should study the awareness of and attitudes towards N&N across Member States". The analysis of the indicator would require to cross-tabulate the results with background indicators such as age, sex and education to find out interrelationships between various factors.
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	EU-countries
Unit	The unit would be relative portion from the answers
Data-update interval	Data would be collected as part of a Eurobarometer, data-update interval is twice in a year.
Interpretation of the data	Survey data would describe the public opinion on nanotechnology in European Member States over the longer time frame. Potential low scores on awareness and negative scores in attitudes would indicate that there is a need to develop education on nanotechnology issues for the public.
Pitfalls in interpretation	The indicator measures a quite generic definition of "nanotechnology" and therefore the results may not correctly reflect the attitudes towards individual products and technologies.
Rating: complexity	2; a simple indicator but takes some efforts to produce
Rating: labour intensity / cost	2: gathering the data takes some effort and

[48] European Commission, COM(2004) 338 final

	collaboration with the parties responsible for Eurobarometer, but subsequently analysing it is quite straightforward
Estimated resources to collect and analyse data	Producing this data would require approximately 1 day to produce the survey questions and 5 days to analyse
Overall assessment	This is a useful metric to monitor the trends in the general attitude. However, the results are quite general. The indicator is reasonably simple to add in the monitoring system.

8.1.2 Example of using the indicator

This section gives an example of using the indicator and presenting the information with a sample real world data. Below is an example of public opinion from the 2008 GSS data.

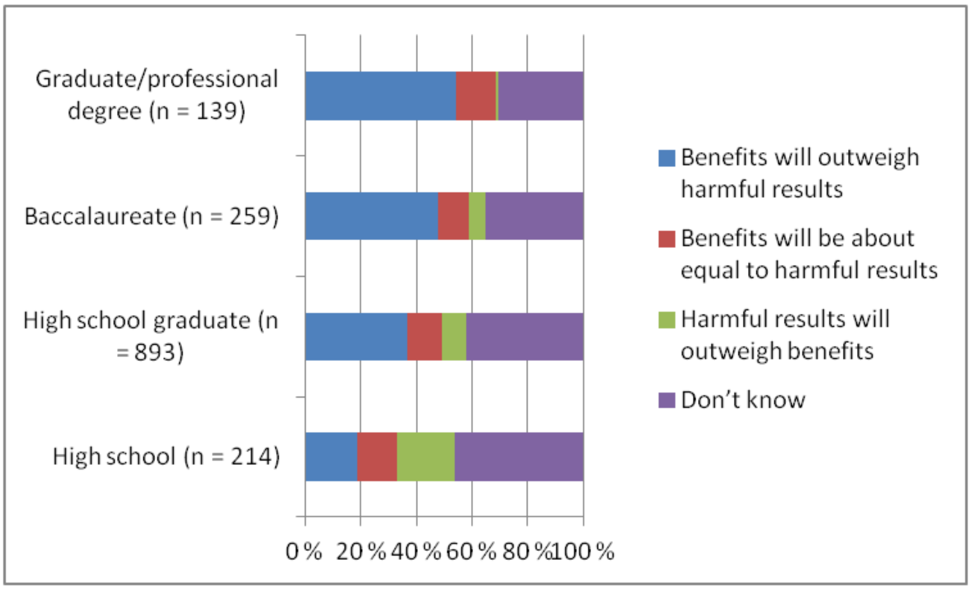

Figure 5. Public assessment of benefits and harms of nanotechnology

Source: University of Chicago, National Opinion Research Center, General Social Survey,2008.

8.2 Stakeholder opinion on nanotechnology

8.2.1 Definition of the indicator

Stakeholder opinion on nanotechnology	
Type of indicator	Qualitative Framework Indicator
Description	Stakeholder opinion survey would be almost like public opinion survey but with a more specific target group. Survey contains some core questions on nanotechnology. Cross-national stakeholder opinion survey data would be collected from individual researchers, research organisations, industrial organisations, public authorities and NGOs.
Policy relevance	The indicator set is relevant for understanding the key dimensions related to expectations and concerns as well as expected benefits and risks. This information can be used to assess various policy measures as well as to launch additional studies related to key issues
Variables	The basic dimensions of the variables would cover the

	following topics: • Benefits • Risks • Concerns • Governance • Awareness • General policies • Research policies
Source of data (and identification of needs for new/better data generation)	A separate survey would be used (in addition to policy survey and company survey). The basic questionnaire would be based on a selection of questions used in the 2009 Public Online Consultation of the document: "Towards a Strategic Nanotechnology Action Plan (SNAP) 2010-2015. Internet-based software package IPM (Interactive Policy Making) used in the public consultation or any other online survey instrument can be used.
Methodology for the compilation of the reliable indicator	The key stages of the survey production would be the following: • *Designing the survey instrument* The questionnaire is suggested to be based on the survey conducted by the EC in the 2009 Public Online Consultation of the document: "Towards a Strategic Nanotechnology Action Plan (SNAP) 2010-2015. This would provide a pre-tested questionnaire as well as comparability across time. The survey is presented in the Supplement 3. • *Gathering the group of respondents* The target group should be collected by the EC staff based on previous studies, networks and projects. The collection of contacts and their contact information needs to be updated and validated as well as cleaned of obsolete information. • *Launch the on-line survey* The survey needs to be converted to an on-line form. The survey can be carried out by any existing survey software. • *Gathering the data* The analysis of the indicator would require to cross tabulate the results with background indicators such as country, organization type and sector to find out interrelationships between various factors.
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Comparing the indicators with demographic data about the firms themselves would enable a breakdown of this figure by country, sector, response group etc.
Unit	The unit depends on the particular question.
Data-update interval	The suggestion is that the survey would be conducted triennially or every 4 years.
Interpretation of the data	Survey data would describe the stakeholders' opinion on nanotechnology in European Union Member States over the longer time frame.

Pitfalls in interpretation	The data represents the opinion of stakeholders, which might use their answers as means to drive various policy interests. The survey results are also quite general and therefore the most interesting or surprising results should be supplemented by separate studies.
Rating: complexity	2: A simple set of indicators but takes a significant effort to produce
Rating: labour intensity / cost	3: Gathering the data takes effort since a separate survey needs to be produced, but subsequently analysing it is quite straightforward
Estimated resources to collect and analyse data	The production of this data will require a separate survey, which will require up to 2 person months.
Overall assessment	A useful indicator set to identify technological and policy barriers and challenges

8.2.2 Example of using the indicator

The example shows the benefits expected from nanotechnology by industry respondents, broken down by sector.

