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Overview and Discussion of the Results of the Pilot Survey on Nanotechnology in Canada

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^{p} preliminary
^{r} revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E} use with caution
F too unreliable to be published

Note

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Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued cooperation and goodwill.

The science and innovation information program

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.

Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.

As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 **(Science and Technology Activities and Impacts: A Framework for a Statistical Information System**, Cat. No. 88-522). The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology** (Cat. No. 88-523).

It is now possible to report on the Canadian system on science and technology and show the role of the federal government in that system.

Our working papers and research papers are available at no cost on the Statistics Canada Internet site at http://www.statcan.ca/cgi-bin/downpub/research.cgi?subject=193.

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Introduction

Nanotechnologies are transforming techniques and processes that are not restricted to one sector but a set that spreads across and throughout the economy. The National Research Council (NRC) characterizes nanotechnology as “convergence within convergence”. In the United States the National Science Foundation (NSF) identifies nanotechnology as a cornerstone of growth and innovation along side biotechnologies and information technologies, each relying on the other.

Nanotechnology is a cross-sector phenomenon and its potential impacts could be significant. Nanotechnologies can be thought of as a whole but as we examine it, the discovery may be made that nanotechnologies are found in the areas as diverse as biotechnology and health, agriculture, electronics and computer technology, environment and energy, optics, and in materials and manufacturing. A challenge to measurement of nanotechnology activities lies in this diversity. As nanotechnologies shift from the research laboratories to the commercial front, their impact on economic and social fronts may become more significant. As in other emerging technologies, locating and identifying of the actors involved in nanotechnologies poses a significant challenge.

Establishing a systematic and consistent process for statistical development and analysis on nanotechnology research and development, and eventual entry into the market will provide key stakeholders, policy analysts and decision makers with a reliable, validated and comparable information base to help inform strategy and policy decision making on the scientific economic, health, environmental and social impacts of nanotechnology. The situation is comparable to the state of statistical knowledge in biotechnology in Canada and internationally in the mid-1980s. Statistics Canada has conducted its initial national nanotechnology survey, believed to be a world first. This paper will discuss the current state of nanotechnology in Canada, discuss some of the issues facing nanotechnology measurement and present the preliminary results of the survey.

In the theory of innovation and technological change, considerable debate has focused on the development, commercialization and socio-economic impacts of emerging technologies such as micro-electronics and information technologies in the late 1970s, biotechnology and genomics in the 1980s, and the Internet in the 1990s. Over the past decade developments in nanoscience and nanotechnology have drawn the attention of governments, industry, academia and the public as to the potential industrial benefits.

Nanotechnology as has been the case with other emerging technologies presents considerable conceptual and practical issues associated with statistical measurements:

- The technologies are emerging: therefore rapidly evolving and not well defined;
- There are few examples of commercial applications and therefore have no baseline outcome statistics such as products, processes and services developed and adopted in the market place;
- The technologies are highly interdisciplinary: therefore not easily classified;
- The technologies are enabling: they have a wide range of potential applications in many sectors;
- The technologies are potentially disruptive, representing both significant benefits and risks in industry as well as for health and environmental applications; and
- The technologies are prone to hyperbole resulting from highly speculative claims from many quarters and misleading use of the terminology.

Definition of nanotechnology

A critical first step in the collection of statistics on expenditures and outcomes on nanotechnology R&D is for stakeholders to agree on a definition of nanotechnology so that government, universities and industry researchers and managers in each sector can consistently report and analyze data using the same language. It should be recognized that there is no internationally accepted formal definition (International Standards Organization, ISO or Organization for Economic Cooperation and Development, OECD) of nanotechnology due to the novelty of this field of research, the multidisciplinary aspects of the technology, and it's rapidly evolving nature.

Even a brief search for a definition of nanotechnology uncovers many competing definitions, making one of the first challenges defining exactly what is nanotechnology at least for statistical purposes. The challenge of defining what exactly is nanotechnology is complicated by the fact that the boundaries surrounding nanotechnology are not clear, nanotechnology cuts across many different sectors of the economy. For example where does nanotechnology end and information technologies and biotechnologies begin? Beyond the interest in the economic impact of nanotechnology are related activities such as regulation, education and training, and government expenditures and activities.

