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CONSIDERATIONS IN MOVING TOWARDS A STATISTICAL FRAMEWORK FOR NANOTECHNOLOGY: FINDINGS FROM A WORKING PARTY ON NANOTECHNOLOGY PILOT SURVEY OF BUSINESS ACTIVITY IN NANOTECHNOLOGY

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FOREWORD

Nanotechnology is an emerging and enabling technology that offers significant promise extending from business opportunities for individual companies to broader socio-economic benefits. However, tracking the development, use and impact of nanotechnology is challenging, due in part to a lack of internationally-comparable indicators and statistics.

In 2007, the OECD Working Party on Nanotechnology (WPN) commenced consideration of issues relevant to the development of a statistical framework for nanotechnology, in consultation with the OECD Working Party of National Experts on Science and Technology Indicators (NESTI). This report presents the findings of that work.

Within the context of work on nanotechnology statistics and indicators continuing for the foreseeable future, this report *i)* summarises the work undertaken to date by the WPN in this area; *ii)* discusses methodological and practical considerations (such as the use of definitions), particularly as highlighted in the development and piloting of the *Questionnaire on Business Activity in Nanotechnology 2010-11*; and *iii)* identifies how work in this area may support the assessment of other emerging technologies.

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EXECUTIVE SUMMARY

In 2007, the OECD Working Party on Nanotechnology (WPN) commenced consideration of issues relevant to the development of a statistical framework for nanotechnology, in consultation with the OECD Working Party of National Experts on Science and Technology Indicators (NESTI). Phases of the project comprised:

- In 2007, an initial identification of available statistics;
- In 2008, a collection of available data and identification of priorities for future data collection by national policy agencies;
- In 2009, publication of an OECD WPN compendium of information and data about nanotechnology;
- In 2010-2011, development, trial and analysis of a pilot survey of business activity in nanotechnology (*Questionnaire on Business Activity in Nanotechnology 2010-2011)*.

This report:

- Summarises the work undertaken to date by the WPN in this area;
- Discusses methodological and practical issues (e.g. the use of definitions) for on-going consideration in work on statistics and indicators for nanotechnology, particularly issues highlighted in the development and piloting of the *Questionnaire on Business Activity in Nanotechnology 2010-2011*;
- Identifies how work in this area may support the assessment of other emerging technologies via an integrated framework.

It is strongly recommended that any future work in this area should be undertaken in consultation with, or by, national statistical agencies working on science and technology indicators. Their expertise in data collection in technology-related areas will assist in both design and implementation, while also facilitating the interpretation of results within the framework of existing national statistics and indicators.

INTRODUCTION

Nanotechnology is an emerging and enabling technology that offers significant promise extending from business opportunities for individual companies to broader socio-economic benefits. It has been defined as "the understanding and control of matter at dimensions between approximately 1 and 100 nanometres, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modelling, and manipulating matter at this length scale".[1]

At the nanoscale, traditional materials can display new optical, mechanical and reactive properties, enabling new functionalities and the development of novel materials, devices and products. Over the last decade, nanotechnology has developed rapidly and across a range of sectors. Application fields include electronic components, chemicals, pharmaceuticals, transport and manufacturing processes. In addition, nanotechnology innovation is increasingly occurring in convergence with other fields including ICT and biotechnology. Synthetic biology is one example, with research in nanotechnology strongly contributing to the development of synthetic systems with cell-like complexity.

Tracking the development and use of nanotechnology is challenging. Publication data can point to scientific developments and patent offices are able to track nanotechnology patenting. These sources can provide some indicators of innovation in the field. However, the impacts of nanotechnology development are poorly monitored and understood due to a lack of internationally-comparable indicators and statistics. Assessments of the impacts of nanotechnology on companies, business and the broader socio-economic environment remain largely unexplored.

There is also a strong need for robust data on scientific and technological (S&T) policies given the large volume of public funding that nanotechnology has received to date. In order to inform S&T policies but also to monitor and assess their impacts, appropriate and well-evidenced indicators are required (e.g. R&D funding figures and measures of industrial usage of nanotechnology).

Within the context of work on nanotechnology statistics and indicators continuing for the foreseeable future, the rest of this report *i)* summarises the work undertaken to date by the WPN in this area; *ii)* discusses methodological and practical considerations (such as the use of definitions), particularly as highlighted in the development and piloting of the *Questionnaire on Business Activity in Nanotechnology 2010-11*; and *iii)* identifies how work in this area may support the assessment of other emerging technologies.

OVERVIEW OF WORK TO DATE BY THE WORKING PARTY ON NANOTECHNOLOGY

Consideration by the WPN of the policy need for internationally-comparable data regarding the development of nanotechnology began in 2007. The resulting OECD publication *'Inventory of National Science, Technology and Innovation Policies for Nanotechnology 2008*' (OECD, 2009a), included a summary of current nanotechnology indicators and identified gaps in the availability of relevant indicators and statistics. It found that most work to develop indicators and statistics had been based on publicly-available publication and patent information, considered to be the most reliable data in terms of international comparability.

Given the breadth of disciplines, applications and sectors involved in nanotechnology, it was recognised that a broad and flexible set of indicators could best suit user needs. However, practical constraints, such as availability of resources in national statistical and policy agencies and the complexity of nanotechnology, led to a drive to prioritise information needs and address them in order of importance.

To do this, WPN delegations were asked in 2008 to indicate their priorities from a list of potential indicators, divided into three major measurement areas – public sector indicators, business sector indicators, and indicators of impact of nanotechnology. Further advice was sought from experts in order to ensure the viability of pursuing the use of specific indicators.

This exercise revealed that, for WPN delegations, measuring nanotechnology activities in the business sector ranked most highly, followed by the impacts of nanotechnology and activities in the public sector. Of activities in the business sector, patenting, human resources and intellectual property (IP) data were priorities, followed by publication activity, investment and commercialisation issues. On the impacts of nanotechnology, broader socio-economic impacts were prioritised most highly, followed by macro- and micro-economic impacts. Finally, for activities in the public sector, patenting was again highlighted, followed by a priority to develop better indicators on R&D funding, on publication activity and on human resources.

Following this, in 2009 the WPN Secretariat published "*Nanotechnology: An Overview Based on Indicators and Statistics*" *(*OECD, 2009b), examining the development and nature of nanotechnology on the basis of available indicators and statistics. The report presented an analysis of data on market and job forecasts, R&D investments, publications and patents, company and product inventories, as well as providing insights from company surveys.

Finally, indicators appropriate to the collection of policy-relevant information were identified and model questions were developed based on these indicators. One important aspect of the task was ensuring that the questionnaire be for 'real-world' use. That work culminated in the production of a draft *Questionnaire on Business Activity in Nanotechnology* in 2010-2011, piloted with the support of WPN delegates. This report draws on the results of that development and piloting activity (see also a summary of the findings of the survey in Annex 1), which highlighted some practical issues that should be considered in future work, as seen below.

METHODOLOGICAL AND PRACTICAL ISSUES FOR ON-GOING CONSIDERATION

The work of the WPN in the area of statistics and indicators for nanotechnology, especially the collation of primary evidence through the *Questionnaire on Business Activity in Nanotechnology*, identified a number of practical issues. For future work, it will be useful to take note of and draw on experiences gained so far, such as these. However, the list of issues presented here is based on the practical experiences of the WPN work and is not exhaustive. Practitioners will need to further consider the specifics and goals of their own work, as well as the local circumstances, in applying this information to their data collection and analysis for nanotechnology.

Definitions of nanotechnology

The term nanotechnology covers a range of activities that cut across a number of scientific fields and a range of industrial sectors. In addition to using a direct definition of 'nanotechnology', in developing a statistical framework it will also be important to consider wider issues - such as an understanding of the core activities that characterise nanotechnology and whether these can be meaningfully defined in order to develop a robust understanding of activity in this area.

The primary purposes of the definitions of nanotechnology drafted by policy agencies in various countries have been to assist in the allocation of R&D funding, to underpin policy strategies and to help in addressing policy issues related to the translation of nanomaterials and nanotechnologies through commercialisation to market. However, these definitions were not developed to facilitate the collection of statistics, an issue highlighted during the development of the *Questionnaire on Business Activity in Nanotechnology* (see Table 1 for the list of definitions in use during testing of the questionnaire). Whilst the precise wording of each of these definitions differs, all contain three fundamental aspects of nanotechnology.