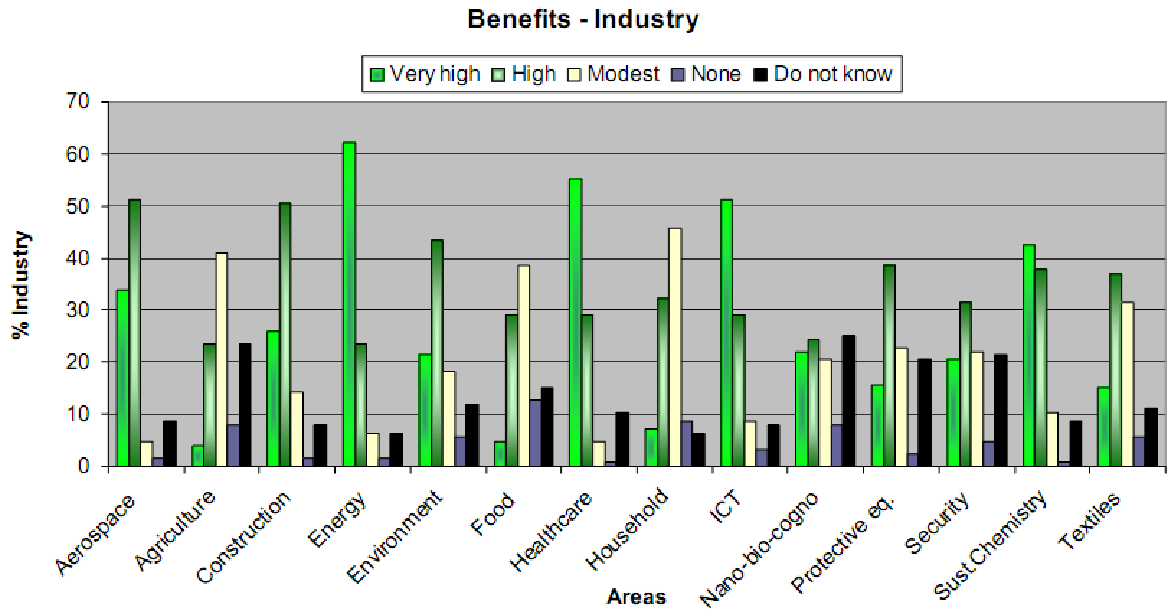

Figure 6. Expected benefits from nanotechnology (Source: 2009 SNAP Public Consultation)

8.3 Nanotechnology infrastructure and networks

Information on Nanotechnology infrastructure and networks may be collected as an additional framework indicator. Since the exact amount of investments in infrastructure dedicated to nanotechnology is difficult to produce, it is advised that the development of infrastructure and networks would be collected as a separate study based on and within the lines produced by Nanoforum in its report "European Nanotechnology Infrastructure and Networks" in 2005 and 2007. The information collected would be based on the previous data and would be updated only.

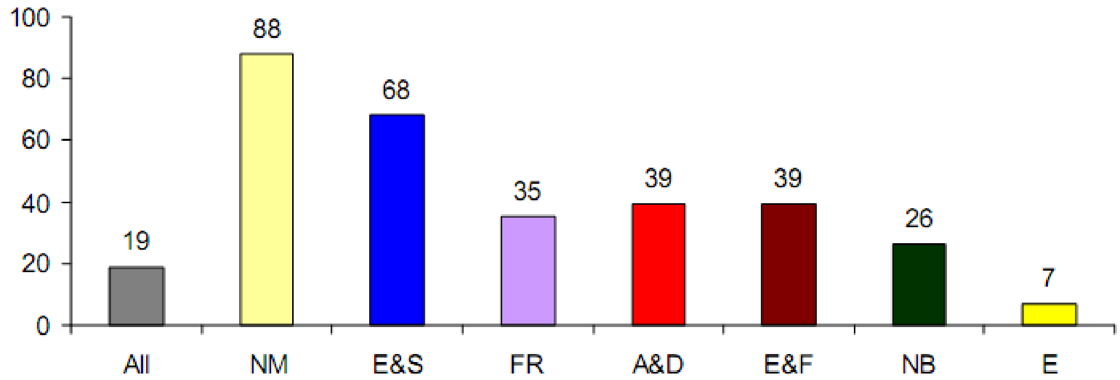

Figure 7. Facilities offering R&D infrastructure for specific areas of NST in the EU and associated states by area. (NM nanomaterials, E&S electronics and systems, FR fundamental research, A&D analytical and diagnostics, E&F engineering and fabrication, NB nanobiotechnology, E energy, All = facilities offering R&D infrastructure for all abovementioned sub-areas). (Source: Nanoforum - European Nanotechnology Infrastructure and Networks, 2005)

9. METHODOLOGICAL ISSUES CONCERNING BIBLIOMETRIC INDICATORS

9.1 Publication data

9.1.1 Publication databases

In the proposed monitoring system it is assumed that access to bibliometric databases is possible. There are several options, but two of them stand out:

- purchase data from a data provider, e.g. Thomson Reuters (TR), or, as an alternative, Scopus.
- get access to data via a research unit or company that have access to the full database.

Bibliometric analyses rely on databases built on publication data and indexing of references. As an example of how this can be achieved we will use TR and their Web of Science database, but we are aware that there are other options. TR indexes worldwide publications and all countries, with only a few exceptions, are represented in the database. Therefore, we can describe the database as having global coverage. With each indicator that builds on the use of TR data there is a possibility to cover all relevant countries.

Nowadays, there are several proceedings databases available where papers in preparation for publication in journals are indexed. In our opinion these are not necessary for the NST monitoring system, but this is a question open for discussion and the answer to a large extent depends on the objectives for the monitoring system. With more advanced ambitions there follows a need to have data sources able to meet the specific set of criteria.

In the following a prerequisite is that data is delivered by the data provider in the format of tagged text files. Each yearly delivery contains more than 1 million new publication records. The provider also complements and corrects old data. Since there is a certain time lag between a scientific document's publication and its entering into the indexes, updates too early in the subsequent year will not include all publications that were published during the preceding year.

9.1.2 Data parsing software

Publication data should preferably be parsed from the delivered files and loaded into a relational database, e.g. a SQL based program, using a loading program that has to be developed.[49] Among the tasks to be fulfilled are the creation of reference values for fields and journal normalisation of citation counts, which have to be calculated and stored in the database. There are many other data preparation issues in the early phases of operation. Some of these actions and procedures are briefly described below.[50]

When the publication records have been loaded into the database, a number of refinements and calculations, as already mentioned, should be performed in order to create a relevant database for indicator calculations and other operations in the context of the Nanometrics system. Among these, the assignment of references to cited articles is of the outmost importance. Data providers have systems for solving these issues and we suggest that the procedures to be established for the Nanometrics system should cautiously be congruent to the system of the data provider.

Setting up an efficient work situation for the use of bibliometric data requires a specialised software and access to bibliometric expertise. There are, of course, several options for this and for a long term investment as a monitoring exercise would be, we recommend acquiring relevant competence and developing the best possible data handling procedures.

9.2 Publication counting issues

There are several methods for counting publications; the choice of which depends on the level of analysis. Beginning at the world level we find that there is no need for dividing publications into

[49] See e.g. www.leydesdorff.net

[50] This part is based on: Sandström, U (2009); Sandström, E & Sandström, U (2008), Kronman et al. (2010).

shares for country, region, institution or author. As soon as we enter the next, country, level we face the problem of assignment of credit to contributing countries. Publications may be counted either in integer counts, full counts or in fractional counts based on the share of addresses, i.e. contributors to the publication. The relation between these concepts can be further explained with more prudent definitions:

P	Full Counting	Number of unique articles per unit
IC	Integer Counting	All authors article shares counted as integers
Frac P	Fractional Counting	Article items divided by the number of authors (or units).

Full (whole) counting gives full credit to a country when at least one of the authors is from this country. Integer counting is used when we want to have a country share based on number of authors from each country – in this case each author is given full credit. Fractional counting is used when we give credit for a publication equal to the fraction of authors from the unit under consideration. These are the main three methods. However, several fractional counting methods exist, including the assignment of extra credit to the first author, or the corresponding author, but equal partition among all the addresses or authors is used here. Fractional counting is important and a necessary part of bibliometrics, as shown by Gauffriau, Larsen et al. (2005).[51]

In most fields of research scientific work is done in a collaborative manner. This is the case also in NST; in general there are two institutional addresses per paper and 12 per cent of articles have more than three institutional addresses. Collaborations make it necessary to differentiate between whole counts and fractional counts of papers and citations. Fractional counts give a figure of weight for the contribution of the group to the quantitative indicators of all their papers. By dividing the number of authors from the unit under consideration with the number of all authors on a paper we introduce a fractional counting procedure. Fractional counting is a way of controlling for the effect of collaboration when measuring output and impact. In consequence, from fractionalised figures we can analyse to what extent the group receives many citations on collaborative papers only, or if all papers from the group are cited in the same manner.

