THE COUNCIL OF CANADIAN ACADEMIES
180 Elgin Street, Ottawa, ON Canada K2P 2K3

NOTICE: The project that is the subject of this report was undertaken with the approval of the Board of Governors of the Council of Canadian Academies. Board members are drawn from the RSC: The Academies of Arts, Humanities and Sciences of Canada, the Canadian Academy of Engineering (CAE) and the Canadian Academy of Health Sciences (CAHS), as well as from the general public. The members of the committee responsible for the report were selected by the Council for their special competences and with regard for appropriate balance.

This report was prepared for the Government of Canada in response to a request from the Minister of Industry. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors — the Committee on the State of Science & Technology in Canada — and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

Library and Archives Canada Cataloguing in Publication

The state of science & technology in Canada / the Committee on the State of Science & Technology in Canada.

Issued also in French under title: L'état de la science et de la technologie au Canada.
Issued also in electronic format.
Includes bibliographical references.

ISBN 0-9781778-2-7

1. Science--Canada. 2. Technology--Canada. I. Council of Canadian Academies. Committee on the State of Science & Technology in Canada
Q127.C2S63 2006a 509'.7109051 C2006-905723-0

Disclaimer:
The Internet data and information referenced in this report were correct, to the best of our knowledge, at the time of publication. Due to the dynamic nature of the Internet, resources that are free and publicly available may subsequently require a fee or restrict access, and the location of items may change as menus and homepages are reorganized.

Council of Canadian Academies
Conseil des académies canadiennes

Printed in Ottawa, Canada
September 2006

Committee on the State of Science & Technology in Canada

Elizabeth Dowdeswell, (*Chair*), Special Advisor, Nuclear Waste Management Organization

Tom Brzustowski, FRSC, FCAE, RBC Financial Group Professor in the Commercialization of Innovation, University of Ottawa

David Dolphin, FRSC, CEO, BC Innovation Council

Don Drummond, Senior Vice President and Chief Economist, TD Bank Financial Group

Jean Gray, FCAHS, Professor of Medicine (Emeritus), Dalhousie University

Peter Grütter, FRSC, Professor of Physics, McGill University

Richard Hawkins, Professor and Canada Research Chair (Tier 1) in Science, Technology and Innovation Policy, University of Calgary

Susan A. McDaniel, FRSC, Professor of Sociology, University of Windsor

Charles Wessner, Program Director, The National Academies; Washington DC

Joseph D. Wright, FCAE, Retired President and CEO of the Pulp & Paper Research Institute of Canada (PAPRICAN)

Staff of the Council of Canadian Academies

Peter J. Nicholson, President
Marc Saner, Executive Vice-President and Director of Assessments

Nancy Neil, Executive Assistant to the President
Samantha Rae, Assistant to the Executive Vice-President
Jennifer Chandler, Senior Associate
Marie-Noëlle Ip, Senior Associate
Katherine Levitt, Senior Associate
Christina Stachulak, Senior Associate

The Council of Canadian Academies

Science Advice in the Public Interest

The mandate of the **Council of Canadian Academies** is to perform independent, expert assessments of the science that is relevant to important public issues. Here 'science' is interpreted broadly to encompass any knowledge-generating discipline, including the natural, social and health sciences, engineering and the humanities. The Council's assessments are performed by independent panels of qualified experts from Canada and abroad.

Operating at arm's length from government, but with 10-year funding of $30 million provided in 2005 by the Government of Canada, the Council carries out studies of subjects proposed by the government, and eventually, by non-governmental and private-sector organizations. The Council is governed by a 12-member Board, a majority of whom are appointed directly or indirectly by the Council's three member Academies — the Canadian Academy of Health Sciences, the Canadian Academy of Engineering and the RSC: The Academies of Arts, Humanities and Sciences of Canada. An 18-member Scientific Advisory Committee, composed of eminent representatives of the broad science community, advises the Council's Board with respect to assessment topic selection, terms of reference, selection of expert panels, and peer review.