For an example of a definition of nanotechnology, the U.S. National Nanotechnology Initiative (NNI) provides:

> Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. (NNI)

Most definitions contain two essential statements: the length scale of 1 to 100 nanometres and the use of unique phenomena at that scale. A definition used by an agency can be affected by the agency's mandate. The principal example is that of the Canadian Institutes of Health Research (CIHR). The overlap of nanotechnology with biotechnology is complex, as many biological structures and processes occur at the nanometre length scale. As a comparison, when the US National Institutes of Health (NIH) reviews its projects for inclusion in NNI reporting, only those R&D projects that use nanotechnology tools and concepts to study biology; that propose to engineer biological molecules toward functions very different from those they have in nature; or that manipulate biological systems by methods more precise than can be done by using molecular biological, synthetic chemical, or biochemical approaches that have been used for years in the biology research community, are classified as nanotechnology projects.[1]

Approaching Measurement of Nanotechnology: Using Lessons Learned

In order to address the numerous questions and issues surrounding nanotechnology, the guidelines outlined in the Science, Innovation, and Electronic Information Division's (SIEID) *Activities and Impacts: A framework for a statistical information system*[2] can be used in conjunction with the lessons learned in recent Statistics Canada surveys (for example the *Biotechnology Use & Development* surveys[3]) to begin to develop a coherent approach to nanotechnology measurement. The framework addresses a series of who, what and where questions, which take the form of:

1. The preceding section was adapted from Fitzgibbons and McNiven.
2. For detailed information the reader is referred to the divisional framework document Science and Technology Activities and Impacts: A framework for a Statistical Information System, Statistics Canada, Ottawa, Catalogue no. 88-522-XIE (1998)
3. See Rose for a comprehensive discussion of the development of biotechnology statistical program.

- *What is nanotechnology*? Nanotechnology is a catch all term of activities and techniques that cuts across sectors and this can be extended further to addressing the question: What is a nanotechnology firm?

- *Who are the actors in nanotechnology*? The usual suspects of academia, business and government will be named but the specifics of these will need to be identified along with their respective roles and contributions.

- *Where is nanotechnology*? This not only refers to physical location but to the sector location, where in the economy is nanotechnology. Nanotechnology cuts across sectors and activities.

- *Why use nanotechnology? What are the results of using nanotechnology?* Issues such as reasons for adopting nanotechnologies and the benefits that resulted from adopting and using nanotechnology can be addressed.

- *How many resources have been committed to nanotechnology*? The expenditures both monetary and human can be explored.

- *How connected*? Over 70% of nanotechnology firms reported collaborative arrangements with universities, other firms and government. As the needs of the firms change so too will these connections.

Based on experience, development of a statistical program on nanotechnology benefits from the meaningful engagement of stakeholders, the use of this framework, and integrating the methodologies and techniques developed and refined in other innovation surveys. An example of lessons learned is the use of a list-based definition. In addition to a statement defining nanotechnology, nanotechnology could be transformed into a list of measurable products and processes, which as an added benefit addresses in part the cross-sector nature of nanotechnology.

The biotechnology statistics program at Statistics Canada serves as a workable model, completing the first national surveys on biotechnology and participating in the development of international definitions and model surveys on biotechnology at the OECD. All these potential steps would benefit from the early and active participation of stakeholders, creation of definitions and concepts that are rigorous enough for international comparisons, but flexible enough to capture and reflect the evolving and multi-sector nature of nanotechnology.

Results of Statistics Canada First Nanotechnology Measurement Activities

Statistics Canada used the following definition of nanotechnology in its initial steps towards collecting information on nanotechnology[4]:

> Nanotechnology is a suite of technologies which enable the direct manipulation, study or exploitation of systems or structures where at least one dimension is on the nanometre length scale (typically less than 100nm).
> The ability to control matter within this regime allows us to exploit phenomena which predominate at these length scales, leading to the production of novel materials and devices which exhibit qualitatively different properties than that of the corresponding bulk material.

4. Methodology and data quality are discussed in Appendix 1.

Respondents are then provided a list of more detailed nanotechnologies. This list was tested with potential respondents who indicated clear understanding and ability to answer[5].

Statistics Canada used the Emerging Technology Survey[6] (ETS) for reference year 2005 to begin to identify and inventory firms engaged in nanotechnology activity. The survey is mailed to all firms in industry codes where nanotechnology has been observed, or where there is a possibility of nanotechnology activities and resulted in a list of potential respondents. These respondents were then sent the Biotechnology Use and Development Survey which contained the pilot survey on nanotechnologies. The ETS has been successfully used to develop information leading to full surveys on other topics. It should be noted that these results are from selected industrial codes and may under-represent the total number of firms in Canada since we are learning more about nanotechnologies and their dispersion almost daily. The results of the survey should be viewed in the context of a pilot survey where untested concepts are tested and evaluated. While accurate given the context, a full survey process dedicated to nanotechnologies would result in more robust results. The Biotechnology Use and Development Survey – 2005 contained a dedicated nanotechnology section that asks basic questions of firms that have been identified as being active in nanotechnology. Results will be presented later in the paper. This process was successfully utilized in 2003 for Bioproducts, contributing to a full survey the following year for Bioproducts.