Fractionalisation can be made on subjects, addresses, authors or any other feature of the publication. Calculations should use a weighting procedure based e.g. on the analysed unit and its fraction of the addresses in the publication. Number of addresses on each publication needs to be counted and denoted as part of the publication record. The total number of addresses is part of each publication record and used as a denominator when calculating fractionalised publication counts and weighted citation indicators.

An example might explain the different measures: Assume the bibliographic description of a paper containing five authors (A, B, C, D, E) from three different institutions (U1, U2, U3). If we know the association between authors and institutions we might find that A – U1; B – U2; C – U3; D – U3; E – U3. With full count we would have one article per unit, i.e. one count per institution. With integer counting we would have five "counts", and with fractional counting we would have 0,2 article shares for U1 and U2 respectively, and 0,6 article shares for U3. The difference between methods is obvious and as collaboration is increasing the rational fractionalisation is given.

9.3 Normalisation issues

There are a number of different categorisations of publication data that could be the basis for normalisation. Normalisation is a standard method for comparing likes with likes and not apples with pears.

9.3.1 Document Types

Publications are often classified according to different document types. There are about 30 different types in the Thomson Reuters (Web of Science) database, fewer in recent years, whereof the most important are Articles, Proceeding Papers, and Reviews,. Categories are not unique and there are to a large extent double assignations of document types as is shown in

[51] Gauffriau M and PO Larsen (2005). Counting methods are decisive for rankings based in publication and citation studies. Scientometrics 64(1): 85-93.

Table 10. In the Table are shown statistics for the 18 journals that accounts for about 90% output in dedicated Nanoscience and Nanotechnology journals.

Table 10. Dedicated Nano Journals 2004-2011: document types in the Web of Science database

Document Category	No of Docs	Per cent
Article	89 807	96,837%
Proceedings Paper	15 714	16,944%
Review	1 124	1,212%
Editorial Material	877	0,946%
Correction	537	0,579%
Letter	223	0,240%
News Item	135	0,146%
Biographical Item	34	0,037%
Book Chapter	6	0,006%
Bibliography	1	0,001%
Book	1	0,001%
Reprint	1	0,001%
Integer Count	**108 460**	**117,0%**
Full Count	**92740**	**100,0%**

Source: Web of Science as of April 23, 2012. Sums add up to more than 100% due to duplicated assignation.

Bibliometric analyses including citation level normalisations (i.e. comparisons to other publications of equal type) take the document type into account, since different document types tend to have different citation characteristics. Out of the document types listed in Table 10, Article, Letter, Proceedings Papers and Review are considered as "citeable documents". These are the only types considered as viable (suitable) for analytical work, i.e. citation analysis. Therefore, when building a Nanometrics system of indicators it is necessary to take the principles of citability into consideration. Otherwise, the data used will be corrupted by Editorials and News Items that are of low importance from the scientific point of view.

9.3.2 Subject categories

When using classification systems, different scientific field categories are assigned to journal and sometimes even to journal issues. The number of fields managed in the Thomson Reuters database has varied over the years; at present there are about 250 subject fields in the database, whereof 247 have been in use since year 2000. An illustration is the subject category "Nanoscience & Nanotechnology" which entered into the Web of Science database in 2005 consisting of 27 journals. Over the years the category has more than doubled to include 59 journals by 2010.

Journal categories are one way of finding a re-based (normalised) average value for a whole field or areas of science and technology. The task is to calculate field reference values in order to establish the field normalisation procedure. Techniques for normalisation are since long a much debated issue in the bibliometric society. Consequently, it is necessary to take part in that discussion and mandatory to follow up on all new initiatives in order to be able to set up an excellent bibliometric instrument for the monitoring system.

The average number of citations for publications of a certain document type a certain year in a certain field is the reference value. The reference value is calculated for each combination of subject field, publication year and document type according to a specific formula given in the fiche called "Quality of Papers".

9.3.3 The subject field "Multidisciplinary Sciences"

Thomson Reuters uses the subject tag "Multidisciplinary Sciences" for journals that contain papers from many different scientific fields, such as *Nature and Science* and *Proceedings of the National Academy of Sciences (PNAS).* This creates a problem for bibliometric analyses involving field relative indexes, since this implicates that papers in these journals are not compared to other papers of their field, but rather to the group of journals that are classified as "Multidisciplinary Sciences". This problem is underscored by the fact that the journals tagged with "Multidisciplinary Sciences" regularly are esteemed journals with high average citation levels. Thus it is likely that the article will receive a low relative citation rate.

A simple solution to find a more article-relevant scientific field classifications is to re-classify all articles in that category, by the use of a simple algorithm, to the subject fields indicated by the references employed by the citing article. This method is called "item by item reclassification" by Wolfgang Glänzel et al.([52])

9.4 Citation issues

Most publications receive relatively few citations, with only a tiny minority being heavily cited.[53] Therefore, citation distributions are skewed and averages are not really meaningful as reference values. This problem is addressed, by using the logarithm of citation values, in the Standardised Citation Score (SCS).[54] But, there are other concerns when we come to citations: Comparing over areas is one problem for a metrics built on scientific publications. Also, the time interval is important and might implicate unfair comparisons when, e.g. young researchers are put side by side to older colleagues.

9.4.1 Citation window

One important factor that has to be accounted for is the time effects of citations. Citations accumulate over time, and citation data should cover comparable time periods. However, in addition, time patterns of citation are far from uniform and any valid evaluative indicator must use a fixed window or a time frame that is equal for all papers, i.e. an appropriate method for normalization of citations has to be found.

While a fixed citation window has some advantages, the open citation window has the advantage of gathering as much citation data as possible for indicator calculation as long as the reference values are considered for each year. There is a good correlation between normalised citation rates calculated from 2-year, 5-year and an open citation window at aggregated levels (larger units like universities or countries).

An open citation window will count references from all publications published up to the time the analysis is performed. For a publication published year 2000 and analysed year 2009, references from publications published years 2000 – 2009 would then count as citations.

9.4.2 Self-citations

Citations can be understood as a quality indicator in the sense that the cited work has been of use for the citing work. This reflects some kind of scientific usability and the number of citations a publication receives can thus be used for performance comparisons.[55] Even when a researcher refers to his own previous work, this can be said to implicate a usability of former work. Many voices in the discussion over scientific quality consider citations as indicators of recognition and consequently they do not accept that self-citations are included in a measure of recognition. There are many reservations against scientometrics based on anecdotes of self-citations.

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[52] See Glänzel, W., & Schubert, A. (2003). A new classification scheme of science fields and subfields designed for scientometric evaluation purposes. Scientometrics, 56(3), 357-367).

[53] Narin and Hamilton (1996)

[54] McAllister, P. R., Narin F., Corrigan J. G. (1983), Programmatic evaluation and comparison based on standardized citation scores, IEEE Transactions on Engineering Management, 30 : 205–211.

[55] C.f. Glänzel & Schoepflin (1999), "...we interpret the concept of citation as one important form of use of scientific information within the framework of documented science communication" (p.32). Information Processing and Management 35 (1999) 31-44.

To summarise, we identify two different narratives behind the self-citation discussion, either the usability narrative, or the recognition narrative. In the latter version, there is no place for self-citations and they have to be taken away from the citation counts in bibliometric studies.