Firstly, definitions typically emphasise the scale of measurement at which research and engineering moves into the nanotechnology domain. Below this threshold, size-dependent phenomena set in (*e.g.* substantial increases in surface area, quantum effects). A threshold of 100 nanometres is most often suggested, although size-dependent phenomena emerge along a continuum that can extend above 100 nanometres. Rather, the threshold is indicative of a point along the continuum at which the laws of classical physics start to give way to quantum mechanical effects and the onset of more recently identified, less well understood phenomena.

Secondly, nanotechnology is stated to be the purposeful "control", "manipulation" or "handling" of matter at a very small scale. This is intended to eliminate from the definition any material or process that has come about through 'accidental' nanotechnology, i.e. nanotechnology that is naturally occurring or that has occurred without purposeful engineering. In this context, a distinction is sometimes made between the so called 'top-down' and the 'bottom-up' approaches to nanoscale research and engineering (see the United Kingdom definition in Table 1). These two approaches originate at opposite ends of the continuum of R&D trajectories in the field of physics. In engineering terms, the 'top-down' approach involves the reduction of material to the nanoscale through cutting, etching, grinding or lithographic techniques. It is currently the more common one, primarily due to its application in the electronics industry, a major user of nanotechnology. In the 'bottom-up' approach, new materials at the nanoscale are constructed through complex, supramolecular chemistry. The bottom-up approach also draws on biotechnology. One potential 'bottom-up' manufacturing process is the controlled self-assembly of molecules, and even macrostructures,

based on manipulation of individual atoms. In particular, the 'bottom-up' approach draws significantly on scientific developments.

Table 1. Nanotechnology definitions in use during testing of the Questionnaire on Business Activity in Nanotechnology in 2010-11

Source	Definition
ISO TC229 Working Definition	Understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nanometres in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications. Utilising the properties of nanoscale materials that differ from the properties of individual atoms, molecules, and bulk matter, to create improved materials, devices, and systems that exploit these new properties.
ISO TCC 229 ISO/TS 80004-1:2010	Nanotechnology: application of scientific knowledge to manipulate and control matter in the nanoscale (size range from approximately 1 nm to 100 nm) in order to make use of size- and structure-dependent properties and phenomena, as distinct from those associated with individual atoms or molecules or with bulk materials
United States: National Nanotechnology Initiative (2001 and 2011)	Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometres, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modelling, and manipulating matter at this length scale.
European Union: Seventh Framework Programme for Research and Development (2007-2013)	Generating new knowledge on interface and size-dependent phenomena; nano-scale control of material properties for new applications; integration of technologies at the nano-scale; self-assembling properties; nano-motors; machines and systems; methods and tools for characterisation and manipulation at nano dimensions; nano precision technologies in chemistry for the manufacture of basic materials and components; impact on human safety, health and the environment; metrology, monitoring and sensing, nomenclature and standards; exploration of new concepts and approaches for sectoral applications, including the integration and convergence of emerging technologies.(1)
Japan: Second Science and Technology Basic Plan (2001-2005)	Nanotechnology is an interdisciplinary S&T that encompasses IT technology, the environmental sciences, life sciences, materials science, etc. It is for controlling and handling atoms and molecules in the order of nano (1/1 000 000 000) metre enabling discovery of new functions by taking advantage of its material characteristics unique to nano size, so that it can bring technological innovation in various fields.
United Kingdom: New Dimensions for Manufacturing: A UK Strategy for Nanotechnology (2002)	Nanotechnology and nanoscience are concerned with materials science and its application at, or around, the nanometre scale (1 billionth of a metre). Manufacturing can reach the nano scale either from the top down, by 'machining' to ever smaller dimensions, or from the bottom up, by exploiting the ability of molecules and biological systems to 'self-assemble' tiny structures. It is in the conjunction of these two approaches, in the meeting of physical and chemical/biological manufacturing, that the potential for revolution lies. From the top down perspective, it interfaces with the larger-scale, more mature 'microsystems technology' being pursued very actively in the United Kingdom and around the world on a more immediate timescale.

Note:1. The European Union also agreed a definition of nanotechnology for regulatory purposes in late 2011: It remains to be seen how this will affect policy definitions

Thirdly, most of the definitions draw attention to the criterion that development and engineering at the nanoscale should also enable "novel" or "new" industrial applications or "technological innovations" based on characteristics arising from size-dependent phenomena.

While useful, single all-encompassing definitions, such as those in Table 1, are too broad for statistical work. For example, it would be important to be able to track the distribution of R&D investments and company activities by nanotechnology sub-areas or application fields, as the key challenges of companies may differ between the sub-areas and application fields. Furthermore, companies may be involved in multiple sub-areas and application fields. Therefore, for statistical purposes, so-called 'list-based' definitions will also be needed, comprising a list of agreed nanotechnology sub-areas.

Nanotechnology actors: The entities a statistical framework could cover

Common groups of actors include academia, companies and government. However, the specifics of these remain to be defined in terms of their respective roles and contributions. For example, consideration needs to be given to: the extent to which the term 'nanotechnology' serves to re-label existing R&D activities; whether important actors may be omitted when using publication and patent data; the degree to which nanotechnology can be identified at company level, and how a nanotechnology company could be defined (especially in the case of larger companies). Questions remain about how actors are connected, or linked together, for example through strategic alliances or collaborations.

The global distribution of R&D investments, publications and patents indicate that over the past decade, nanotechnology patents have largely been concentrated in a few countries and high-technology regions of the world. The United States dominates in this context (with the San Francisco, Boston, New York and Los Angeles regions), followed by Japan and some of the larger European Union countries (Germany, France, and the United Kingdom). Nonetheless, some smaller countries are also identified as being very active relative to their size and there has been rapid growth in "newcomer" countries such as Korea, India and especially China, all of which are characterised by rapid growth rates in the number of publications and patents, albeit from a low base.

It is also clear that both universities and companies need to be considered in the ownership of intellectual property. Given the role of small- and medium-sized enterprises (SMEs) in this technology area, it may also be interesting to examine the distribution of patent ownership by company size. In addition, structures such as public-private partnerships may own significant patent portfolios, information which may in turn provide insights into strategic alliances or collaborations.

Location and distribution of nanotechnology

This not only refers to physical location but also to the sectoral location, *i.e.* where nanotechnology activity is occurring in the economy as nanotechnology cuts across sectors and activities. It also draws to a significant extent on science, research and development in the public research sector. Nanotechnology start-up companies may primarily provide R&D services rather than products and could therefore be given an industrial classification in the service sector or in manufacturing. The classification might change over time as the technology matures. There are also questions about how larger, broadly-based companies engaged in nanotechnology can be identified; how suitable sampling frames can be defined; which scientific fields and industrial sectors should be covered; and whether companies in the service sector play a significant role.

When considering available data, nanotechnology patenting is distributed across a broad range of *sub-areas and application fields*, highlighting the depth and range of applications of this emerging technology and underscoring its general-purpose nature. Most patenting has occurred in nanoelectronics and nanomaterials, both of which are generic technology areas in their own right. Nanotechnology patenting has also shown very high growth in the application fields of electronics, chemicals and instruments. It may be that incremental developments related to 'traditional' top-down approaches to nanoscale engineering explain the proliferation of applications in electronics and materials. In contrast, more disruptive bottom-up approaches may still be confined to university laboratories and are yet to appear in the patent data.

Whilst a statistical framework for nanotechnology should be flexible enough to cover a broad range of the main nanotechnology sub-areas and application fields, what these may be currently remains unclear in this developing technology area. At the same time, a framework should be flexible enough to capture convergence between nano- and biotechnologies, and even more complex convergence between nano- and biotechnologies, information technology and cognitive sciences ("NBIC").

Impacts of nanotechnology

Broad issues of interest here include the reasons for adopting nanotechnologies and the benefits that result. At a more detailed level, when designing appropriate indicators and statistics this could include consideration of the impacts of use, the degree to which nanotechnology impacts on the nature of company dynamics (entry and exit) and industrial organisation, as well as longer term socio-economic developments.