The founding members of the Council of Canadian Academies are:

RSC: The Academy of the Arts, Sciences and Humanities of Canada, is the senior national body of distinguished Canadian scientists, scholars and artists. The RSC consists of approximately 1,700 Fellows: men and women from across the country who are selected by their peers for outstanding contributions to the natural and social sciences and in the arts and humanities. The RSC is a charitable organization incorporated by an Act of Parliament in 1883.

The **Canadian Academy of Engineering** is an independent, self-governing and non-profit organization established in 1987. The approximately 275 Fellows of the Academy are professional engineers from all disciplines and are elected on the basis of their distinguished service and contribution to society, to the country and to the profession.

The **Canadian Academy of Health Sciences** was created in 2004 as successor of the Canadian Institute of Academic Medicine. The CAHS encompasses the full breadth of academic health sciences, including all the medical and allied health sciences ranging from fundamental science to social science and population health. The approximately 135 members currently elected to the CAHS are recognized for their leadership, creativity, distinctive competencies and commitment to the advancement of academic health sciences.

www.scienceadvice.ca

ACKNOWLEDGEMENTS

This project was undertaken in response to a request from the Government of Canada, through the Minister of Industry, outlining questions regarding the state of science and technology (S&T) in Canada. The study charge led to the appointment of the Committee on the State of Science & Technology in Canada. During the course of its deliberations, the committee sought assistance from many people and organizations who provided valuable advice and information for consideration. Special thanks are due to Derek Jansen, Vice-President of EKOS Research Associates Inc., and his colleagues who skilfully administered an online survey, the results of which constitute a core base of information for this report. Special thanks are also due to Éric Archambault and Grégoire Côté, respectively President and Project Director of Science-Metrix, who provided the bibliometric and technometric data analysis employed in the study; to Javier Gracia-Garza of the Office of the National Science Advisor for his assistance in consolidating information from within the federal government; and to Craig Wilson of Foreign Affairs and International Trade Canada who coordinated the provision of information from Canada's S&T network abroad.

This report was reviewed in draft form by the individuals listed below who were selected by the Board of the Council of Canadian Academies for their diverse perspectives, areas of expertise, and broad representation of the scientific and technological communities. The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered fully by the committee, and many of their suggestions have been incorporated in the report. The reviewers were not asked to endorse the final report, as it is exclusively the responsibility of the committee. We thank the following individuals for their reviews:

Mel Cappe, President, Institute for Research on Public Policy

Adam Chowaniec, Chairman of the Board of Directors, Tundra Semiconductor Corporation

Michael Clegg, Donald Bren Professor of Ecology & Evolutionary Biology, University of California, Irvine and Foreign Secretary, US National Academy of Sciences

Charles H. Davis, Edward S. Rogers Sr. Research Chair in Media Management and Entrepreneurship and Professor, Faculty of Communication & Design, Ryerson University

Henry Friesen, FRSC, FCAHS, Former Chair Genome Canada and Former President Medical Research Council

Fred Gault, Director of the Science, Innovation and Electronic Information Division, Statistics Canada

Louis Maheu, FRSC, Full Professor, Department of Sociology, Université de Montreal

Martin Moskovits, FRSC, Dean of Science and Professor of Physical Chemistry, University of California, Santa Barbara

Luc Soete, Director of UNU-MERIT and Professor of International Economics, University of Maastricht

Mary Anne White, University Research Professor and Director of the Institute for Research in Materials, Department of Chemistry, Dalhousie University

We extend a special thank you to the many individuals who advised informally on various aspects of the study and particularly on the design of the online survey. Distribution of the survey was generously assisted by many volunteers in government, universities, and the business and NGO sectors. We thank them all. And lastly we thank the 1,529 respondents to the survey. Their investment of time and wisdom has contributed immeasurably to the final report.

Elizabeth Dowdeswell, Chair
Committee on the State of Science & Technology in Canada

TABLE OF CONTENTS

Summary and Main Findings

This summary document is an abridged version of the full report and is thus more extensive than a conventional executive summary. It includes substantially all of the findings of our study and many of the data tables and graphics from the full report. Though designed to be reasonably self-contained, this abridgment necessarily omits a great deal of important context, additional evidence, and elaboration that will be found in the report and its appendices.