Self-citations can be defined in several ways; usually with a focus on co-occurrence of authors or institutions in the citing and cited publications. In this monitoring system we follow the recommendation to eliminate citations where the first-author coincides between citing and cited documents. If an author's name can be found at other positions, as last author or middle author, it will not count as a self-citation. This more limited method is applied for one reason: if the whole list of authors is used the risk for eliminating the wrong citations will be large. On the down-side we will probably have a senior- bias with this method; this will probably not affect units of assessments, but caution is needed in analysis on the individual level. Anyhow, the big question is whether self-citations should be taken away or not. The answer is not self-evident, but an up-to-date monitoring system must include procedures for a relevant elimination of self-citations.

9.5 Harmonisation issues

9.5.1 Addresses

Normally, bibliographic databases require a considerable amount of data cleaning before they can be confidently used for analytical purposes. Typically, publication data are provided with addresses that can be parsed into several fields: Complete address as supplied by the publisher, includes Organisation; Sub-organisation (e.g. department); Postal code; Street address; City; State or region and Country. Postal code can be very useful for the work with harmonisation of addresses.

The formats for these addresses are originally supplied by the authors. Consequently, there may be many different variants of the main organisation name, especially for organisations outside the US; in the US the TR personnel seem to have good knowledge and they correct institutional names. When institutional names are translated into English there may appear several synonyms, e.g. the technical university in Stockholm, KTH, appears as both *Kungl Tekn Hogskolan* and *Royal Inst Technol* and many other names. Actually, with many years of experience, and with few exceptions, most European universities appear under 15-30 synonyms. This makes the harmonisation work tedious and time consuming. Therefore, it is needed to perform, in this stage of data preparation, a script that translates the most common institutional names into one standard name. Using such a script a large part of the harmonisation work can be automated and manual correction of the address field is not an impossible task. The software VantagePoint is one option for this using of fuzzy matching with rule sets. Already harmonising the most common institutional name variants – e.g. "Linkoping Univ" and "Univ Linkoping" into "Linkoping Univ"; "Univ Leiden" and "Leiden Univ" into "Leiden Univ" – reduces a large part of the address variation in the database.
As pointed out in the ObservatoryNano report[56] there are "umbrella organisations" which consist of multiple branch organisations, e.g. Max Planck Gesellschaft in Germany. Well-known umbrella organisations are the CNRS in France, RAS in Russia and CSIC in Spain, but there are also a number of American university addresses which require data modification in order to give more detailed information.

9.5.2 Author names

For most of the indicators in the monitoring system there is no need for an author name cleaning procedure. The only indicator that needs such an exercise is the manpower estimate. Author names are not unique in the database, as there are homonyms and synonyms. Therefore, it is necessary to use specific measures in order to identify distinct authors as there are no identifier of persons in the input data, and no simple way to tell if two identical author names denote the same one or two different persons (a homonym), but there are possible automatic solutions to this problem proposed by Soler (2007) and Guerney et al. (2012.)[57].

[56] Newman et al (2010) Report on Benchmarking Global Nanotechnology Scientific Research: 1998-2007.
[57] Soler, J.M. (2007): Separating the articles of authors with the same name. Scientometrics, 72 (2): 281-290; Gurney, T; Horlings, E; van den Besselaar, P (2012): Author disambiguation using multi-aspect similarity indicators. Scientometrics Vol 91 (2): 435-449

The author names are registered in the Thomson database using the form *Lastname, Initial(s).* Problems like varying transliteration, non-consistent use of initials and mix-up of middle names and given names might cause problems when trying to locate the publications of a specific researcher. Other problems can be described as homonyms or synonyms. In the first case two or more persons have the same name, in the latter case one distinct author/person appear under two or more variations of a name.
To put it simply, TR source files contain a list of author names and a list of author addresses. For records entered into the Web of Science (TR) before 2008 there is no absolute correlation between names and addresses, except for the corresponding author name. As author names and author addresses are processed in sequence according to the information from the journal issue, a relation between the first author name and the first author address can be presumed, but there are no guaranties that this is the case. In 2008 records contains an indication of which author names and addresses are related. The reprint address also contains an author name, and therefore this information can be used as an identifier of an author-affiliation relation.

9.6 Cluster analysis

The goal of cluster analysis is to divide data into a number of subsets (clusters) according to some given similarity measure, e.g. co-occurrence of references[58]. Bibliographic coupling is an established method within bibliometrics and has been shown, by Klavans and Boyack (2010),[59] to work well for the purpose of clustering of related papers into coherent groups (clusters). The methods applied for bibliometric visualization are well established and have been applied to bibliometric data since the 1970s or even earlier – they can be considered as standard methods in the context of bibliometric studies.

9.7 Example data for indicator fiches

With the presentation of indicator fiches there are example data. It should be noted that data were collected from two different samples:

1) Publications (articles) in journals categorised as "Nanoscience & Nanotechnology" (2004-2011)[60] and,
2) Publications (articles) identified using a keyword based search strategy similar to the one developed by the Georgia Tech team[61].

The sample data represent two different delineation strategies and can therefore to some extent illustrate differences between them. However, the main reason as to why two strategies were developed in this project are to be found in the fact that the second strategy gave a too large sample for some of the analyses that were to be used for hot topics and the specific noun phrase methodology applied (hardware capacity limitation).

In both cases example data were collected as downloads from Internet Web of Science (March and June, 2011). Please, note that example data operations do not represent the normalisations recommended in this text.

All our calculations and all our visualizations are shown as examples and have been performed using an internally developed software program. The program integrates statistical calculations, co-occurrences, visualizations, text-based analysis (e.g. noun phrases) etc.

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[58] Chen, CM (2003): Mapping Scientific Frontiers: The Quest for Knowledge Visualization. Berlin: Springer Verlag.
[59] *JASIST* vol 61, iss 12, pp 2389-2404 DOI: 10.1002/asi.21419 "Which citation approach represents the research front most accurately?" C.f., Klavans, R. & Boyack, K. W. (2008). Thought leadership: A new indicator for national and institutional comparison. Scientometrics, 75(2), 239–250.
[60] Leydesdorff, L (2008): The delineation of nanoscience and nanotechnology in terms of journals and patents: A most recent update. SCIENTOMETRICS Vol 76 (1): 159-167 DOI: 10.1007/s11192-007-1889-3
[61] Porter, A.; Youtie, J; Shapira, P; et al. (2008): Refining search terms for nanotechnology. Journal of Nanoparticle Research Vol 10 (5): 715-728 DOI: 10.1007/s11051-007-9266-y

10. DATA SOURCES: COMPANY SURVEY

Data for some impact indicators could be obtained by adding questions to existing data collection processes (the European Venture Capital Association (EVCA) survey, The Project on Emerging Nanotechnologies (PEN) Product Inventory), and these will become increasingly important as the diffusion of nanotechnology increases. However, some types of input and impact data will only be able to be obtained by asking companies directly. Therefore a company survey is proposed which could be run on an annual basis to provide important indicator data about the progress of nanotechnology development.

However, there are some methodological challenges in the design and distribution of the survey and in the analysis of survey results which will need to be taken into account. These will be discussed in the following sections. This analysis is informed both by expert engagement and a study of other nanotechnology surveys that have been carried out around the world (see box 1).

Other Company Surveys

Verein Deutscher Ingenieure (VDI)
VDI carried out a survey of German nanotechnology companies in 2003. 800 companies were approached, of which 450 were found to be active in nanotechnology. The list of survey recipients was mainly built from company lists, including VDI's own.
The company landscape included 66% manufacturers of nanomaterials or nano-intermediates, and 29% users of externally developed technology. 75% reported that nanotechnology had opened new markets, and 60% that it had increased competitiveness in existing markets. Barriers to innovation were found to have included funding costs and a lack of skilled personnel.