5. The Nanotechnology section of the survey (pages 15 and 16).
6. The Emerging Technology Survey 2005

Profile of the Nanotechnology Sector in Canada

Distribution

In 2005, 88 firms reported involvement in nanotechnology; the vast majority (91%) were active in research and development (R&D) and 27%[7] reported they were in the production/or market stage. Firms reported the greatest involvement in nanomaterials (43%) and nanobiotechnology (42%), followed by nanomedicine, nanophotonics and nanoelectronics. Some firms reported activity, primarily research and development, in more than one category.

Small firms accounted for 81% of all respondents, with medium and large firms accounting for 8% and 10% of firms. Provincial distribution of the firms found Ontario with 30 firms (34%), followed by Quebec with 25 (28%), British Columbia with 19 (21%) and Alberta with 12 (14%) firms. The remaining firms are spread across Canada. The size distribution and provincial distribution of stage of development and nanotechnology category followed similar patterns as Canada as a whole[8].

Details of the preceding and following discussions can be found on the accompanying tables. The table numbering system, beginning with Table 26 is a direct reflection of the question pattern on the questionnaire. Data tables can be found in Appendix 2.

Financial Details

Firms reported $28 million in nanotechnology revenues in 2005, an increase of 19% over revenues in 2004. However this is far less than the nearly doubling of revenues to $55.8 million forecast by respondents for the year 2007. Quebec accounted for the majority of revenues with 52%, with Ontario following at 22%, British Columbia at just under 14% and Alberta at 12%. Financial data for the rest of the provinces is not available due to small number respondents in those provinces. The 72 small firms earned 88% of all nanotechnology revenues in 2005.

Nanotechnology R&D expenditures totaled just over $40 million in Canada, a 12% increase from 2004. Again Ontario leads the provinces with 38% of nanotechnology related R&D, followed closely by British Columbia at 35%, Quebec at 22%, and Alberta at just under 5%. Total Canadian nanotechnology R&D expenditures rose 12% between 2004 and 2005, with firms forecasting expenditures of an addition $18 million a year by 2007. Contracted out R&D makes up about 6% of total nanotechnology R&D expenditure in 2005, with the forecast this will increase by 136% in 2007 at which time it will almost double to just under 10% of nanotechnology R&D spending. Not surprising is the fact that 93% of nanotechnology R&D is undertaken by small firms, as they account for 82% of all firms.

In 2005, 22 firms attempted to raise capital for nanotechnology related activities. Of these only 8 small firms were successful in raising just over $16.5 million. This demonstrates a fairly significant failure rate and could be of importance to the future growth of the nanotechnology sector and of concern to stakeholders. Provincial data is not available.

Surprising, given the early stage of development of the nanotechnology sector, 34 firms reported a total of 559 intellectual property instruments in 2005. Patents made up 60% of the total and pending patents comprised 28%, followed by technology transfer agreements at 26% of the IP activity, licensing agreements made up 20% with the balance comprised of the ‘other’ category.

7. Some firms reported involvement in both areas.
8. Details are available in the accompanying tables.

The majority of firms were in Quebec with 14 firms reporting 112 IP instruments, almost all were patents or pending patents. In Ontario, 13 firms reported 226 IP instruments, of which 56% were patents or pending patents. Four British Columbia firms reported 177 IP instruments of which 77% were patents and an additional 15% were pending patents. Other provincial data are unavailable.

The unexpected high number of patents has been investigated and verified. The survey question only asks the number of patents and other IP instruments without geographic parameters. Therefore it is possible that the double counting has occurred raising the total number reported. These patents also may not be unique to Canada.

Human Resources

The number of nanotechnology employees is small, with 88% of the 380 total nanotechnology employees found in small nanotechnology firms. The majority (76%) have full time duties as nanotechnology employees and the remaining 25% were employees with part time nanotechnology duties. Ontario leads with 36% of nanotechnology employees, followed by Quebec with 32%, British Columbia with 22% and finally Alberta with just over 8%. Overall 15% of firms, virtually all small firms, reported difficulty in attracting nanotechnology employees, with scientist and technical staff the most commonly cited areas of difficulty. Provincial data availability is limited but 40% of firms in British Columbia reported difficulty finding nanotechnology staff, more than double the percentage of the next highest province Quebec at 19% and Canada as a whole. In BC scientist and technical shortages were the most common difficulty reported.