1. The Charge – This report responds to a request in June 2006 from the Government of Canada, via the Minister of Industry, for advice as to Canada's strengths and capacity in science and technology (S&T), specifically to help better understand:

- The scientific disciplines in which Canada excels in a global context
- The technology applications where Canada excels in a global context
- The S&T infrastructure that currently provides Canada with unique advantages
- The scientific disciplines and technological applications that have the potential to emerge as areas of prominent strength for Canada and generate significant economic or social benefits.

2. What is Science & Technology? – In this report, science and technology are regarded as a *joint* entity rather than as two separate endeavours, hence the symbol, *S&T*. The scope of S&T encompasses disciplines in the natural sciences (the study of nature); the social sciences, humanities and health sciences (the study of human beings); and engineering (the creation and study of artifacts and systems). Our conception of S&T includes the myriad connections from science to technology and vice versa.

3. S&T and Innovation – Strength in science and technology is considered to be essential for a modern country's *ongoing* capacity to innovate and compete in the knowledge-based global economy. The connection between S&T and innovation begins with invention – an invention being the practical demonstration of a new idea that may derive from research results, from needs expressed in the market, or from the experience and imagination of individual inventors. The successful commercialization of inventions, or their significant application in society, produces 'innovations'. There is no linear progression from research through invention to innovations. Instead, the process involves false starts, blind alleys and feedback loops, and it includes obstacles that have little to do with the quality of the S&T involved. Above all, it requires talented, highly skilled people with a vision who are also entrepreneurial, energetic and persistent.

4. What is S&T Strength? – There is no simple, one-dimensional measure of Canada's S&T strength. The concept is inherently multidimensional and encompasses (a) the quality of science and technology in Canada; (b) the magnitude or intensity of the Canadian effort in various domains of S&T; (c) the trend of the foregoing factors (are we gaining or losing ground?); and (d) the extent to which our S&T capabilities can be applied effectively to achieve social and economic objectives. Qualitative judgments that integrate multiple dimensions and factors are unavoidable.

5. The Global Perspective – Strength in a global context matters for Canada because it determines our ability to compete for increasingly mobile resources of people and investment capital, and to participate in global knowledge-sharing networks that operate at the leading edge both of science and of technology development. We have therefore analyzed Canada's S&T strengths, relative to our size, against norms that are typical of other economically advanced countries of the OECD group, including the United States. We also note the growing importance of emerging economic giants, such as China and India, that are becoming forces to be reckoned with in increasingly sophisticated areas of S&T.

6. What the Report Seeks to Answer and What It Does Not – Our study focuses on describing the strength of the principal building blocks of Canada's S&T system. We also identify certain areas where we appear to be comparatively weak or declining in S&T capacity. It was beyond our mandate to analyze the difficult but crucial question of how S&T strengths become translated into the outcomes that ultimately contribute to Canada's economic performance and quality of life. Neither do we recommend on S&T policy or on priorities for the allocation of support.

7. Science & Technology Strength Through Four Lenses – There is no single best practice for assessing a nation's S&T strengths. We have therefore chosen four different approaches, or "lenses," to evaluate the questions posed:

- **Opinion Survey:** A large-scale, online survey of the opinion of Canadian S&T experts. These informed opinions represent, collectively, a broad and integrated picture.
- **Metrics:** An analysis of bibliometric data (the quantity and quality of published research in scientific journals) and technometric data (patents granted). This gives a narrower, but more precise, internationally comparable perspective.
- **View from Abroad:** A summary of reports and comments obtained from foreign sources that complements the self-assessment of the opinion survey.
- **Literature:** A review of relevant publications, including internationally comparable indicators of important aspects of S&T strength at the national level.

Our findings are based primarily on the first two of these lenses, and most extensively on the survey, which is the principal source of new insight in this study.

8. Survey of Informed Opinion – The target respondents for the online survey were senior people considered to be well informed on S&T in Canada, including those with both broad and highly specialized backgrounds. Access to the survey was distributed by the Council through a network of contacts in universities, governments, the private sector and in the Council's member Academies. We estimate that the link to the survey website was distributed to roughly 5,000 individuals from whom 1,529 completions were received over a three-week period between July 17 and August 8, 2006.