Centre for Manufacturing Sciences (NCMS)
This US survey was carried out in 2005. Approaching 6000 subscribers to Small Times magazine, NCMS heard from 595 companies. 18% of these already had commercial products at this time, and 40% planned to release them within three years. Top rated commercialisation challenges were high processing costs and long times to market.

Statistics Canada: Emerging Technology Survey (2005)
By virtue of being a national statistics agency, Statistics Canada was able to approach all companies from industry codes known to be using nanotechnology. 88 companies were found to be involved in nanotechnology, accounting for 28 million USD in nanotechnology revenue, and 380 employees.

Nanotech in Finnish Industry
This survey was carried out biannually, most recently in 2008. The survey was carried out by Spinverse on behalf of Tekes, and found 202 companies with nanotechnology activities in some form, 65 of which had commercial products or processes. The survey also captured investment information, finding that industrial investments totalled 56.6 million Euro and venture capital 9.5 million Euros.

10.1 Survey Design

The fundamental principles of survey design are that the survey should:

- ask for information in a clear and consistent manner
- respect the time of the survey respondent by keeping questions to the minimum required
- ask only for information of which there is a reasonable expectation that the respondent will be able to provide

The following questions have been proposed for the company survey, with associated commentary to explain the rationale behind each question.

Introduction
The introduction to the survey should clearly state who is conducting the survey and for what purpose. The data protection policy should also be stated, as well as what feedback the respondent can expect to receive after completing the survey. An example of this text would be:

Thank you for participating in this survey, administered by Spinverse on behalf of the European Commission Directorate General for Research and Innovation. The data provided by this survey will contribute to a better understanding of the impact of nanotechnology, as well as identifying challenges and bottlenecks that need to be addressed.

Your answers will be treated in strict confidentiality. Individual answers will only be seen by a limited number of Spinverse and European Commission personnel, and will never be circulated outside these organisations. Data from this survey will be reported in aggregate form, and it will not be possible to identify individual responses.

To thank you for participating in this survey, we will give you preview access to the results before they are published more widely.

About you and your company
The questions in this section provide basic demographic data about the respondent, in order to support analysis by sector, country, etc.

1. What is your company name?

____

2. When was your company founded?

____

3. In which country is your company's headquarters located?

____

It will be important to understand whether the position of the respondent should be taken into account when analysing their responses. This could be the case where a division manager has limited visibility to nanotechnology usage in other areas of their company, for example.

4. What is your job title?

____

The respondent will also be asked to define which industry their company is primarily working in, according to the National Accounts in Europe (NACE) industry classifications[62]. Respondents selecting 'C – Manufacturing' (which is expected to account for the majority of respondents) will be asked to specify their industry in more detail. Use of this standardised system of classifications will ensure that responses are compatible with those gathered by other statistical agencies.

5. What is your company's primary industry?

____

6. If you have selected Manufacturing, what is your company's specific sector?

____

Financial Information
Companies will be asked to provide some financial information about their company, to enable indicators about the economic and employment impact of nanotechnology to be derived.
7. What was your company's total headcount in 2010?

____

8. What was your company's annual revenue in 2010?

[62] See http://ec.europa.eu/competition/mergers/cases/index/nace_all.html for a complete list

____

9. What is your company's operating profit (EBIT) as a percentage of revenue in 2010?

____

10. Are your company's shares publicly listed? If so, where?

____

A question about whether the company has received one or more venture capital investments will be asked. This will provide data for the 'venture capital' indicator, particularly providing information for companies whose investment has not been publicly disclosed. The second part of this question would only appear if the company answers affirmatively to the first part.

11. Has your company received venture capital investment within the last five years?
( ) Yes
( ) No

12. If you have answered yes to the previous question, please indicate the amount and date of investment?

	Date	*Investment Amount, Currency*	*Investors*
Seed	_____	_____	_____
Round A	_____	_____	_____
Round B	_____	_____	_____
Round C	_____	_____	_____
Other	_____	_____	_____

Use of nanotechnology

The most important set of questions relate to the respondent company's use of nanotechnology. Question 13 specifically attempts to determine the company's place in the nanotechnology value chain.

13. What is your company's involvement in nanotechnology?

- Produce nanomaterials
- Integrate nanomaterials into intermediate materials
- Use nanotechnology-enabled materials in our products
- Produce tools or instruments for production or analysis of nanomaterials
- Provide services linked to nanotechnology
- Other

14. If you have selected other, please explain your answer here:

____

The survey should also attempt to establish the extent to which the respondent company is using nanotechnology, defined in terms of share of revenue, headcount, and products. Comments from the survey pilot pointed out that this would be the most difficult question to answer, and therefore the results should be interpreted with caution. Sources of error include the respondents not knowing the nanotechnology usage of products elsewhere in their organisation, or being unable to break down research staff working on several products according to the type of technology used.

15. What percentage of your company's:

- products are nano-enabled
- employees work in nanotechnology related roles
- revenue comes from nano-enabled products or services

How do you expect this to increase in the short to medium term?

	Current Position	*Short Term (0-2 years)*	*Medium Term (2-5 years)*
Products (%)	_____	_____	_____
Employees (%)	_____	_____	_____
Revenue (%)	_____	_____	_____

16. Please indicate your firm's annual investment - expressed as a proportion of turnover - in nanotechnology-related activities at the following stages:

This may include expenditure on research and development facilities, personnel and equipment, investments in collaborative research projects, spending on production facilities and personnel, and sales and marketing expenses.

	Total (%)	*In Europe (%)*
Basic Research	_____	_____
Applied Research	_____	_____
Product Development	_____	_____
Production	____	_____
Sales and Marketing	_____	_____

The next question will help to clarify the dissemination of nanotechnology, according to the same NACE industry classifications that were used in the first part of the survey.

17. Which sectors do you sell your nanotechnology-enabled products to? (Hold CTRL to select multiple answers)
Agriculture, forestry and fishing
Mining and quarrying
Manufacturing
Electricity, gas, steam and air conditioning supply
Water supply; sewerage; waste management and remediation activities
Construction

18. If you have selected Manufacturing, which specific sectors do you sell to? (Hold CTRL to select multiple answers).
Manufacture of food products
Manufacture of beverages
Manufacture of tobacco products
Manufacture of textiles
Manufacture of wearing apparel
Manufacture of leather and related products
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Manufacture of paper and paper products
Printing and reproduction of recorded media
Manufacture of coke and refined petroleum products
Manufacture of chemicals and chemical products
Manufacture of basic pharmaceutical products and pharmaceutical preparations
Manufacture of rubber and plastic products
Manufacture of other non-metallic mineral products
Manufacture of basic metals
Manufacture of fabricated metal products, except machinery and equipment
Manufacture of computer, electronic and optical products
Manufacture of electrical equipment
Manufacture of machinery and equipment not elsewhere classified
Manufacture of motor vehicles, trailers and semi-trailers
Manufacture of other transport equipment
Manufacture of furniture
Other manufacturing
Repair and installation of machinery and equipment

A question about the geographical distribution of markets for nanotechnology-enabled products will help to clarify whether companies are selling into international customers and value chains.

19. What is the geographical distribution of your markets for these products? (Answers should total 100%)
Europe (%) ________________
North America (%) ________________

Asia (%) ________________
Rest of World (%) ________________

20. How much impact do you believe nanotechnology will have on your business in the next year?

	Short Term (0-2 years)	*Medium Term (2-5 years)*
Strong Positive Impact		
Positive Impact		
No Impact		
Negative Impact		
Strong Negative Impact		

The final question will ask about barriers to development of nanotechnology, which will help to pinpoint areas of concern in specific technologies or sectors.

21. To what extent do the following factors affect your ability to develop and introduce nanotechnology-enabled products?