Company case studies can provide some guidance to key issues in terms of the short-term effects, but longer-term effects on productivity, industrial renewal and growth are much harder to consider through this approach due to the immature nature of the field. It may be possible in future survey work to address these key issues, while harmonisation of specific survey questions would facilitate comparisons across countries, nanotechnology sub-areas and application fields. Company case studies undertaken by the WPN highlighted impacts on the following aspects of company activity in particular: R&D and human resources (due to the immature and complex nature of nanotechnology); funding (due to large required investments); the entry of new companies in existing value chains and the development of relevant business models; and concerns about public perception of environment, health and safety (EHS) issues (OECD, 2010).

The availability of information regarding the short-term impacts of nanotechnology on companies would facilitate further analysis relating nanotechnology developments to patterns of entry, diversification and exit of companies; to productivity at the plant, company and industry level; and to economic growth at the economy-wide level.

Use of data sources

A wide variety of methodological approaches to data collection are possible, and a number of factors contributed to the selection of the final approach used in the pilot survey. Some of the possible approaches and associated considerations are noted below, including a brief assessment of merits and limitations, highlighting databases and surveys that appear most relevant to nanotechnology. It should be stressed that it is important to consider not only new data sources and methodologies, but to also emphasise the potential for building on existing sources.

Existing databases

Databases (including publication and patent records) can be a useful tool for understanding the early development of nanotechnology and broad differences across countries. R&D funding databases of granting entities can be quite extensive, with detailed information such as titles, keywords and, in some cases, abstracts, as well as the names of research leaders, teams and institutions. They can provide consistent, comparable data over time. Data coverage, analysis and quality control, however, pose a number of challenges. First and foremost, existing databases are not specifically designed with the intention of capturing nanotechnology data. Given the interdisciplinary nature of the field, key words and terminology often differ across countries and technology fields. Keyword searches in databases often require a review by a subject-area expert to ensure consistency. However, they can provide insights about the volumes, funders, performers and content of R&D, innovation and applications.

Company and other surveys

Survey data can provide insights into the activities and business environments of companies involved in nanotechnology. Company surveys can probe some of the intricacies of topics such as the raising of capital, provision of human resources and challenges experienced during investment and commercialisation, thereby providing information to policy-makers. However, surveys related to nanotechnology could encounter difficulties in finding respondents all across the economy, raising the challenge of accurately and completely developing a sampling frame and thereby impacting the achievement of accurate measurement.

In order to undertake a company survey, a target population would need to be identified. Consideration would also need to be given to the methodology by which target populations could be systematically identified and contacted. Since nanotechnology partly involves a new population of actors (comprising both new and established companies, and actors from industrial sectors and the R&D service sector), spread out across a broad range of sectors of the economy, there is little likelihood that existing registers or classification systems would effectively identify all the actors. Construction of custom lists, sampling, keyword searches and involvement of experts are other methods that can be used to identify target populations.

A number of countries make use of a two-part method for company surveys. These comprise a core questionnaire that remains fixed over time and a separate module that is changed between survey cycles. This approach may well suit the dynamic nature of the field of nanotechnology and provide flexibility to address policy concerns and issues as they arise. Topics to be addressed in a core questionnaire may include company revenues, R&D investments, human resource counts, product pipelines and stages of development. A good candidate for a theme to be addressed in a module could be 'challenges in commercialisation of nanotechnology'.

Surveys could also be developed to gather information on internal R&D activities of governments and their funding of nanotechnology research and utilisation. This data would complement searches and analysis of administrative databases. Such surveys could also address broader issues related to science, technology and innovation policies in the context of public perception and environmental health and safety (EHS) concerns related to nanotechnology etc., and may need to be conducted by both federal and regional governments due to the different system of policy governance across countries. In order to consider the adoption and diffusion of nanotechnology, as well as impacts, end users and the broader public may also need to be included as nanotechnology is adopted in different areas of the economy and society. However, the development of this type of survey was beyond the scope of the WPN project.

Wider issues

Other methodological challenges include the need to establish the parameters of nanotechnology and its convergence with other technologies such as biotechnology. For example, it will become increasingly important to explore the question of where biotechnology ends and nanotechnology begins. However, these methodological challenges, in the absence of validated definitions and nomenclature and clear sampling frames, also present a window of opportunity to adopt existing methods or to develop new and innovative methods to aid in the development of comparable and reliable nanotechnology statistics and indicators.

The potential need for new types of indicators may warrant new methodological considerations. The identification of keywords and products (e.g. based on internet searches) requires special consideration in terms of biases involved, for example, related to language, the nature of keyword search algorithms, definitional issues, etc. Some of these methodologies have already been discussed and tested but unresolved issues remain. One advantage of using the internet as a data source is that the data can be collected almost in real-time. However, as the data sources themselves change quickly, a system to ensure continuity of data collection also has to be established.

AN INTEGRATED FRAMEWORK FOR ASSESSING EMERGING TECHNOLOGIES

Innovation within emerging technologies is often closely linked across technologies, e.g. in some aspects of synthetic biology. Clarity in definition and categorisation is needed in order to create accurate statistics, but such overlaps (convergence) between technologies could lead to erosion of data quality and potential misinterpretation, for example, through factors such as the double counting of publications and patents. In addition, emerging technologies share some measurement challenges, such as definitional issues in separating one technology from another and in putting boundaries on the extent of the definition of the emerging technology.

This suggests that it may be appropriate to consider their joint measurement through an integrated framework. This would allow such challenges to be approached in a more systematic manner and also build in attempts to identify technology sub-groups, thus allowing comparisons across technology areas.

Box 1. Statistics Canada: Surveys of emerging technologies, 2005 to 2007

Between the years 2005 and 2007, Statistics Canada conducted a Survey of Emerging Technologies over three survey cycles and was able to examine the extent to which a range of emerging technology areas overlapped. The categories were: nanotechnology; biotechnology; bioproducts; functional foods and nutraceuticals; and emerging environmental technologies. The survey was distributed to respondents in all areas of the economy in which these technologies had been, or could be, in use. It identified respondents amongst relevant sub-groups of companies to receive subsequent dedicated surveys tailored to the relevant topic and technology(s).

Results revealed that 70% of nanotechnology firms also undertook activity in areas such as biotechnology and bioproducts. Of the biotechnology firms, the survey revealed that 54% also undertook activity in technologies other than biotechnology. Of firms engaged primarily in the area of bioproducts, 74% also undertook activity in areas other than bioproducts. This high rate of firms undertaking activities in multiple technology domains demonstrated a close relationship between these technologies. Additional analysis of this type of data may provide greater clarity on the links and overlaps between technologies.

As a result of that emerging technology survey, the 2007 survey of biotechnology firms undertaken by Statistics Canada also included a pilot survey of nanotechnology firms. This survey revealed that 55% of the 88 nanotechnology firms responding also undertook biotechnology activities, mainly in the area of human health.

An integrated framework for measuring emerging technologies requires consideration of the criteria for defining them, which includes definitions. The development of model questions could benefit from the identification of key themes that are common to emerging technologies. Existing surveys related to these technologies may provide a good basis for this. Themes might include: drivers for investment; R&D investments; collaboration; modes and types of innovation; human resources; intellectual property; business models; challenges during commercialisation; revenues from technology-based activities; and primary areas of application.

Consistent with these findings, the OECD Working Party of National Experts on Science and Technology Indicators (NESTI) initiated a project to examine the feasibility of developing an integrated framework for the measurement of enabling technologies and their applications. This project aims to formulate a common conceptual and methodological framework that can be used across the field of emerging and enabling technologies such as ICTs, biotech, nanotech, etc. Such a framework could help to simplify work in this area by avoiding unnecessary replication of similar conceptual and methodological frameworks for individual technologies, while potentially enabling greater consistency in approaches.

CONCLUSIONS

The rapidly emerging nature and widespread application of nanotechnology makes measurement a challenge and a simple indicator set is unlikely to provide a comprehensive assessment. Rather, the use of a variety of methods (including database analysis, survey data and internet searches) could be combined. The OECD Working Paper *Nanotechnology: An Overview Based on Indicators and Statistics* published in 2009 aimed to develop some initial indicators to facilitate the collection of comparable, policy relevant data regarding nanotechnology.