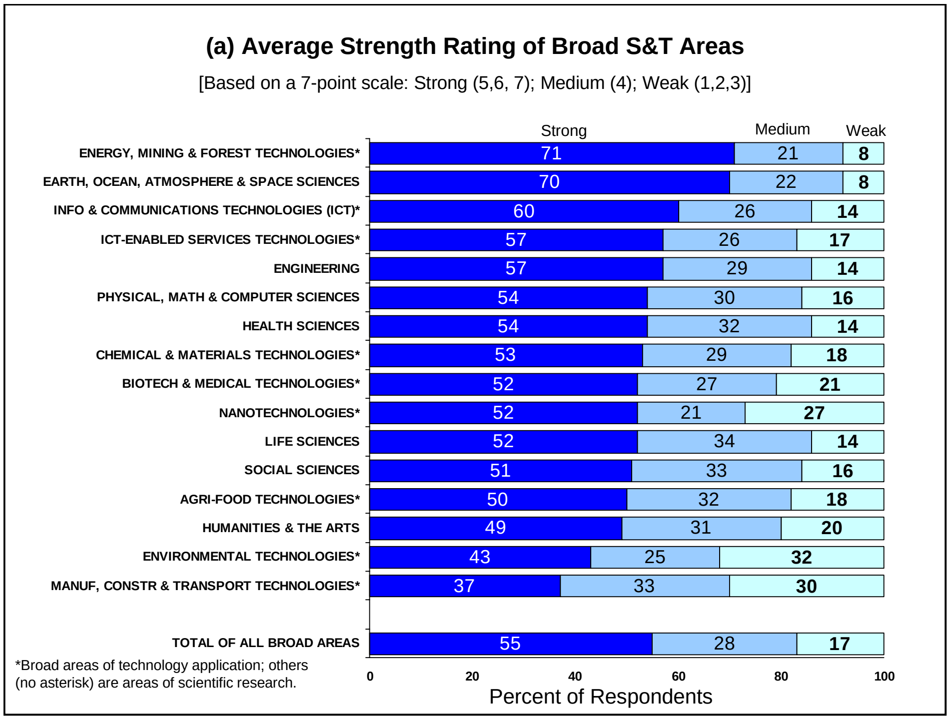
The reported results are not the views or the interpretation of the committee or of the Council of Canadian Academies. They are the views of a significant fraction of Canada's senior S&T community. The overall picture of S&T strengths portrayed by the survey results is remarkably consistent whether based on the responses of the university community; of those associated with business; or with government. The survey numbers speak for themselves and should be regarded as an amalgam of fact, informed judgment and aspiration.

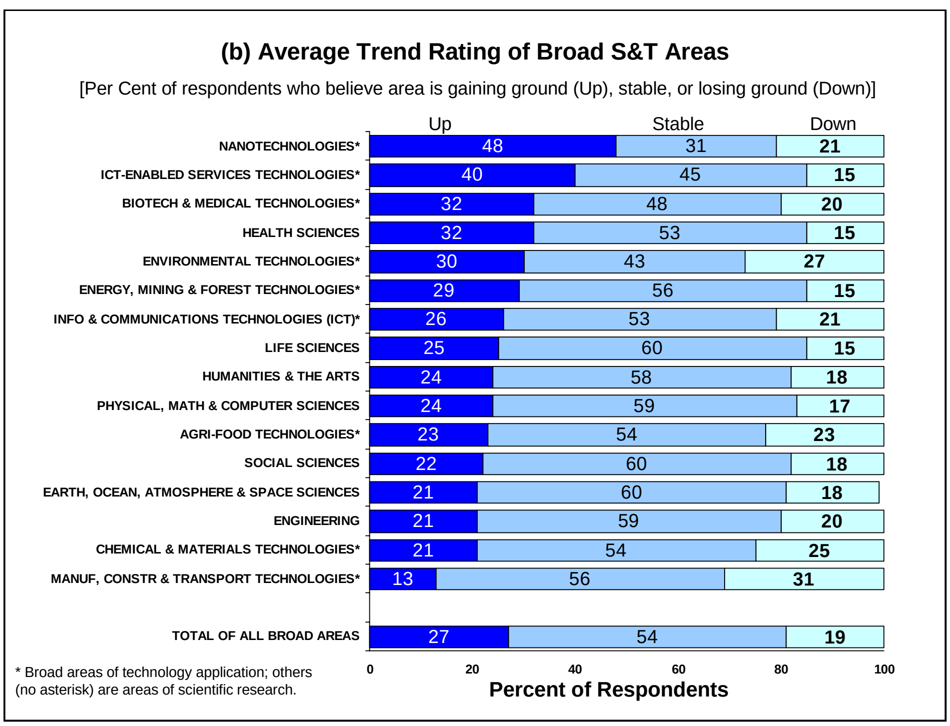
9. Aggregate Strength in Broad Areas of S&T – In **Figure 1**, we summarize the views of survey respondents as to Canada's strength, and its trend, in 16 broad areas of S&T. Strength, **Figure 1(a)**, was rated on a seven-point scale (7 high) and trend, **Figure 1(b)**, reflects respondents' opinion on whether Canada has been gaining ground (against other advanced countries), losing ground, or has been relatively stable. The perception of strength is greatest for technologies and sciences related to natural resources, and second for information and communications technologies (ICT). Comparative weakness is seen in manufacturing, construction and transportation technologies and in environmental technologies. The perception of upward movement is strongest for nanotechnologies (i.e., technologies related to physical, chemical and biological phenomena at nanometer [10^{-9}m] scale), in new ICT-enabled services (e-commerce, e-health, etc.) and in health sciences and biotechnologies.