Rank each of the following items on the scale: No Impact / Low to Moderate Impact / Moderate Impact / Moderate to Significant Impact /Significant Impact
- Technology and Production
- Fundamental understanding of technology
- Reproducibility of technology
- Reliability and durability of technology
- Challenges in scaling up production
- Shortage of suitable standards
- Organisational Factors
- Shortage of funding for research and development
- Shortage of funding for production
- Challenges in recruiting personnel with suitable training
- Intellectual property issues
- Markets
- Distribution challenges
- Value chain challenges (i.e. shortage of suitable partners)
- Customers are satisfied with existing products
- Products are too expensive for customers
- Customer acceptance affected by safety or regulatory issues

24. What other factors affect your ability to develop and sell nanotechnology-enabled products?
____

10.2 Distribution

10.2.1 Developing the survey

An online survey tool should be used, enabling anyone with an internet connection to respond to the survey. Custom programming of a survey tool would require more time to produce, though this would mean that the data could feed directly into an existing database of companies. Alternatively there are a number of good online questionnaire providers available at low cost, such as SurveyGizmo[63], which would cost 49 USD per year for a single user carrying out multiple surveys. A draft version of this survey has been implemented in SurveyGizmo at http://www.surveygizmo.com/s/599749/impact-of-nanotechnology .

For a Europe-wide survey, availability in major community languages other than English is likely to also increase response rate; German, French, Spanish, Italian and Polish could be used. Translation work could be carried out by the 'network partners' identified below.

[63] http://www.surveygizmo.com/

10.2.2 Distributing the survey

The most effective surveys have been carried out by those organisations that are already known to the survey respondent, such as Spinverse in Finland and VDI in Germany. In addition to increasing the confidence of the respondent that their information will be protected, these organisations are also likely to have the best visibility of companies using nanotechnology in their regions, broadening the reach of the survey.

A partnering approach is therefore recommended with which specific organisations would be identified in regions and asked to distribute the survey to their members. The offer for these partners could be that raw data from their regions only would be shared with them once the survey is complete. This could be implemented by filtering results by region.

More broadly, an invitation to participate in the survey could be distributed through the following channels:

- Contact people at EC-funded nanotechnology projects
- NMP National Contact Points
- Networks and Platforms (e.g. Nanofutures, European Technology Platforms, Nanoforum)

10.2.3 Increasing Response Rates

The average response rate to online surveys is around 5%. Several nanotechnology company surveys that have taken place have substantially exceeded this rate, with response rates of 30% or more. The three most important factors in increasing response rate have been:

- Trusted organisation behind the survey
- Clear benefit for those completing the survey
- Regular reminders by e-mail and phone

In addition to having a trusted organisation behind the survey, there must also be a clear benefit for a representative of a company to spend valuable time completing the survey. The rationales used in the Finnish and German studies were that the survey results would inform the design of future government support and funding programmes. If a company believes their participation in a survey is likely to affect future resource allocation decisions, they will be more inclined to participate – although this does also introduce a risk that survey responses will be modified to benefit the company.

An idea suggested by a workshop participant was that respondents could be encouraged to respond to the survey by being given preferential access to valuable data. Access to the survey results before they are released to the wider public could be one possibility, as would a benchmarking report showing how the company stands in relation to other firms. The other firms would not be identified, to protect their confidentiality.

Respondents rarely react immediately, and tend to require at least reminder e-mails and even phone calls. This is optimally carried out by someone with knowledge of the organisation in question, which would be another reason to use a local partner.

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SUPPLEMENT 1
INDICATOR FICHE TEMPLATE WITH META DATA

Name of indicator	
Type of indicator	Describes the type of indicator, whether it is based on quantitative or qualitative data. Describes whether the indicator describes RTD inputs, throughputs, outputs or impacts related to nanosciences and technologies (NST).
Description	Basic definition and description of the indicator. The basic information includes what phenomenon/issue that the indicator aims to measure (i.e. a capacity to tell the story), what actual factor the indicator measures, what kind of information it provides.
Policy relevance	What is the relevance of the indicator in terms of political actions and how meaningful is the indicator to various audiences (e.g. EC, stakeholders) The description includes the link with key policy issues regarding NST development as well as links with general economic policy objectives (e.g. the European action plan for Nanosciences and Nanotechnologies 2005-2009).
Variables	This describes the various factors that construct the indicator, including the name, the scale etc.
Source of data (and identification of needs for new/better data generation)	This describes the availability and accessibility to data i.e. where to get the data and how to get it: e.g. registers, survey database, literature-based sources etc., access to Web of Science, PATSTAT etc. Brief description of data collection in case the indicator is not available from existing statistical sources, e.g. make a survey or study. More comprehensive guidelines are given in a separate section.
Methodology for the compilation of the reliable indicator	Describes in detail how to extract, compile and analyse the data so that we get an indicator. E.g. "dedicated question in a company survey (survey methodology detailed in a separate section) etc."
Scope and coverage (Possible reliable sub-indicators and/or breakdowns)	Describes the comparability of the indicator e.g. across countries, regions, sectors (e.g. public/private), firm size etc.
Unit	Describes the unit of analysis, e.g. Euro; Absolute, relative etc.
Data-update interval	Describes the frequency of recurrence and punctuality
Interpretation of the data	Describes how the information provided by the data should be interpreted i.e. what does it tell to us about the issue.
Pitfalls in interpretation	This describes the reliability and validity issues with indicator definitions, the quality of the data as well as

	the relevance of the indicator
Rating: complexity	Describes the complexity of gathering, analysing and interpreting the data in the scale from 1 (easy) to 5 (difficult)
Rating: labour intensity / cost	Describes the needed human and financial resources needed for gathering, analysing and interpreting the data in the scale from 1 (light) to 5 (heavy)
Estimated resources to collect and analyse data	Information about the level of required resources to collect the data on each indicator. E.g. "desk research, one man-day of work" or "company survey, duration two months, design 5 man-days of work, analysis 4 man-days of work".
Overall assessment	Gives a brief assessment on the importance and relevance of the indicator as well as a "cost-benefit" analysis comparing the importance of the indicator with the complexity and needed resources to gather and analyse the needed data.

SUPPLEMENT 2
SUGGESTED QUESTIONS TO THE MODIFIED POLICY QUESTIONNAIRE

In order to utilise the previous experiences in collecting data on nanotechnology investments and to be able to use compatible definitions of the used indicators, we propose to add questions from a survey template used by the OECD Working Party for Nanotechnology in 2008. In addition to data on public R&D funding the survey can be also used as a tool to assess human resources.

The survey template is presented below:

RESEARCH AND DEVELOPMENT (R&D) FUNDING

1) Does your government and/or related agencies commit dedicated R&D funding to the field of nanotechnology (by the definition of nanotechnology used in your country)?

Yes

No

If Yes, please provide:

1.1 The year when this public R&D funding started

____

1.2 The total accumulated amount of this public R&D funding until present

____

1.3 A breakdown of this public R&D funding in millions of your currency by the years as indicated in the table below, including estimates for the next three years.