Nanotechnology encompasses an evolving set of technologies, activities and products. Therefore an evolving set of indicators may be required to ensure its accurate and useful measurement. Indicators familiar to many stakeholders could be complemented by methods and indicators that are forward looking and that capture the dynamic nature of this sector.

In addition, a more complete understanding of nanotechnology would result from comparisons with other enabling technologies, such as ICT and biotechnology. S&T policies could benefit from the findings of an integrated framework relating to such emerging and enabling technologies by identifying issues of a cross-cutting nature, or identifying where there are important differences.

It is also likely to prove useful for future data collection exercises for these to be undertaken by, or in consultation with, national statistical agencies working on science and technology indicators. Their proven expertise in data collection in technology-related areas can help to avoid design and implementation pitfalls while facilitating the interpretation of results within the framework of existing national statistics and indicators.

ANNEX 1: PILOT QUESTIONNAIRE ON BUSINESS ACTIVITY IN NANOTECHNOLOGY – SUMMARY

Overview

This element of the project aimed to: develop a practicably usable questionnaire that would gather data on business activity in the nanotechnology sector; pilot this instrument; and based on feedback revise the questionnaire for future reference.

Expert input, participating country insights and wider WPN work contributed to the development of the final questionnaire format. For example, issues for examination were drawn from the WPN project *The Impacts of Nanotechnology on Companies: Policy Insights from Case Studies*. A summary of the six areas addressed is in the table below:

Table A1.1 Summary of the areas addressed in the Questionnaire on Business Activity in Nanotechnology

- Section 1 - Nanotechnology in the company: single definition (used as a screening question); list-based definition (identified as field of application); use of nanotechnology within the company; company operations involved; field of production, if relevant; source of key technology; source of infrastructure or equipment.
- Section 2 - Company information: location of corporate head office; year company founded; trading of shares publicly; main field of company activity; subsidiary status.
- Section 3 - Revenue and R&D: company sales/revenues and percentage related to nanotechnology; R&D expenditure and percentage related to nanotechnology; where no current revenue, anticipated year of first revenue; activity in international markets.
- Section 4 - Human resources: numbers of employees (total) and those involved in nanotechnology; experience of staff recruitment for nanotechnology; collaborative alliances; use of specialist nanotech service providers.
- Section 5 - Finance and intellectual property: experience of raising funds for nanotechnology activity; types of IP instrument in use and whether earning revenue.
- Section 6 - Understanding of local regulatory environment.

The questionnaire was designed to survey a range of micro- to multinational companies. Co-ordinators from the six participating countries (Australia, Canada, France, Israel, Italy and Japan) were requested to select and contact five companies each. Once questionnaires were returned, co-ordinators reviewed the responses for completeness and contacted the companies as necessary for clarification and further comment.

To maintain confidentiality, co-ordinators transferred individual questionnaire responses (and any additional written comments) to a reporting template. In addition, co-ordinators were asked to provide qualitative comments on the responses and impressions gained from discussions with the respondents.

The questionnaire was agreed by the WPN delegates and was circulated to participating countries in October 2010. In total, information was gathered on 20 companies ranging from micro (0-1 employee) to multinationals (160 000 employees) and were a mix of recently and long-established enterprises (with the

date of establishment ranging from 1889 to 2010). However, due to the small number of respondents there was no attempt to gather statistically-valid data. An analysis of responses can be found in Annex 2 and an amended questionnaire (following feedback received) can be found in Annex 3.

In practice, the draft instrument provided preliminary validation of the relevance of the issues and the overall structure and logic of the questions and pre-identified responses. However, feedback and subsequent consideration identified some areas where a re-focusing of questions may prove beneficial, dependant on the specific policy aims of future questionnaires (these are discussed immediately below). Considerations of regional/local nomenclature and understanding would also prove essential in any future use of this outline questionnaire.

Definitions

When developing the questionnaire, the WPN used the ISO TC229 Working Definition (see Table 1, of this document) as the single definition. As a starting point for a list–based definition, the Canadian example (from Statistics Canada) was used. Until 2008, Statistics Canada was one of the few statistical agencies to have used a list-based definition for nanotechnology in national surveys.[2] The Canadian list-based definition used in 2007 comprised:

- *Nanomaterials:* organic and inorganic nanocomposites, nanopowders, nanoparticles, nanocoatings, carbon nanotubes;
- *Nanodevices:* sensors, MEMS, and nano-enabled MEMS;
- *Nanoelectronics:* photonics, nano-optical devices/sensors or light emitters;
- *Nano-enabled industrial processes*: nano-enabled catalysts including systems such as nanofabrication. *Nanomedicine*: nanopharmaceuticals, and nano-based drug delivery systems;
- *Other nanotechnologies*: nano-enabled industrial products, nano-enabled consumer products, nano-tools, hardware, instruments and software, and nanobiotechnologies.

This was refined based on expert interviews and input from delegates to the WPN and the final list as used in the questionnaire is below.

Table A1.2 Nanotechnologies/applications used in the Questionnaire on Business Activity in Nanotechnology

List of nanotechnologies/applications used in the draft questionnaire	
Nanomaterials	Nanomagnetics
Nanoelectronics	Nanomechanics
Nanophotonics	Filtration and membranes
Nanobiotechnology	Nanodevices
Nanomedicine	Nanotools
Nanoinstruments	Other fields, please identify

In responding, companies used each of the pre-identified categories in this list, with the *OTHER FIELDS* category identifying: nanostructured materials, catalysis, and software for modelling and simulation. Furthermore, one respondent suggested that there was a strong overlap between the nano-instruments, nano-devices and nano-tools categories and that these categories should be distinguished by additional definitions.

The piloting of the survey generated the suggestions that three categories be revised into two replacement categories, and that two additional categories be included in the list. While these suggestions are potentially useful, and have been noted in the amended questionnaire, there are no doubt other emerging

sub-fields that could be justifiably included. Initial stocktaking work conducted by NESTI also notes that the definitions in use for statistical purposes are in many cases drawn from or reflect national policy priorities.

The pilot focused on applications rather than technology domains, as many of the technology domains can be used in multiple applications, and the focus of the survey was on the application in which nanotechnology was being used, rather than which specific nanotechnologies were in use. However, in future use it is suggested that practitioners consider the focus of their questionnaire (e.g. to reveal the technologies being developed, or indicate the applications in which nanotechnologies may be utilised) as the relevance of the above list based definition may differ (and may need to be amended).

Use of nanotechnology within the company (Question 1.4 and 1.5)

The pre-identified responses offered in the pilot of the questionnaire (Question 1.4) relating to this issue were selected with the intention of allowing policy makers to distinguish between areas of activity that may be the responsibility of different government agencies. However, companies responding to the pilot suggested an alternate approach that may be more consistent with current industrial activity. This was to replace two categories (nanotechnology 'as an input to production' and 'as a process') with a single category of being a user/integrator of nanotechnology products.

Furthermore, data regarding the provision and use of specialist services relevant to nanotechnology, for example specialist metrology or legal services, also need to be captured. Whilst question 1.5 sought information regarding the 'service' aspect of nanotechnology activity within the companies surveyed, it may be beneficial to develop a question focused specifically on provision and use of specialist services.

Based on a small pilot it is not possible to draw any firm conclusions, but countries wishing to collect policy relevant data or statistics about nanotechnology should consider which pre-identified activities will be covered and whether a specific question on provision and use of specialist services should be included.

Industrial Classification: Field of activity (Question 2.6)

Question 2.6 included a pre-identified list of selected industry fields drawn from standard industrial classification lists and was based on the fields in which nanotechnology businesses were known to be operating. These fields were drawn from the much larger list contained in the International Standard Industrial Classification of All Economic Activities, Rev.4 (ISIC).[3] Annex 4 identifies how these were derived from the ISIC Rev 4 structure.

The majority of the 20 respondents were clustered under 'Manufacturing', 'Human Health', and 'Professional, scientific and technical activities', and this is consistent with anecdotal evidence of the major fields of operation of nanotech companies. However, with such a small pilot, review based on further testing or by reference to more complete lists based on ISIC or national industrial code structures is advised.