Discussion on Current Profile

These results illustrate the level of activity of nanotechnology in Canada and although it is a relatively small sector at the moment, nanotechnologies are believed to hold the ability to develop into the next transformative (or emerging, or disruptive, or platform) technology. A single pilot survey is not robust enough to definitively answer all the issues surrounding nanotechnologies. But by placing the results of the survey in the context of SIEID key questions on development of indicators, the results demonstrate the ability to begin to address and measure the following key questions.

- *What is nanotechnology*? For statistical purposes further discussions on definition is required, but this survey provides an empirical test of one type of definition that respondents understood and were able to provide meaningful responses.
- *Who are the actors in nanotechnology*? There are 88 mainly small firms concentrated in four provinces, but distributed across Canada.
- *Where is nanotechnology*? We begin to see nanotechnology concentrating in nanomaterial and nanobiotechnology, however much work remains to further refine where in the economy nanotechnology will be found. This is a primary challenge facing all emerging technologies.
- *Why use nanotechnology? What are the results of using nanotechnology?* Firms reported $28 million in nanotechnology revenues, the key reason for a firm's existence. However the over $40 million in nanotechnology R&D could be viewed as an investment in the firm and hope for future revenues. The whys and results (impacts?) are areas for future long term inquiry.
- *How many resources have been committed to nanotechnology*? With 380 employees and over $40 million in R&D (with a further 46% increase to over $58 million for 2007) we see a small but growing commitment of resources to nanotechnology. Of significance is that only 8 of 22 small firms that attempted to raise capital were successful. They did however report raising over $16 million to further their efforts in nanotechnology.
- *How connected*? Over 70% of nanotechnology firms reported collaborative arrangements with universities, other firms and government. As the needs of the firms change so too will these connections.

The pilot survey on nanotechnology has successfully begun to address these critical questions but much work remains in order to monitor, measure, and analyze this emerging technology.

Ongoing and Future work

Questions on nanotechnology are included in the Survey of Advanced Technology - 2007 with results expected in 2008. Inquiries on nanotechnology R&D expenditures are included in the 2006 survey Research and Development in Canadian Industry which uses a combination of tax and survey data. These surveys are intended to provide concrete information on nanotechnologies as well as test concepts and definitions, with the intent to implement dedicated nanotechnology surveys in the future.

These surveys will provide useful information not just on R&D expenditures, but will also provide information on the where to find nanotechnology activity in the Canadian economy. This will aid in accurate coverage for potential future dedicated nanotechnology surveys. Currently all nanotechnology activities at Statistics Canada are done on an ad hoc unfunded basis. Inclusion of nanotechnology in the Federal S&T survey and other existing surveys is being explored. Nanotechnology is likely approaching the stage when an organized statistical program would benefit stakeholder representing a cross-section of perspectives. A workshop focused on this question may serve as a catalyst for development of statistical information.

The Office of the National Science Advisor has examined nanotechnology expenditures by Federal government departments and agencies. Initiatives are currently under way in international forums (e.g. ISO TC229); OECD-CSTP-NESTI-; International Risk Governance Council, UNESCO) that are looking into the public policy implications for the development and commercialization of nanotechnologies. These initiatives will require commonly recognized definitions, statistical protocols and frameworks to inform discussions and help guide decision making. Over the past decade considerable progress has been made in the development of emerging technology statistics, most notably in biotechnology.

Canada has been very active in the discussions at the OECD, where nanotechnologies have drawn much interest, and development of statistics has been identified as one of the priorities amongst participating nations. Nanotechnology is scheduled to be included in CSTP (Committee for Scientific and Technological Policy) discussions scheduled in spring of 2007 – where Canada will express its support for the establishment of the new Working Party. Assuming approval by the CSTP, the first meeting of the new CSTP Working Party on Nanotechnology will be formed with the objectives developing a work plan and on the prioritization of projects to be undertaken.