	2009	*2010*	*2011*	*2012 (estimate)*	*2013 (estimate)*	*2014 (estimate)*
Total public R&D funding						
Give currency						

1.3.1 If you cannot provide an estimate for the next three years please indicate whether the public R&D funding will increase, stay at the same level or decrease during this period

____

1.4 An indicative percentage breakdown of this amount of public R&D funding provided to the main R&D performing sectors as indicated in the table below:

Sector	*% of total for 2009*	*% of total for 2010*	*% of total for 2011*	*% of total for 2012 - 2014 (estimate)*
Higher education (universities and equivalent)				
Public research institutes				
Business enterprises				
Other (please specify):				
TOTAL ACCUMULATED PUBLIC R&D FUNDING	100%	100%	100%	100%

1.5 An indicative percentage distribution of the total accumulated government R&D funding amount by nanotechnology relevant areas as indicated in the table below

Technology Area	*% of total*
Electronics	
Nanobiotechnology (including medicine and pharma)	
Measurement, instruments	
Energy	
Nanomaterials	
Environment	
Other	
Health and safety	
Ethical, legal and societal issues	
Others, which?	
TOTAL ACCUMULATED PUBLIC R&D FUNDING	100%

3) Please also provide available estimates/subjective observations about whether the private business enterprise sector funding will increase, stay at the same level or decrease in your country during the next three years (please tick one option):

	Increase	Stay at the same level	Decrease
2012			
2013			
2014			

HUMAN RESOURCES

3) Do you have any data or information about the number of nanotechnology related scientists, researchers, teachers, company employees etc. available or demanded in the future in your country or have any studies been undertaken on these issue?

Yes

No

If Yes, please send us references to relevant information or studies that are available in your country.

4) What are the needs of your country in the future with respect to human resources in general in the field of nanotechnology, for example related to the adequacy of the present education system to supply company employees and researchers with the relevant skills?

____

5) Has your government and/or related agencies provided support for the introduction of specific education and training programmes aimed at the development of these human resources related to nanotechnology?

Yes

No

If Yes, please describe a few of the main ones that you consider significant and indicate whether any one of them have specifically been targeted for the needs of companies:

____

6) Will your government and/or related agencies introduce measures to attract foreign experts to work on nanotechnology in your country?

Yes

No

If Yes, please describe how:

____

7) Is your government and/or related agencies considering any changes to existing approaches with respect to human resource requirements related to nanotechnology in the near future?

Yes

No

If Yes, which are these changes and for what reason?

SUPPLEMENT 3
STAKEHOLDER CONSULTATION SURVEY

The questionnaire is a revised and shortened version of the Public Online Consultation of the document: "Towards a Strategic Nanotechnology Action Plan (SNAP) 2010-2015. As opposed to the original survey, instead of an open consultation this would be a directed consultation with a predefined group of respondents. The questionnaire is presented below:

Respondent profile

For individuals:

- Name, age, gender, country, e-mail.
- From which perspective are you interested in nanotechnologies:

… I work in a company dealing with nanotechnologies or with nano-enabled products
… I am a researcher
… I work for an authority
… I work for, or I am active in, a trade union
… I belong to a non-governmental organisation
… Other specific reason: ____

For organisations / companies:

- Name of organisation, register ID or not, country, e-mail.
- Type of organisation:

… Manufacturing or trading company involved in nanotechnologies
… Manufacturing or trading company not involved in nanotechnologies
… Association of companies (sector: ____________________________________)
… Research institute or Higher education institute
… Trade union
… Non-governmental organisation
… Other: ____

For public authorities:

- Name, country, e-mail.
- Type of public authority:

… Regulatory authority
… Authority involved in research policy
… Authority involved in market surveillance
… Authority involved in market authorisation
… Decentralised, regional authority
… Centralised authority

2. Which of the following reflects your opinion about nanotechnologies best?

… I have high expectations from nanotechnologies
… I am reasonably optimistic about nanotechnologies
… I am not really convinced that the benefits justify the effort and the potential risks
… I am opposed to nanotechnologies
… I am without an opinion so far

Comment: ____

3. Please indicate for each area what level of benefits you expect from nanotechnologies

	Very high	High	Modest	None at all	Don't know
Aerospace, automotive, and transport (e.g. weight reduction, self-cleaning coatings)					
Agriculture (e.g. efficient fertilizers, pesticides delivery)					
Construction (e.g. stronger materials, insulation materials,					
Energy (e.g. solar cells, other forms of energy conversion,					
Environment (e.g. supply of drinking water, wastewater treatment, soil remediation, emission					
Food and feed (e.g. active packaging, preservatives, enriched food, flavour, smell, taste and colours)					
Health care (e.g. diagnostics, treatment,					
Household products and other consumer products					
ICT (e.g. computing, storage, communication, media)					
Nano-bio-cogno-technology applications (e.g. human enhancement)					
Protective equipment					
Security (e.g. detection of dangerous substances, tracking					
Sustainable chemistry (e.g. enhanced process efficiency by catalysis)					
Textiles/Clothing					

4. Please indicate for each area what level of risk you expect from nanotechnologies:

	Very high	High	Modest	None at all	Don't know
Aerospace, automotive, and transport (e.g. weight reduction, self-cleaning coatings)					
Agriculture (e.g. efficient fertilizers, pesticides delivery)					
Construction (e.g. stronger materials, insulation materials,					
Energy (e.g. solar cells, other forms of energy conversion, batteries, other forms of energy storage)					
Environment (e.g. supply of drinking water, wastewater treatment, soil remediation, emission reductions)					
Food and feed (e.g. active packaging, preservatives, enriched food, flavour, smell, taste and colours)					
Health care (e.g. diagnostics, treatment,					
Household products and other consumer products					
ICT (e.g. computing, storage, communication, media)					
Nano-bio-cogno-technology applications (e.g. human enhancement)					
Protective equipment					
Security (e.g. detection of dangerous substances, tracking of objects or of persons)					
Sustainable chemistry (e.g. enhanced process efficiency by catalysis)					
Textiles / Clothing					

5. What are your main concerns about the present situation of nanotechnologies?

	Major issue	Smaller issue	Not an issue	No opinion
Europe lagging behind its competitors in exploiting the benefits of nanotechnologies				
Obstacles to innovation				
Lack of tools to implement and enforce existing regulation on environment, health and safety				
Lack of adequate information to the public on benefits and potential risks				
Lack of uniform terminology				
Lack of knowledge and transparency regarding products on the market containing nanomaterials				
Lack of proper consumer product information				
Lack of public dialogue / debate				
The possible toxicity of poorly understood nanomaterials				
The possible effects of nanomaterials on workers' health				
The possible risks from accidents when manufacturing nanomaterials				
The possible effects of nanomaterials on the environment				
Lack of new specific regulations - especially related to Nano- bio-cogno-applications (e.g. enhancement)				
Lack of adequately skilled personnel				
Security and privacy issues (e.g. the possibility to track persons)				
Ethical issues (e.g. human enhancement)				

6. How should the EU policy actions related to nanotechnologies be developed?

	Do more	Keep as now	Do less	No opinion
Active communication and dissemination of information				
Public dialogue with stakeholders including targeted feedback				
International dialogue				
International cooperation				
Support to the EU foresight studies				
Develop education and training in Nanosciences and Nanotechnologies				
Remove barriers to innovation in Nanotechnologies				
Incentives and tools facilitating innovation in Nanotechnologies				
Development of infrastructure for nanotechnology application studies including assessment				
Address safety concerns linked to Nanotechnologies				
Promote cost-effective measures to minimise exposures				
Develop better tools for assessment of risk and benefits for Nanotechnologies				
Adapt existing legislation for nanomaterials				
Improve the implementation of existing legislation				

7. Which research actions related to nanotechnologies should be reinforced or reduced in the EU?

	Do more	Keep as now	Do less	No opinion
EU-wide coordination of national / regional R&D				
Support research needed for implementing regulation (research into the safety of nanomaterials and into methods for toxicity testing and for monitoring)				
Support enabling research (into understanding, measurement, testing, imaging, and modelling of materials and properties at the nanoscale)				
Support research into applications that can contribute to EU policy objectives (such as health, environment and climate, energy, water, workers' protection, ...)				
Support research into industrial applications leading to more eco- efficient production (e.g. chemicals, biotechnology)				
Support research into other industrial applications of nanotechnologies with a high potential for innovation, new employment and new markets				
Support the development of research infrastructures				
Support centres of excellence including their networking				
Support research on ethical, legal and social aspects of nanotechnology				
Promote industrial involvement in EU R&D projects				
Foster the industrial exploitation of nano R&D results				
Ensure ethical review of EU nano R&D projects				
World-wide international cooperation				

8. Other suggestions - Comments

SUPPLEMENT 4
THE LONG LIST OF INDICATORS

During the project and the feedback for the first progress report several alternative indicators that could be used to monitor NST development were discussed. Based on the feedback, several of these indicators have been analysed. In the following paragraphs a brief summary of the indicator analysis is given. These indicators are not yet included in the monitoring system, due to various reasons related to data availability, reliability and the cost of collecting data. They may however be included in the system in the future, if their use becomes more feasible.