The chemical industry is also a major producer and user of nanotechnology. It was omitted from the list used in the pilot. However, it is suggested that countries wishing to collect nanotechnology statistics, perhaps using the questionnaire as a starting point are advised to also include 'Manufacturing – Chemicals' as a pre-identified category. Where possible it would be preferable to utilise the complete industry code structure in use by the national statistical agency or at the international level.

In addition, respondents to the pilot were requested to mark only one main field of activity; however 7 of the 20 respondents marked more than one main field of activity. In economic and industry statistics, the use of industry structure codes (for example ISIC) is intended to allow classification of statistical entities to the main productive economic activity they carry out.

Where surveys seek to capture the development and use of new, emerging or enabling technologies, it may be beneficial to consider survey questions or other mechanisms that capture the breadth of corporate

operations, including those that occur in more than one industry sector. In the specific case of nanotechnology, alternative approaches may also assist in distinguishing between the following categories of nanotechnology-related products: nanotechnology products; nano-enabled products; and products that utilise nano-processes. This issue warrants further attention.

Ownership status of company (Section 2)

The countries participating in the pilot debated the best approach to this issue during development of the draft instrument. The principal issue was how best to distinguish between companies whose shares are publicly traded (and thus are required to provide significant public disclosure on financial, management and strategic approaches) from those who operate 'privately'.

From the results of the pilot, it is clear that the current question is not well adapted for crossing the boundaries of differing national legal nomenclatures and local practice. Thus countries wishing to collect nanotechnology statistics using the questionnaire as a template may need to consider local customisation of this question for national use**.**

ANNEX 2: FINDINGS FROM THE PILOT QUESTIONNAIRE ON BUSINESS ACTIVITY IN NANOTECHNOLOGY

Notes on the format of reporting tables in this Annex:

a) The total number of company respondents (by country) was as follows:

AUSTRALIA: 5 CANADA: 1 FRANCE: 5 ISRAEL: 3 ITALY: 1 JAPAN: 5

b) Where the number of respondents to a specific question differs from the above country total (e.g. three responses were received to a specific question from Australia, rather than five), this is indicated in brackets as follows. For example:

COUNTRY:	*AUSTRALIA (3)*	*CANADA (0)*	*FRANCE (5)*	*ISRAEL (1)*	*ITALY (0)*	*JAPAN (3)*

c) In many of the tables below, the categories appearing in the left column (here, Major City Regional Location) are not identical to the pre-identified responses in the questionnaire. Rather, the information provided by respondents has been grouped into categories that are more likely to be of policy interest. For example Q2.1 asked for a specific address, but responses have been grouped as:

COUNTRY	*AUSTRALIA (5)*	*CANADA (1)*	*FRANCE (5)*	*ISRAEL (3)*	*ITALY (1)*	*JAPAN (5)*
MAJOR CITY	*4*	*1*	*3*	*2*	*0*	*5*
REGIONAL LOCATION	*1*	*0*	*2*	*1*	*1*	*0*

d) Many questions asked respondents to: *indicate all that apply*. For this reason the totals do not sum to the number of respondents for these questions. For example Israel and Japan received multiple responses in Q2.6:

COUNTRY	*AUSTRALIA (5)*	*CANADA (1)*	*FRANCE (5)*	*ISRAEL (3)*	*ITALY (1)*	*JAPAN (5)*
MANUFACTURING	*3*	*0*	*4*	*3*	*0*	*5*
NON-MANUFACTURING	*4*	*0*	*0*	*2*	*1*	*1*
OTHER	*1*	*1*	*1*	*2*	*0*	*0*

SECTION 1 - NANOTECHNOLOGY IN THE COMPANY

Q1.1 & Q1.2: Definitions

Utilised as an introduction and screening question. Not of importance in the pilot as companies were specifically selected for nanotechnology activity.

Q1.3: Year of commencement of nanotechnology activities.

Country:No. of years of nanotech activities	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
20>	0	0	3	0	0	3
11-20	2	0	0	0	0	2
6-10	2	0	2	2	0	0
2-5	1	1	0	0	1	0
<2	0	0	0	1	0	0

*Q1.4: Fields of **application** and **use** of nanotechnology*

Application: across the 20 respondents all fields were used. The OTHER category was used to identify 'nanostructured materials' and 'catalysis'.

Use: across the 20 respondents all fields were utilised.

Q1.5: Operations involved in nanotechnology

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Product or service R&D	5	1	5	3	1	5
Production	4	1	5	2	1	3
Number of respondents marking all categories	1	1	5	2	0	1

The OTHER category was used to identify: standardisation/normalisation activities.

Q1.6: Field of production

At Q1.5 16 of the 20 respondents indicated 'Production' as an operational area involved in their nanotechnology activities. These companies were requested to identify their field of production in this question. All categories were used except for *nano-tools* (though this is possibly due to the very small sample size of the pilot).

Q1.7: Source of technology

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
In house R&D	4	1	5	3	1	5
Other sources	4	1	4	2	1	4

The OTHER category was used to identify: historic material; purchase of previous company; scientific projects; and client.

Q1.8: Source of infrastructure or equipment

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy(1)*	*Japan (5)*
Developed in house	3	1	4	3	1	4
Manufactured in house	2	1	4	3	1	3
Collaboration	3	1	3	2	0	1
Acquired/other	1/1	0	0	0	1/0	0

The OTHER category was used to identify*:* a shareholder university and contracting engineers.

SECTION 2 - COMPANY INFORMATION

Q2.1: Where is the head office of your company?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Major city	4	1	3	2		5
Regional location	1	0	2	1	1	0

Q2.2: Is this the same location provided on page 1 of the survey?

The majority of respondents answered yes, indicating they were located at the company head office.

Q2.3: Does your company have additional branches?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Domestic	2	0		0	0	4
International	2		2			

Q2.4: In what year was your company founded?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Oldest	1999		1889	2001		1899
Youngest	2008	2006	2006	2010	2007	1996

Q2.5: Are shares in your company traded on a public stock exchange?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	1		3	0	0	4
No	3	1	2	3	1	1

Q2.6: What is the main field of activity for your company?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Manufacturing	3		4	3	0	5
Non-manufacturing	4			2	1	1
Other	1	1	1	2	0	
Number of respondents indicating more than one category	2	0	1	2	0	2

Q2.7: Is your company owned by another company?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	2	0	0	0	0	0

Q2.7A: If yes, what percentage of your company does it own?

Country:	*Australia (2)*	*Canada (0)*	*France (0)*	*Israel (0)*	*Italy (0)*	*Japan (0)*
	[100%] DNR					

Q2.7B: Where is the parent company located?

Country:	*Australia (2)*	*Canada (0)*	*France (0)*	*Israel (0)*	*Italy (0)*	*Japan (0)*
Same country	1 1x DNR					

SECTION 3 - REVENUE AND R&D

Q3.1: Please complete the following table, also indicating the currency you are reporting (Note: currency and units were asked for as relevant, but the table below indicates whether a response was received)

Country:	*Australia (5)*	*Canada (1)*	*France (4)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Anticipate rising revenue	4	DNR	2	1	1	1
100% revenue from nanotech	4	1	1	0 2 DNR	1	0
100% R&D spend on nanotech	4	1	1	3	1	0
International markets	3	1	2	2	0	3
USA	2	1	2	1		0
Europe	3		2	2		2
Asia	0	1	2	1		2

SECTION 4 - HUMAN RESOURCES

Q4.1: Please indicate your company's typical employment level for 2008 by completing the table below. Do not include students. If '0' (zero) indicate '0'

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
>250 Large			2			3
>50 <249 Medium						1
< 49 Small	4	1	3	2		
<10 Micro	1			1	1	
Number indicating 100% employees nanotech	3	1	2	0	0	0

Q4.2: Has your company experienced difficulty in attracting qualified nanotechnology employees?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	3	0	1	2	1	0
Multiple employee categories	3		0	2	1	
Other	0		0	0	0	

Q4.3: Does your company have formal alliances or collaborative arrangements with other entities?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	5	1	5	3	1	4
Number noting >2 categories	3	1	5	3	1	4
Other	0	0	0	0	0	0

Q4.4: Does your company access specialist nanotechnology service providers?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	3	0	2	1	0	2

SECTION 5 - FINANCE AND INTELLECTUAL PROPERTY

Note: a number of respondents chose not to respond to some of these questions on the basis that they were confidential matters.