10. A Granular Assessment of S&T Strengths – The 16 broad areas in **Figure 1** conceal a great deal of variation among their component sub-areas of research and technology application. Survey respondents rated Canada's strength, and trend, in respect of 197 sub-areas distributed among the broad areas (and from which the averages in **Figure 1** were derived.) Individuals were asked to rate only those sub-areas for which they felt they could provide an informed opinion. The median number of responses for the 197 sub-areas was 220. The pattern of ratings remained essentially unchanged as the total number of survey responses increased from 1,000 to 1,500. This suggests that the results would not have changed significantly even had the survey remained open longer.

Figure 1

Average Strength and Trend Ratings of Broad S&T Areas





11. Four Clusters of Canada's S&T Strength – **Figure 2** is a core result of the survey and tabulates results for the 50 sub-areas of research and technology application that received the highest *strength ratings* — defined as the weighted average, or mean value, of respondents' ratings on the seven-point scale. (Results for all 197 sub-areas are tabulated in **Appendix A**.) The sub-areas in the table are listed in descending order of rated strength, though small differences should *not* be regarded as being of significance. Each line of the table also includes the percentage of respondents who believe the particular sub-area is strong (ratings 5, 6, 7) or weak (ratings 1, 2, 3), as well as the percentage who believe it is gaining ground globally (up) and losing ground (down). The final column identifies four *clusters* that emerge from the survey ranking as macro-areas of particular Canadian strength. These are:

- Natural Resources – Canada has substantial strength in the sciences and technology applications related to natural resources, and in particular to mining and energy.
- ICT – Canada has a long-standing strength in the sciences and technologies related to telecommunications, computers and robotics, and more recently in the application of information and communications technologies in "new media" and related content.
- Health & Related Life Sciences and Technologies – Canada demonstrates strength in a number of the major components of the health sciences — e.g., cancer research and control; neuroscience; circulatory and respiratory health; infectious diseases and immunity — as well as in emerging multidisciplinary fields — e.g., Aboriginal health; aging; gender and health. These health sciences are supported by notable strength in genomics and proteomics, applied not only to human health but also to plant and animal biotechnology.
- Environmental S&T – Canada is strong in certain environmentally related sciences and technologies including climate science, oceanography, hydrology, environmental engineering, fuel cell and hydrogen technologies, and urban geography.

The shaded sub-areas in **Figure 2** are those for which the net upward momentum — i.e., the difference between the percentage of respondents who believe the area is gaining ground (up) and those who see it losing ground (down) — is especially high. These 21 sub-areas are the "double winners" that are in the top 50 according to *both* strength rating and net upward trend.