Summary

Despite the challenges facing systematic measurement of nanotechnology, precedent can be found in the approaches undertaken and results seen. Many of the challenges can be addressed using methods and techniques have been developed and refined that addresses the who, what, where, why and what results, and the how much, and how connected questions raised in SIEID's divisional framework. Canada is a leader in development of both national biotechnology statistics and international definitions. The list-based definition of biotechnology tentatively adopted by the OECD is based on the Canadian list-based definition successfully implemented in Statistics Canada surveys. Nanotechnology can adapt many of these techniques in order to develop meaningful and timely statistics. Measurement of nanotechnology is in its infancy, and much work and many challenges remain.

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Appendix 1

Methodology

The Biotechnology Use and Development Survey (BUDS), administered by the Science, Innovation and Electronic Information Division (SIEID), provides information on companies developing innovative products or processes using biotechnologies. **The 2005 version of the survey also provides information about the key characteristics of firms that are using or developing nanotechnology.**

The survey's target population includes all firms, in Canada, in selected NAICS codes. The establishments of an enterprise located in the same province and industry type were grouped to form the statistical unit. Excluded from the survey were not-for-profit organizations, universities, government laboratories, hospitals. In addition, respondents had at least $100,000 in R&D expenditures or at least 5 employees according to the Business Register. The questionnaire was prepared with active input from partners and in consultation with a group of biotechnology experts with a variety of specialties and interests. Following the initial design work, the questionnaire was presented to a sample of potential respondents, whose comments on the design and content were incorporated into the final version. The 2005 survey questionnaire included a section on nanotechnology.

The survey was conducted in two stages. First, the Emerging Technology Survey a simple questionnaire with five Yes/No questions was mailed to 11,800 firms. The list of recipients was compiled from the list of firms identified in previous Biotechnology Use and Development Surveys, from the set of firms identified by the Business Register as belonging to a predetermined list of NAICS codes and finally firms identified by other means as involved in biotechnology or nanotechnology.

A section on nanotechnologies was also included in the questionnaire. Stratification was made using these 3 variables: NAICS, province and size. Size is based on the number of employees of the provincial enterprise: i) 0-49 employees; ii) 50-149 employees and iii) 150 employees and more.

A challenge facing the survey and indeed all research into the nature of an emerging technology is the fact that nanotechnology is not single product or process nor a single group of products or processes. It is a broad spectrum of products and processes spanning Human Health, Agriculture, the Environment and other industries and classifications. The sampling techniques are consistent with this situation, and the sample reflects not a single well-defined industry but a developing sector with a variety of characteristics, some known and some unknown.

Responding to this survey is mandatory. Data are collected directly from survey respondents. Data was collected through respondent completed questionnaires in paper format (mail or fax).

The quality of the data has been checked against quality standards at Statistics Canada, namely, data relevance, accuracy, timeliness, accessibility, interpretability and coherence. Estimates were vetted for compliance with confidentiality rules. Data quality was assessed in consultation with the methodology team, and when the data were unreliable, they were not published. Data accuracy was insured by conducting cognitive interviews in both official languages with potential respondents. Their comments were integrated into the final design and wording of the questionnaire.

Confidentiality

Statistics Canada is prohibited by law from releasing any data that would divulge information obtained under the Statistics Act that relates to any identifiable person, business or organization without the prior knowledge or the consent in writing of that person, business or organization. Various confidentiality rules are applied to all data that are released or published to prevent the publication or disclosure of any information deemed confidential. If necessary, data are suppressed to prevent direct or residual disclosure of identifiable data.

Appendix 2 – The Tables

Notes

No reliable data were available for the Atlantic provinces, nor for Manitoba and Saskatchewan.

Table numbers are based on the relevant questions from the Biotechnology Use and Development Survey questionnaire.