Q5.1: Has your company attempted to raise capital?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	4	1	2	3	1	4
Successfully	4	1	2	3	1	4
Value:	AUD	CAD	EUR	USD	EUR	Yen
max	100m	12m	25m	2m	2m	2Bn
min	500k		86k	1m		
Less	1	0	0	0	1	1
Same	2	1	1	3	0	1
More	0	0	0	0	0	0

Q5.2: Does your company own any nanotechnology related intellectual property instruments?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	4	1	5	3	1	3
	Range of the responses					
Patent	1 - 70	3	3 – 120	1 – 8	2	17 – 110
Pending Patents	1 - >100	34	40-50	5 – 25	0	62 - 100
Licensing Agreements	0 - many		2	2	1	0
Technology Transfer Agreements	0 - many	1	0	0	0	0
Other, please specify	0	0	0	0	0	0

Q5.3: If yes, has your company received revenue from this instrument/s?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
Yes	1	1	3	1	0	0

Q5.4: If yes, what is the amount of the revenue in the 2008 financial year?

Country:	*Australia (1)*	*Canada (1)*	*France (3)*	*Israel (1)*	*Italy (0)*	*Japan (0)*
Response	AUD 1.4m	DNR	EUR 1.5m	DNR		

SECTION 6 - UNDERSTANDING OF THE LOCAL REGULATORY ENVIRONMENT

Q6.1: In your primary country of operation can you identify the main agency/body(ies) responsible for the regulation of nanotechnology in your field?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
YES	3	0	4	1	0	3
NO	2	1	1	2	1	2

Q6.2: Is more than one regulatory agency/body involved?

Country:	*Australia (3)*	*Canada (0)*	*France (5)*	*Israel (1)*	*Italy (0)*	*Japan (3)*
YES	1		4	DNR		3
NO	2		1			0

Q6.3: Are the regulatory requirements of the body clearly set out?

Country:	*Australia (3)*	*Canada (0)*	*France (5)*	*Israel (1)*	*Italy (0)*	*Japan (3)*
YES	2		4	DNR		3
NO	1		1			0

Q6.4: Are the regulatory standards clearly set out?

Country:	*Australia (3)*	*Canada (0)*	*France (5)*	*Israel (1)*	*Italy (0)*	*Japan (3)*
YES	2		4	DNR		2
NO	1		1			1

Q6.5: Are the regulatory requirements SPECIFIC to nanotechnology

Country:	*Australia (3)*	*Canada (0)*	*France (5)*	*Israel (1)*	*Italy (0)*	*Japan (3)*
YES	0		1	1		3
NO	3		4			0

Q6.6: Does the regulatory body have clear mechanisms for you to make enquiries?

Country:	*Australia (3)*	*Canada (0)*	*France (4)*	*Israel (1)*	*Italy (0)*	*Japan (5)*
YES	2		2	1		3
NO	1		2			0

Q6.7: Are they responsive to industry needs?

Country:	*Australia (3)*	*Canada (0)*	*France (5)*	*Israel (1)*	*Italy (0)*	*Japan (3)*
YES	2		3	1		3
NO	1		2			0

Q6.8: IF NO (TO Q6.1) Did this impact on your company's decision to locate your main operations in this country?

Country:	*Australia (2)*	*Canada (1)*	*France (0)*	*Israel (3)*	*Italy (1)*	*Japan (2)*
YES						1
NO	2	1		3	1	1

Q6.9: Does your company manage its own regulatory affairs in your primary country of operation?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
YES	5	Response unclear	5	3	1	4
NO	0		0	0	0	1

Q6.10: Do you think the approach to regulation needs to change in this country?

Country:	*Australia (5)*	*Canada (1)*	*France (5)*	*Israel (3)*	*Italy (1)*	*Japan (5)*
YES	1	0	3	2	0	0
NO	4	1	1	1	1	4

Q6.11 IF YES TO 6.10 please describe how it should change and why these changes are necessary

Country:	Australia (1)	France (2)	Israel (2)
	Simple clear approach to chemicals regulation	Needs to establish a clear international definition of nanomaterials to allow the traceability of nanomaterials along the value chain. There is a necessity for an internationally harmonised definition.	There should be a section in the institute of standards dedicated to nanotechnology. There should also be a section in the "work safety institute" dedicated to nanotechnology. There needs to be clearly defined standards working specific with nanomaterials. It is very serious consultancy in chemical industry but not specific to nanotechnology.

ANNEX 3: BUSINESS ACTIVITY IN NANOTECHNOLOGY QUESTIONNAIRE

Note: areas shaded in grey are amendments that have been made to the original questionnaire format based on feedback.

The term **company** will be used in this survey to also include firm and enterprise.	**Practitioners suggestions for consideration**
INTRODUCTION Nanotechnology is a broadly-based enabling and transformative group of technologies that may hold widespread implication for a number of sectors across industry and society. It is a field where science and related technologies are advancing rapidly, and are poised to enter the economy. This survey is designed to collect data about the applications of nanotechnology in order to provide stakeholders with a better understanding of its roles in the economy.	
COMPLETING THE SURVEY WHO SHOULD COMPLETE THE SURVEY? A knowledgeable senior person in your company, firm or enterprise, such as a Research and Development (R&D) manager or production manager, can complete this questionnaire. More than one person may be needed in some cases.	**This questionnaire is arranged by themes. Practitioners may prefer to group questions by the most appropriate respondent. Responses to this questionnaire may require input from:** **- R&D Managers** **- Production Managers** **- Chief Financial Officers or Accountants** **Practitioners may wish to consider this issue if adapting this instrument**

WHO WILL USE THE SURVEY? The OECD and its member countries are conducting this survey to produce a profile of companies engaged in the production and/or development of nanotechnology. The survey focuses on the key characteristics and activities of companies that develop or produce nanotechnology products as part of their company's activities.	
Details of Respondent Company Full Name of Company_____ Full address of Company _____ Name of person completing this form_____ Position of person completing this form_____ Contact Details Phone_____ Email_____	
DEFINITION: Nanotechnology is defined for this survey as: Understanding and control of matter and processes at the nanoscale typically but not exclusively below 100 nanometres in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications utilising the properties of nanoscale materials that differ from the properties of individual atoms molecules and bulk matter to create improved materials devices and systems that exploit these new properties. (ISO)	

SECTION 1: NANOTECHNOLOGY AREAS OF ACTIVITY

1.1 Does your company use nanotechnology or undertake activities relevant to the definition of nanotechnology provided above?

Yes / No ***(Circle*** *appropriate response)*

Practitioners may wish to include a specific time period.

1.2 If you are NOT currently using any of the above, do you plan to use within 2 years?

Yes / No ***(Circle*** *appropriate response)*

If YES *to 1.1 or 1.2, please complete the remainder of the survey.*

If NO *please complete section 2 and then return survey as per instructions on the final page.*

This question was developed with the rapid expansion of use of nanotechnology by industry in mind.

Practitioners may wish to consider if this question is relevant to the aims of their survey.

1.3 In what year did your company begin its nanotechnology activities?

1.4 Please identify **all the applications of nanotechnology** used in your company and how you use it by **indicating with ✓.** If you are NOT currently using the technology, please identify the technologies you plan on using within the next two years by i**ndicating with ✓.**

Application of Nanotechnology	**All current or planned uses** Indicate by ✓					
		Proposed that category [i] replace categories [ii] and [iii]				
		Production or Manufacturing operations				
	In research & development	**User or integrator of nanotechnology product [i]**	As an input to production [ii]	As a process [iii]	Manufacture of intermediate goods	In finished goods for sale to consumers
Nanomaterials		***[Amendment from pilot study]***				
Nanoelectronics						
Nanophotonics						
Nanobiotechnology						

For this policy questionnaire, no definitions were provided for the following terms :

- use of nanotechnology (Q1.1)
- nanotechnology activities (Q1.1 & 1.2)
- applications of nanotechnology (Q1.4)
- nor for the identified "uses" (Q1.4)
- company operations (Q 1.5)

This approach anticipated that respondents would take a broad view of nanotechnology in answering this questionnaire.