Figure 2

Top 50 Sub-Areas in Order of Strength (Weighted Average of Seven-point Ratings)

* Sub-areas marked with an asterisk are areas of technology application. The others are areas of research. Shaded sub-areas are those in the top 50 ranked by net upward trend – i.e., Up minus Down. The first column (Numb. Resps.) is the number of survey participants who rated each sub-area.

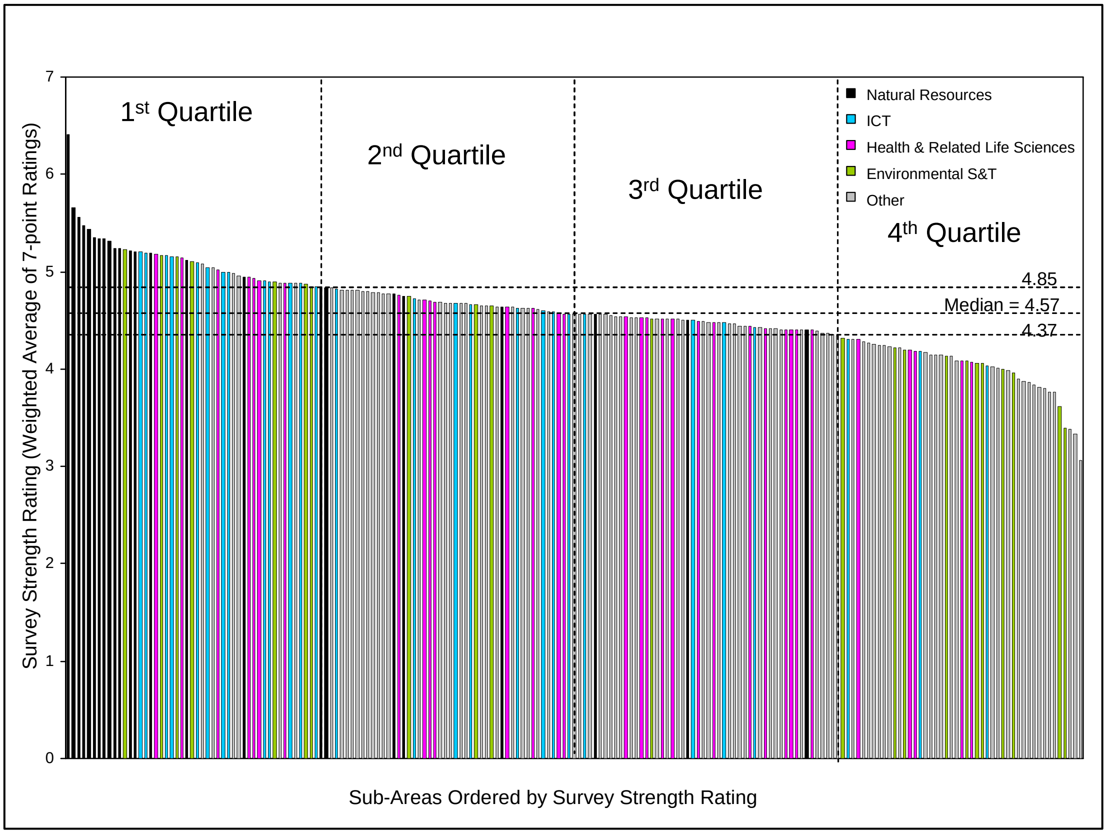
				Percentage of Respondents				
	Sub-Areas	Numb. Resps.	Mean	Strong	Weak	Up	Down	Cluster
1	Oilsands and Related*	316	6.41	97	1	77	2	Natural Res
2	Conventional Oil & Gas Exploration/Extraction*	305	5.66	84	1	43	3	Natural Res
3	Hydroelectric Power*	291	5.56	79	2	22	9	Natural Res
4	Resource Production in Cold Climates*	254	5.48	86	5	36	9	Natural Res
5	Geology	234	5.44	81	4	21	18	Natural Res
6	Mining Exploration*	249	5.35	77	3	24	8	Natural Res
7	Mineral Extraction & Primary Processing*	237	5.34	77	3	23	10	Natural Res
8	Aluminium Production*	120	5.34	76	3	34	12	Natural Res
9	Physical Geography, Remote Sensing	247	5.32	80	4	30	14	Nat Res/Envir
10	Petroleum / Polymer Eng	244	5.24	78	7	46	9	Natural Res
11	Genetics (Medical)	381	5.24	75	6	42	10	Health & Rel
12	Geochem & Geochronology	170	5.23	74	5	21	16	Nat Res/Envir
13	Mining & Mineral Processing	218	5.22	78	4	30	12	Natural Res
14	Offshore Oil and Gas*	287	5.21	74	6	35	8	Natural Res
15	Comms & Network Eng	233	5.20	76	7	27	19	ICT
16	New Media, Multimedia, Animation, Gaming*	169	5.19	77	10	59	8	ICT
17	Geophysics & Seismology	198	5.19	71	8	20	14	Natural Res
18	Genetics, Genomics & Proteomics	474	5.18	74	9	51	12	Health & Rel
19	Hydrology	208	5.17	75	4	25	14	Environ
20	Telecom Equipment*	313	5.17	75	9	25	32	ICT
21	Broadband Networks*	302	5.16	71	8	31	16	ICT
22	Oceanography	241	5.15	73	7	25	27	Environ
23	Cancer Research	441	5.14	73	6	44	9	Health & Rel
24	Pipelines*	260	5.12	68	4	22	4	Natural Res
25	Climate Science	265	5.11	72	7	26	19	Environ
26	Wireless Networks*	330	5.09	72	11	38	16	ICT
27	Cold Climate Construction*	217	5.08	75	11	28	11	
28	Optics, Laser Physics	188	5.05	68	11	38	13	ICT
29	Astronomy, Astrophysics, Cosmology	207	5.05	67	12	25	13	