Table 26.1 Firms using or planning to use nanotechnology in 2005, by region

	All Nanotechnology firms	Use in research and development	Use in production or on market	Plan to use in 2 years
	number			
Canada				
All nanotechnologies	**88**	81	24	14
Nanophotonics	**17**	13	5	x E
Nanoelectronics	**14**	14	3	x E
Nanobiotechnology	**37**	34	3	7
Nanomedicine	**18**	16	4	3 E
Nanomaterials	**38**	36	12	10
Quantum computing	**0**	0	0	0
Self assembly	**7**	7	3 E	F
Instrumentation development	**12**	12	3 E	F
Other	**F**	F	0	0
Quebec				
All nanotechnologies	**25**	22	14	3 E
Nanophotonics	**6**	5	3 E	0
Nanoelectronics	**4**	4	3 E	0
Nanobiotechnology	**6**	6	F	F
Nanomedicine	**0**	0	0	0
Nanomaterials	**19**	17	8	3 E
Quantum computing	**0**	0	0	0
Self assembly	**F**	F	0	0
Instrumentation development	**3 E**	3 E	3 E	0
Ontario				
All nanotechnologies	**30**	28	6	7
Nanophotonics	**6**	4	F	0
Nanoelectronics	**4**	4	0	0
Nanobiotechnology	**13**	11	0	F
Nanomedicine	**10**	9	x E	F
Nanomaterials	**10**	10	3 E	7
Quantum computing	**0**	0	0	0
Self assembly	**3 E**	3 E	0	0
Instrumentation development	**4 E**	4	0	F
Alberta				
All nanotechnologies	**12**	9	x E	F
Nanophotonics	**F**	F	0	0
Nanoelectronics	**3 E**	3 E	0	0
Nanobiotechnology	**7**	5	0	F
Nanomedicine	**3 E**	3 E	0	0
Nanomaterials	**5**	4	x E	0
Quantum computing	**0**	0	0	0
Self assembly	**0**	0	0	0
Instrumentation development	**5**	5	0	0
British Columbia				
All nanotechnoloties	**19**	19	x E	3 E
Nanophotonics	**x**	x E	0	x E
Nanoelectronics	**3**	3 E	0	x E
Nanobiotechnology	**9**	9	F	F
Nanomedicine	**3**	3 E	x E	F
Nanomaterials	**4**	4	0	0
Quantum computing	**0**	0	0	0
Self assembly	**3**	3 E	3 E	F
Instrument development	**0**	0	0	0

Preliminary data, subject to revision.
Source: Biotechnology Use and Development Survey, 2005.

Table 26.2 Firms using or planning to use nanotechnology in 2005, by size

	All Nanotechnology firms	Use in research and development	Use in production or on market	Plan to use in two years
	number			
All firm sizes				
All nanotechnologies	**88**	81	24	14
Nanophotonics	**17**	13	5	x E
Nanoelectronics	**14**	14	3 E	x E
Nanobiotechnology	**37**	34	3 E	7
Nanomedicine	**18**	16	4	3 E
Nanomaterials	**38**	36	12	10
Quantum computing	**0**	0	0	0
Self assembly	**7**	7	3 E	F
Instrumentation development	**12**	12	3 E	F
Other	**F**	F	0	0
0 to 49 employees				
All nanotechnologies	**72**	69	19	12
Nanophotonics	**13**	12	x E	x E
Nanoelectronics	**14**	14	3 E	x E
Nanobiotechnology	**34**	31	3 E	7
Nanomedicine	**15**	13	4	3 E
Nanomaterials	**31**	29	11	8
Quantum computing	**0**	0	0	0
Self assembly	**7**	7	3 E	F
Instrumentation development	**10**	10	3 E	0
50 to 149 employees				
All nanotechnologies	**7**	7	0	0
Nanophotonics	**x E**	x E	0	0
Nanoelectronics	**0**	0	0	0
Nanobiotechnology	**F**	F	0	0
Nanomedicine	**3 E**	3 E	0	0
Nanomaterials	**3 E**	3 E	0	0
Quantum computing	**0**	0	0	0
Self assembly	**0**	0	0	0
Instrumentation development	**0**	0	0	0
150 employees and over				
All nanotechnologies	**9**	4	5 E	F
Nanophotonics	**x E**	x E	x E	0
Nanoelectronics	**0**	0	0	0
Nanobiotechnology	**x E**	x E	0	0
Nanomedicine	**0**	0	0	0
Nanomaterials	**5 E**	3 E	F	F
Quantum computing	**0**	0	0	0
Self assembly	**0**	0	0	0
Instrumentation development	**F**	F	0	F

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 27.1 Revenues and research and development (R&D) expenditures of nanotechnology firms, by region

	2004	2005	2007 forecast
	$ thousands		
Canada			
Total revenues from nanotechnology	23,572	28,150	55,896
Total R&D spending on nanotechnology	35,938	40,299	58,676
Total nanotechnology R&D spending contracted out to others	3,365	2,413	5,682
Quebec			
Total revenues from nanotechnology	12,699	14,625	27,241
Total R&D spending on nanotechnology	9,194	9,049	11,731
Total nanotechnology R&D spending contracted out to others	525 E	1,156	1,180
Ontario			
Total revenues from nanotechnology	5,026	6,228	15,526
Total R&D spending on nanotechnology	11,406	15,276	18,585
Total nanotechnology R&D spending contracted out to others	531	F	526
Alberta			
Total revenues from nanotechnology	2,531 E	3,448 E	5,476 E
Total R&D spending on nanotechnology	1,066	1,824 E	1,255
Total nanotechnology R&D spending contracted out to others	107 E	115	238 E
British Columbia			
Total revenues from nanotechnology	3,210 E	F	7,610
Total R&D spending on nanotechnology	14,037	14,119	27,053
Total nanotechnology R&D spending contracted out to others	2,203 E	1,101 E	3,738 E