Graduates in science, mathematics and computing field
The indicator shows the relative share of science, mathematics and computing field in relation to all fields in higher education. It gives a general view of how the national education systems produce graduates with the general skills in science, mathematics and/or computing. However, it does not provide nanotechnology specific graduates and has been considered as too general.

S&E Technicians
The number of Science and Engineering (S&E) technicians is one potential indicator measuring the human resources in science and technology (HRST) related to nanotechnology. Eurostat does not differentiate technicians but does have a category for "Scientists and Engineers". The strength of the indicator is widespread availability but the problem on the other hand is that it is not possible to differentiate nanosciences or nanotechnology (NST) from the figures. Therefore the indicator is not very accurate in measuring NST specific researchers and technicians.

S&E Doctorates
Another possible indicator analysing the human resources in nanotechnology could be the number or relative share of S&E doctorates. The strength of the indicator is widespread availability but the problem on the other hand is that it is not possible to differentiate nanosciences or nanotechnology (NST) from the figures. Therefore the indicator is not very accurate.

Higher Education courses in NST offered per country
This indicator has the potential to measure the devotion to nanotechnology in higher education. Unfortunately at the moment the collection of data is rather time consuming and difficult and is not feasible. However, this indicator is studied in the NMP Scoreboard project and if an efficient methodology for collecting data is developed in that project the indicator could be added later to the Nanometrics indicator framework.

Higher Education degrees in NST awarded per country
This indicator is a good measure for human resources in NST. However, since nanotechnology is only sporadically categorised in the educational statistics across Europe, the collection of data would be too time consuming at the moment.

Investments in in-house training
This indicator would give a good description of the educational investments in the companies. The data is not available at the moment but an estimate on training investments could be added to the company survey.

Investments in life-long-learning
This indicator would give a good indication on how continuous building of skills and knowledge would contribute to the NST human resources base. At the moment it is difficult to differentiate NST activities from this indicator and therefore it is not feasible to use this indicator except using it as general background data.

Industrial R&D expenditure
Industrial R&D expenditure (private R&D expenditure) is an important indicator although difficult to measure. Since nanotechnology does not fit typical industry and sectoral classifications, the data is difficult to capture from official R&D statistics. Consultancy companies have extended information gathering to the private sector although the public availability of such data is poor. However, this data has been used previously by the EC e.g. in the 2005 report "Nanotechnology R&D in Europe and Beyond"[64], where the estimates of the private R&D funding were based on the information from Lux Research and Technology Review.

Another approach for assessing the private sector R&D investments is to use the data collected from the company survey and estimate the private investments from that data. Survey data is always partial but with high enough response rate the estimate is relatively accurate. The approach proposed for using the company survey is presented in the monitoring system.

Number of publicly listed NST companies
Number of publically listed nanotechnology companies indicates the commercial success and "maturing" of nanotechnology business since public listing typically requires a certain size and development stage from the companies. A problem with the indicator is that data on NST companies is rather time consuming to extract. Moreover, many of the largest companies working with nanotechnology are multinational companies (e.g. Philips, HP, 3M,) working in several fields and therefore the figures on nanotechnology may be misleading. However, trough desk study or using e.g. existing company databases collected by various organisations it is possible to distinguish some more dedicated listed nanotechnology companies.

Price–earnings ratio (P/E ratio) taken from publicly listed NST companies
The analysis regarding the number of publicly listed companies applies also to this indicator. Since nanotechnology is an enabling technology, distributed in several sectors and many listed companies having nanotechnology as only one of several fields of R&D, it is difficult to distinguish nanotechnology from the general R&D figures of the companies.

Speed to Innovation
Speed to innovation is an innovative and elegant indicator that measures the ability to translate research results into patents in the shortest possible time. The indicator also includes the role of star scientists. It combines the publication data with the patent data. However, the data needs a good deal of manual work in order to put addresses on companies etc. and was deemed to be too complex to produce at this point.

Nanotechnology products and applications
Quite little is known about companies applying nanotechnology innovations for new processes and products. While it is difficult to get information on products and technologies for those nanotechnology applications that are not commercialised but used in-house, there is some information available on commercialised nanotechnology products. The largest existing database at the moment is the product inventory by the Project on Emerging Nanotechnologies at the Woodrow Wilson International Centre for Scholars in the US (see www.nanotechproject.org/). Product listings in the inventory have been compiled through a web-based search based on selected criteria: products that can be readily purchased by consumers, that are identified as nanotechnology-based by the manufacturer or other source and of which nanotechnology-based claims appear reasonable.

During the time of analysing the data (May 2011), in the Consumer Products Inventory there were 1317 products, produced by 587 companies, located in 30 countries. This is a significant increase of 1015 in August 2009[65] and 212 in 2006. The inventory data is freely available as long as a reference to the source is made. Compiling the data from the database is already

[64] A report compiled by Unit G4: Nanosciences and Nanotechnologies, European Commission, Directorate General for Research and Innovation
[65] The data in the inventory has been used also by the OECD based on the August 2009 data (OECD (2010) The impacts of Nanotechnology on Companies: Policy insights from Case Studies, OECD Publishing.

available by country although detailed calculations on number of companies per country need to be calculated manually.

The database has received a lot of criticism that it provides incomplete information where the marketing term "nano" may dominate over real nano content. From that perspective the inventory tells more about the use of the nano term. In addition, the focus of nanotechnology product databases on consumer products does not represent business-to-business products as well as products used in-house e.g. by the big companies. As a conclusion, this indicator was valued not solid enough to be included in Nanometrics system.

Infrastructure and networks

Nanotechnology infrastructure is an important indicator on the investments and capabilities devoted to the research and development in NST. There are no statistics available differentiating NST infrastructures, but some data has been collected. Nanoforum.org has collected information on nanotechnology infrastructure and networks in 2005 and 2007[66]. These studies could be used as base for assessing the development of infrastructure, the quality of the infrastructure and key networks.

[66] European Nanotechnology Infrastructure and Networks. Sixth Nanoforum Report. July 2005; European Nanotechnology Infrastructure and Networks. Sixth Nanoforum Report (Second edition). July 2007

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Public investments in nanotechnology have thus far largely supported fairly broad based scientific research. It is now time to take stock of the situation by synthesising the latest data available on research and economic activity in nanotechnology, to develop and follow-up indicators, and to formulate strategy options for a European nanotechnology R&D strategy. The NANOMETRICS study establishes a monitoring system that allows to collect data for monitoring the economic and innovation performance of a range of sectors of economy in which nanosciences & nanotechnologies do or could play a significant role. *Part I: Monitoring System*, develops metrics to examine how nanoscale research, products, and markets are evolving over time. *Part II: Case Studies*, presents detailed analyses of selected key domains.

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