	Sub-Areas	Numb. Resps.	Mean	Percentage of Respondents				Cluster
				Strong	Weak	Up	Down	
30	Neurobiology / Neurosciences	331	5.02	67	11	39	14	Health & Rel
31	Computer Software Development & Theory	258	5.00	68	9	27	16	ICT
32	Telecom Services*	277	5.00	68	10	25	18	ICT
33	Aerospace Products and Parts*	184	4.98	66	11	22	20	
34	Electricity Distribution*	246	4.96	64	11	19	18	
35	Forestry Engineering	208	4.95	67	11	23	18	Natural Res
36	Genomic and Proteomic Technologies*	408	4.94	67	12	46	15	Health & Rel
37	Circulatory & Respiratory	337	4.93	63	6	27	10	Health & Rel
38	Infection & Immunity	384	4.91	65	10	43	13	Health & Rel
39	Artificial Intell, Robotics	262	4.91	64	15	31	18	ICT
40	Electronic & Photonic Eng	240	4.90	64	11	27	17	ICT
41	Meteorology	208	4.90	58	5	12	12	Environ
42	Visual & Creative Arts	126	4.89	67	16	49	12	
43	Neuroscience, Mental Health, Addiction	340	4.89	64	12	36	14	Health & Rel
44	Quantum Informatics	167	4.89	60	17	51	12	ICT
45	Electrical Engineering	231	4.89	58	9	17	20	
46	Satellite Systems, Services*	270	4.88	62	14	23	20	ICT
47	Fuel Cells & Hydrogen*	241	4.87	65	18	32	24	Environ
48	Geography; Urban & Environmental Planning	165	4.85	67	13	31	21	Environ
49	Computer Databases, Information Systems	234	4.85	63	12	27	13	ICT
50	Pulp & Paper*	129	4.85	61	12	10	36	Natural Res

12. The Distribution of Strength – **Figure 3** depicts all 197 sub-areas in order of strength rating. While there are obviously some clear and important areas of Canadian strength and of relative weakness identified by the survey, the majority of sub-areas of S&T in Canada lie in a broad middle ground. (The weighted average on the seven-point scale declines by only 0.5 — from 4.85 to 4.35 — for the 100 sub-areas ranked between 50th and 150th.) It is not meaningful to distinguish sharply between the rankings of sub-areas in this broad middle ground. These include many fields where Canada is not world-leading, but that are nevertheless necessary to absorb, and adapt to Canadian needs, science and technology that is developed elsewhere. By definition, not everyone can be at the top, though all can aspire to be. The result of such aspiration is to maintain the pressure to continuously upgrade performance and thereby to ensure that Canadian S&T capabilities, overall, are globally competitive.