Further, definitions were not included for the specific applications identified in question 1.4, reflecting a number of issues;

- the rapidly evolving nature of the field of nanotechnology, including the on-going emergence of new sub-fields
- the absence of agreed definitions for sub-fields of nanotechnology.

Nanomedicine							Practitioners may wish to consider if these approaches are appropriate or relevant to the aims of their survey.
Nanomagnetics							
Nanomechanics							
Filtration and membranes							
Nanotools (for manipulation, nanolithography and nanofabrication							
Nanoinstruments or devices (for observation, analysis or control)							
Catalysis							
Software for modelling and simulation							
Other Fields, please identify _____							

1.5 Please identify **all** the areas of your company's **operations involved in nanotechnology** and related activities by **indicating with ✓.**

Company Operation	**Indicate all those that apply by ✓**
Product or Service R&D	
Production/Manufacturing **If yes**, please answer question **1.6** below	
Quality Control	
Marketing	
Legal, Regulatory, or Intellectual Property Affairs	
Environmental, Health and Safety Activities	
Imports/Exports	
Standardisation/Normalisation **[*Suggested Amendment based on pilot]***	
Other (please specify) _____	

This question was developed to provide an indication of the stages of the nanotechnology value chain in which the businesses are active. For example, legal and marketing operations related to nanotechnology, for R&D or manufacturing firms, would indicate activities related to commercialisation.

Further, this wide range of operations also encompasses specialist nanotechnology service providers, such as EHS monitoring specialists

Nor were definitions provided for the terms used in this question.

Practitioners may wish to consider their specific needs and may wish to delete some categories or to ask separate questions regarding some of these issues if further information is required.

1.6 ONLY FOR THOSE indicating **production/manufacturing** in 1.5 above:

Please indicate all the product types your company **manufactures with ✓.**

PRODUCT TYPE	INDICATE ALL THOSE THAT APPLY BY ✓
Nanotools (e.g. atomic force microscope, nanoimprint lithography, nanomanipulators)	
Nanomaterials (e.g. nanoparticles, nanotubes, quantum dots, fullerenes)	
Nanointermediates (e.g. coatings, optical components, nanocomposite)	
Intermediate nano-goods (component parts of a finished good incorporating nanotechnology e.g. plane engine blades)	
Finished goods incorporating nanotechnology (e.g. cars, clothing, computers, pharmaceuticals, mobile phone**)**	

This question has been developed further to include an additional category of intermediate goods incorporating nanotechnology.

1.7 How did your company a**cquire or develop the key** technologies used in your company's nanotechnology activities? Indicate all that apply by ✓.

Organisation	**Indicate all those that apply by ✓**
Historic Material [Suggested Amendment based on pilot]	
In-house R&D	
R&D commissioned from other company, specialised laboratory etc	

This question was developed based on input from experts in the field and was considered a fair typology of the current sources of nanotechnologies, rather than nanomaterials.

Practitioners may wish to consider if this approach is appropriate to the aims of their survey.

Acquired from or in partnership with (NB: acquired includes M&A activity)	
University/ academic institution	
Government laboratory	
Other research institution	
For-profit company	
Other (please specify) _____	

1.8 Where did your company **source the infrastructure or equipment** used in your nanotechnology activities? In-house, collaborative development, acquisition or through access to external facilities.

Indicate all that apply by ✓

Sources of infrastructure or equipment	**Developed**	**Manufactured**
	Indicate all that apply by ✓	
In-house		
In collaboration with another organisation With what type of organisation? _____		
Acquired (including through M&A activity) From what type of organisation? _____		
Other _____		

SECTION 2: GENERAL COMPANY INFORMATION

This section is often placed at the end of the questionnaire. As the survey is modular, Practitioners may wish to consider if these approaches are appropriate or relevant to the aims of their survey.

2.1 Where is the head office of your company?

City/Country _____/ _____

2.2 Is this the same location provided on page 1 of the survey? **Yes / No** ***(Circle** appropriate response)*

This question was based on developing evidence that nanotechnology companies are "born global", that is, that the physical location of branches/factories is highly internationalised right from the beginning. Questions 2.2 and 2.3 are intended to assist practitioners countries understand this issue.

2.3 Does your company have additional branches? **If yes,** where are the branches located?

City/Country _____/ _____

City/Country _____/ _____

City/Country _____/ _____

2.4 In what year was your company founded? _____

Practitioners may wish to consider if this information is available from other sources, for example administrative databases.

2.5 Are shares in your company traded on a public stock exchange?
Yes / No ***(Circle** appropriate response)*

Practitioners may wish to make use of relevant terminology including legal nomenclature.

2.6 What is the main field of activity for your company?

Main Field of Activity	Please mark only One by ✓
Agriculture, forestry and fishing	
Mining and quarrying	
Manufacturing – CHEMICALS [Suggested inclusion based on pilot]	
Manufacturing - COSMETICS	
Manufacturing - FOOD	
Manufacturing - COMPUTER AND ELECTRONIC	
Manufacturing - TEXTILES & CLOTHING	
Manufacturing - MOTOR VEHICLES AND TRUCKS	
Manufacturing - OTHER	

This question was based on input experts in the field, regarding the industry sectors most likely to be surveyed, and that the pilot was to be managed by policy agencies rather than statistical agencies.

Practitioners, based on the aims of their survey, may wish to use standard ISIC Rev 4 or NACE groupings.

Electricity, gas, steam and air conditioning supply		
Water supply; sewerage, waste management and remediation activities		
Construction		
Wholesale and retail trade; repair of motor vehicles and motorcycles		
Transportation and storage		
Accommodation and food service activities		
Professional, scientific and technical activities INCLUDES R&D companies and R&D activities		
Academic Research and Education		
Human Health		
Arts, entertainment and recreation		
OTHER:		

2.7 Is your company owned by another company?

Yes / No *(Circle appropriate response)*

2.7A If yes, what percentage of your company does it own? _____%

2.7B Where is the parent company located?
City/Country _____/ _____

Practitioners may wish to consider if this information is available from other sources, for example administrative databases.

SECTION 3: REVENUES / RESEARCH & DEVELOPMENT (R&D) EXPENDITURES

3.1 Please **complete** the following table, also **indicating the currency and units e.g. thousands,** you are reporting
If information is not available please provide a realistic estimate, clearly stating that the figure is estimated. Please report for all fiscal years. If '0' (ZERO), please indicate. Do not leave blank.

*Note – Our aim is to collect data for each alternate year, **however**, the onset of the global financial crisis in 2008 has severely impacted some high tech companies and we are interested in assessing this impact. For this reason, we request you complete data for the years 2008 & 2009 and a forecast for 2012.*

	2008	2009	2012 Forecast
INSERT CURRENCY ➤			
Total Company Sales/ Revenues (all sources)			
% of REVENUES from Nanotechnology	%	%	%
% of Total from all nanotechnology	%	%	%
% from NANO-PRODUCTS or NANO DEVICES	%	%	%
% from Products INCORPORATING nanotechnology	%	%	%
A - Total Company expenditures on R&D performed within the company (intramural R&D)			
% of A (above) directed to Nanotechnology R&D	%	%	%
B - Total Company expenditures on R&D performed outside the company (e.g. contributions and contracts to third parties)			
% of B (above) directed to Nanotechnology R&D	%	%	%

Practitioners may wish to consider possible overlap and consistency with national R&D and technology-related surveys.

Current understanding suggests nanotechnology data from such sources is likely to be limited, but availability may differ between countries. Nonetheless, the consistency between these questions and those in formal statistical surveys should be considered.

In particular, care should be exercised in ensuring that the concept of R&D used in questions can be compared with reported figures on intramural and extramural R&D – namely R&D carried out within or outside the enterprise, independent of the sources of funds - to avoid the double-counting of R&D.