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 27.2 Revenues and research and development (R&D) expenditures of nanotechnology firms, by firm size

	2004	2005	2007 forecast
	$ thousands		
All firm sizes			
Total revenues from nanotechnology	23,572	28,150	55,896
Total R&D spending on nanotechnology	35,938	40,299	58,676
Total nanotechnology R&D spending contracted out to others	3,365	2,413	5,682
0 to 49 employees			
Total revenues from nanotechnology	21,060	24,769	52,226
Total R&D spending on nanotechnology	33,150	37,355	56,196
Total nanotechnology R&D spending contracted out to others	2,903	2,091	5,314
50 to 149 employees			
Total revenues from nanotechnology	188 E	323 E	F
Total R&D spending on nanotechnology	1,088	1,292 E	638
Total nanotechnology R&D spending contracted out to others	23 E	23 E	23 E
150 employees and over			
Total revenues from nanotechnology	2,324 E	3,058 E	3,670 E
Total R&D spending on nanotechnology	1,701	1,652	1,842
Total nanotechnology R&D spending contracted out to others	439	298 E	345 E

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 28a.1 Human resources in nanotechnology in 2005, by region

	number
Canada	
Total number of employees with nanotechnology responsibilities	380
Total number of full-time employees with nanotechnology responsibilities	287
Total number of part-time employees with nanotechnology responsibilities	93
Quebec	
Total number of employees with nanotechnology responsibilities	121
Total number of full-time employees with nanotechnology responsibilities	96
Total number of part-time employees with nanotechnology responsibilities	25
Ontario	
Total number of employees with nanotechnology responsibilities	138
Total number of full-time employees with nanotechnology responsibilities	92
Total number of part-time employees with nanotechnology responsibilities	46
Alberta	
Total number of employees with nanotechnology responsibilities	32
Total number of full-time employees with nanotechnology responsibilities	24 [E]
Total number of part-time employees with nanotechnology responsibilities	8
British Columbia	
Total number of employees with nanotechnology responsibilities	84
Total number of full-time employees with nanotechnology responsibilities	73
Total number of part-time employees with nanotechnology responsibilities	10

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 28a.2 Human resources in nanotechnology in 2005, by firm size

	number
All firm sizes	
Total number of employees with nanotechnology responsibilities	380
Total number of full-time employees with nanotechnology responsibilities	287
Total number of part-time employees with nanotechnology responsibilities	93
0 to 49 employees	
Total number of employees with nanotechnology responsibilities	335
Total number of full-time employees with nanotechnology responsibilities	273
Total number of part-time employees with nanotechnology responsibilities	63
50 to 149 employees	
Total number of employees with nanotechnology responsibilities	25 E
Total number of full-time employees with nanotechnology responsibilities	4 E
Total number of part-time employees with nanotechnology responsibilities	21 E
150 employees and over	
Total number of employees with nanotechnology responsibilities	19 E
Total number of full-time employees with nanotechnology responsibilities	10
Total number of part-time employees with nanotechnology responsibilities	F

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 28b.1 Firms experiencing difficulty in attracting nanotechnology employees by type of position, by region

	percent
Canada	
Firms experiencing difficulty	15
Scientist	16
Professional manager	9
Technical	14
Other	x E
Quebec	
Firms experiencing difficulty	19
Scientist	19
Professional manager	13
Technical	19
Other	0
Ontario	
Firms experiencing difficulty	0
Scientist	10
Professional manager	0
Technical	5
Other	0
Alberta	
Firms experiencing difficulty	10
Scientist	10
Professional manager	10
Technical	10
Other	0
British Columbia	
Firms experiencing difficulty	40
Scientist	25
Professional manager	17
Technical	25
Other	x E

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 28b.2 Firms experiencing difficulty in attracting nanotechnology employees by type of position, by firm size

	percent
All firm sizes	
Firms experiencing difficulty	15
Scientist	16
Professional manager	9
Technical	14
Other	x E
0 to 49 employees	
Firms experiencing difficulty	19
Scientist	19
Professional manager	11
Technical	17
Other	x
50 to 149 employees	
Firms experiencing difficulty	0
Scientist	0
Professional manager	0
Technical	0
Other	0
150 employees and over	
Firms experiencing difficulty	0
Scientist	0
Professional manager	0
Technical	0
Other	0