3.2 If your company does not currently derive revenue from nanotechnology activities, what year do you expect to generate revenues from your nanotechnology activities? _____ (Year)

3.3 Does your company currently derive revenue from international markets?

Yes / No *(Circle appropriate response)*

If yes, what were your top three international markets by country?

1	
2	
3	

SECTION 4: HUMAN RESOURCES IN NANOTECHNOLOGY

4.1 Please indicate your company's typical employment level for 2008 by completing the table below. Do not include students. If '0' (zero) indicate '0'.

If an employee fulfils more than one duty, please report their primary responsibility. Count each person only once.

	Number of employees in 2008
Total number of employees	
Total number of employees involved in nanotechnology activities (full time equivalents)	

4.2 Has your company experienced difficulty in attracting **qualified** nanotechnology employees?

Yes / No *(Circle appropriate response)*

If yes, what type of position(s) was your company attempting to fill?

Please indicate all that apply by ✓

Scientist	
Engineer	
Professional Manager	
Technical manager	
Technical operator	
Other, please specify _____	

4.3 Does your company have formal alliances or collaborative arrangements with other entities?

Yes / No *(Circle appropriate response)*

If yes, what type of organisation? Please indicate all that apply by ✓

Nanotechnology incubator/research centre	
Other nanotechnology active company	
Other company	
Federal government	
Provincial/regional/state governments	
Academic institutions (same country)	
Academic institutions (other country)	
Public research organisations	
Infrastructure centre	
Other, please specify _____	

4.4 Does your company access specialist nanotechnology service providers?

Yes / No *(Circle appropriate response)*

SECTION 5: FINANCE AND INTELLECTUAL PROPERTY

5.1 Has your company attempted to raise capital for nanotechnology projects?

Yes / No *(Circle appropriate response)*

If yes, were you successful? **Yes / No** *(Circle appropriate response)*

If yes, how much did you raise? _____

CURRENCY _____

If yes, was this less, the same amount or more than you hoped to raise?

Less / same / more *(Circle appropriate response)*

Over what timescale (months/years) was this undertaken?

Practitioners may wish to consider how they define 'nanotechnology projects'.

5.2 Does your company own any nanotechnology related intellectual property instruments?

Yes / No *(Circle appropriate response*

If yes, Please indicate all that apply with a ✓ and how many

Patents		Number _____
Pending Patents		Number _____
Licensing Agreements		Number _____
Technology Transfer Agreements		Number _____
Other, please specify _____		Number _____

5.3 If yes, has your company received revenue from this instrument/s?

Yes / No *(Circle appropriate response)*

5.4 If yes, what is the amount of the revenue in the 2008 financial year?

_____ CURRENCY _____

SECTION 6: REGULATION OF NANOTECHNOLOGY	
6.1 In your primary country of operation can you identify the main agency/body(ies) responsible for the regulation of nanotechnology in your field? **Yes / No** *(Circle appropriate response)* ***if YES please answer Q6.2 - 6.7*** **if No go to Q 6.8**	To avoid confusion, practitioners may wish to note 'primary country of operation' can be different to location of the company Head Office, as referred to at Q2.1. It may also be useful to state more precisely the scope of the term 'operation' e.g. production or sales.
6.2 Is more than one regulatory agency/body involved? **Yes / No** *(Circle appropriate response)*	
6.3 Are the regulatory requirements of the body clearly set out? **Yes / No** *(Circle appropriate response)*	
6.4 Are the regulatory standards clearly set out? **Yes / No** *(Circle appropriate response)*	
6.5 Are the regulatory requirements SPECIFIC to nanotechnology? **Yes / No** *(Circle appropriate response)*	
6.6 Does the regulatory body have clear mechanisms for you to make enquiries? **Yes / No** *(Circle appropriate response)*	
6.7 Are they responsive to industry needs? **Yes / No** *(Circle appropriate response)* ***Please go to Q 6.9***	
6.8 **If No** Did this impact on your company's decision to locate your main operations in this country? **Yes / No** *(Circle appropriate response)* ***Please go to Q 6.9***	
6.9 Does your company manage its own regulatory affairs in your primary country of operation? **Yes / No** *(Circle appropriate response)*	
6.10 Do you think the approach to regulation needs to change in this country? **Yes / No** *(Circle appropriate response)*	

6.11 If **YES** Please describe how it should change and why these changes are necessary

Thank you for your co-operation!

Please return the completed survey to:

Include return instructions here

ANNEX 4: CONCORDANCE TABLE – ISIC REV 4 AND THE INDUSTRY CATEGORIES USED IN THE QUESTIONNAIRE

ISIC Rev.4 (International Standard Industrial Classification of All Economic Activities, Rev.4)	► ISIC Rev 4 category ➨ derived	Categories used in the Questionnaire on business Activity in Nanotechnology
A - Agriculture, forestry and fishing	►	Agriculture, forestry and fishing
B - Mining and quarrying	►	Mining and quarrying
C - Manufacturing		
10 - Manufacture of food products	➨	Manufacturing - FOOD
11 - Manufacture of beverages	➨	Manufacturing - FOOD
12 - Manufacture of tobacco products		
13 - Manufacture of textiles	➨	Manufacturing - TEXTILES & CLOTHING
14 - Manufacture of wearing apparel	➨	Manufacturing - TEXTILES & CLOTHING
15 - Manufacture of leather and related products 16 - Manufacture of wood and of products of wood…… 17 - Manufacture of paper and paper products 18 - Printing and reproduction of recorded media 19 - Manufacture of coke and refined petroleum products		
20 - Manufacture of chemicals and chemical products	➨	Manufacturing - COSMETICS * Derived from Division: 20 - Manufacture of chemicals and chemical products Group: 202 - Manufacture of other chemical products Class: 2023 - Manufacture of soap and detergents, cleaning and polishing p-reparations, perfumes and toilet preparations
21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations 22 - Manufacture of rubber and plastics products 23 - Manufacture of other non-metallic mineral products 24 - Manufacture of basic metals		
25 - Manufacture of fabricated metal products, except machinery and equipment		
26 - Manufacture of computer, electronic and optical	➨	Manufacturing - COMPUTER AND ELECTRONIC
27 - Manufacture of electrical equipment 28 - Manufacture of machinery and equipment n.e.c.		
29 - Manufacture of motor vehicles, trailers and semi-trailers	➨	Manufacturing - MOTOR VEHICLES AND TRUCKS
30 - Manufacture of other transport equipment	➨	Manufacturing - MOTOR VEHICLES AND TRUCKS
31 - Manufacture of furniture		
32 - Other manufacturing	► ➨	Manufacturing - OTHER
33 - Repair and installation of machinery and equipment		
D - Electricity, gas, steam and air conditioning supply	►	Electricity, gas, steam and air conditioning supply

E - Water supply; sewerage, waste management and remediation activities		
F - Construction	►	Construction
G - Wholesale and retail trade; repair of motor vehicles & motorcycles	►	Wholesale and retail trade; repair of motor vehicles and motorcycles
H - Transportation and storage	►	Transportation and storage
I - Accommodation and food service activities	►	Accommodation and food service activities
J - Information and communication		
K - Financial and insurance activities		
L - Real estate activities		
M - Professional, scientific and technical activities	►	Professional, scientific and technical activities
69 - Legal and accounting activities	➨	INCLUDES R&D companies and R&D activities
70 - Activities of head offices; management consultancy activities 71 - Architectural & engineering activities; technical testing & analysis 72 - Scientific research and development 73 - Advertising and market research 74 - Other professional, scientific and technical activities 75 - Veterinary activities	➨	INCLUDES R&D companies and R&D activities
N - Administrative and support service activities		
O - Public administration and defence; compulsory social security		
P - Education	➨	Academic Research and Education
Q - Human health and social work activities	➨	Human Health
86 - Human health activities 87 - Residential care activities 88 - Social work activities without accommodation		Human Health
R - Arts, entertainment and recreation	►	Arts, entertainment and recreation
S - Other service activities		
T - Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use		
U - Activities of extraterritorial organisations and bodies		
		Other

NOTES

1 National Science and Technology Council, the National Nanotechnology Initiative – Supplement to the President's 2011 Budget, 2010.

2 Survey on Emerging Technologies 2007, Statistics Canada.

3 See United Nations Statistics Division website at: http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27

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