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 29.1 Nanotechnology firms having alliances or collaborative arrangements with other entities, by region

	number
Canada	
Firms having alliances or collaborative arrangements	55
Nanotechnology incubators	3 E
Other nanotechnology firms	19
Other firms	21
Federal government	11
Provincial governments	3 E
Foreign governments	6
Universities	36
Other	8
Quebec	
Firms having alliances or collaborative arrangements	16
Nanotechnology incubators	F
Other nanotechnology firms	8
Other firms	7
Federal government	5 E
Provincial governments	3 E
Foreign governments	F
Universities	11
Ontario	
Firms having alliances or collaborative arrangements	16
Nanotechnology incubators	0
Other nanotechnology firms	5 E
Other firms	5
Federal government	F
Provincial governments	0
Foreign governments	F
Universities	13
Alberta	
Firms having alliances or collaborative arrangements	11
Nanotechnology incubators	F
Other nanotechnology firms	3 E
Other firms	3 E
Federal government	F
Provincial governments	0
Foreign governments	F
Universities	6
British Columbia	
Firms having alliances or collaborative arrangements	11
Nanotechnology incubators	0
Other nanotechnology firms	3 E
Other firms	5
Federal government	3 E
Provincial governments	0
Foreign governments	F
Universities	6

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 29.2 Nanotechnology firms having alliances or collaborative arrangements with other entities, by firm size

	number
All firm sizes	
Firms having alliances or collaborative arrangements	55
Nanotechnology incubators	3 E
Other nanotechnology firms	19
Other firms	21
Federal government	11
Provincial governments	3 E
Foreign governments	6
Universities	36
Other	8
0 to 49 employees	
Firms having alliances or collaborative arrangements	45
Nanotechnology incubators	3 E
Other nanotechnology firms	14
Other firms	19
Federal government	9
Provincial governments	3 E
Foreign governments	6
Universities	28
50 to 149 employees	
Firms having alliances or collaborative arrangements	7
Nanotechnology incubators	0
Other nanotechnology firms	3 E
Other firms	F
Federal government	F
Provincial governments	0
Foreign governments	0
Universities	6
150 employees and over	
Firms having alliances or collaborative arrangements	F
Nanotechnology incubators	0
Other nanotechnology firms	F
Other firms	0
Federal government	0
Provincial governments	0
Foreign governments	0
Universities	F

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 30 Success in raising capital for nanotechnology projects

	Firms that attempted to raise capital	Firms that raised capital	Capital raised
	number		$ thousands
Canada	22	8	16,585 E

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 31a Firms possessing nanotechnology related intellectual property (IP) instruments in 2005

	number
Canada	**34**
By region	
Quebec	14
Ontario	13
Alberta	x E
British Columbia	x
By firm size	
0 to 49 employees	28
50 to 149 employees	3
150 employees and over	3 E

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 31b.1 Nanotechnology related intellectual property instruments by type of instrument in 2005, by region

	number
Canada	
Patents	337
Pending patents	156
Licensing agreements	20
Technology transfer agreements	38
Other	8 E
Quebec	
Patents	55
Pending patents	57
Licensing agreements	F
Technology transfer agreements	F
Other	0
Ontario	
Patents	116 E
Pending patents	70 E
Licensing agreements	12
Technology transfer agreements	28 E
Other	F
Alberta	
Patents	24 E
Pending patents	0
Licensing agreements	0
Technology transfer agreements	x E
Other	0
British Columbia	
Patents	137 E
Pending patents	27 E
Licensing agreements	5 E
Technology transfer agreements	5 E
Other	F

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

Table 31b.2 Nanotechnology related intellectual property instruments by type of instrument in 2005, by firm size

	number
All firm sizes	
Patents	337
Pending patents	156
Licensing agreements	20
Technology transfer agreements	38
Other	8 E
0 to 49 employees	
Patents	273
Pending patents	114
Licensing agreements	19
Technology transfer agreements	35
Other	8 E
50 to 149 employees	
Patents	26 E
Pending patents	0
Licensing agreements	0
Technology transfer agreements	3
Other	0
150 employees and over	
Patents	39 E
Pending patents	42 E
Licensing agreements	F
Technology transfer agreements	0
Other	0

Preliminary data, subject to revision.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005.

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