Figure 3

Full Sample of Sub-Areas Ordered by Survey Strength Rating



13. Interpretation of the Detailed Sub-Area Results – We have been content to let the survey results speak for themselves. Neither the time available nor our own expertise permits the depth of interpretation that the detailed sub-area results require. For the most part, this task must be left to the various expert communities and other users of the report. We nevertheless draw attention to certain noteworthy features of the results, simply as examples of some of the issues and questions they raise.

14. Natural Resources – Oilsands and Related Production Technologies was, by a wide margin, given the highest ranking (as to both strength and trend) of any item in the survey. Canada is seen to be virtually in a class by itself in this technology. There are, nevertheless, still challenges to be overcome in developing more cost-efficient and environmentally friendly extraction and upgrading methods — in short, there is a continuing need for extensive S&T.

Some areas of weakness in the natural resources cluster emerged from survey responses, notably in forest-related technologies — e.g., sawmills, conservation methods and even timber-harvesting technologies, and pulp and paper (where more respondents see Canada losing ground than gaining.) These weaknesses are noteworthy in view of the great economic importance of the forest sector.

15. Information and Communications Technologies – The survey confirmed Canada's international high standing with respect to ICT infrastructure (e.g., wireless and broadband networks). On the other hand, the telecommunication equipment sector in Canada is believed by a third of respondents to have been losing ground, while only a quarter saw the sector gaining. This perhaps reflects the pullback following the dotcom implosion.

The ICT field demonstrating the most promise in the view of respondents — i.e., with the highest net upward trend rating — is New Media, Multimedia, Animation and Gaming, where Canada is internationally recognized as a leader, with a number of successful companies as well as a reputation for superb skills training.

16. Health & Related Life Sciences – Many of the traditional foundation disciplines – e.g., Microbiology, Physiology — were judged by survey participants not to be particularly strong in Canada. The same pattern is observed in other areas of the survey and reflects a clear trend of aspiration toward transdisciplinary work. There is a paradigm shift under way in the way science is done around the world. Multidisciplinarity is becoming the norm, as illustrated, for example, by the subjects around which the Canadian Institutes of Health Research (CIHR) are organized. Networked collaboration, both across Canada and globally, is becoming common in most fields of research. All of this means that researchers today identify less and less with traditional subject areas such as physics, chemistry, biology, sociology, civil engineering. Aspiration and activity are shifting to areas such as biotechnology and nanoscale science wherein the traditional foundation disciplines become submerged as component competencies that are required to address these new areas. For example, the classic discipline of physiology is re-appearing in the new garb of systems biology and Canada's traditional strengths in chemistry and physics are being enlisted in nano- and bio- science.

There is a rather striking contrast between Canada's considerable research strength in the health and related sciences and our much more limited strength in areas of medical technology. (Exceptions are genomics/proteomics and, to a lesser extent, medical imaging.) In particular, we note the perceived weakness of pharmaceutical development — a mean strength of only 4.18, or 165th out of the 197 sub-areas. The survey conclusion in this case reflects the views of 433 respondents and thus appears to be quite robust.

17. Environmental S&T – The Environment cluster presents a challenge, as it does not have deep strength at present in respect of technology application — e.g., clean hydrocarbons, biofuels, energy cogeneration and wind power were all rated well down the list. Moreover, respondents are sharply divided on whether Canada is gaining or losing ground in many of these areas. Several fields of environmental science, on the other hand, are perceived to be very strong, a conclusion also borne out by our bibliometric analysis. There is considerable correlation in Canada between environmental S&T capabilities and the natural resources sector. In view of the increasing importance of sustainable resource use, and of clean energy in particular, Canada's global role in environmental S&T relates primarily to the environment–resources nexus.

18. Other Areas of Strength . . . and Some Weaknesses – Respondents identified a number of important fields of strength that are not categorized within the four main clusters. (The clusters, taken together, encompass 55 percent of the 197 sub-areas.) For example, Canada has exceptional strength in Astronomy, Astrophysics and Cosmology (strength rating of 5.05) that has increased over time in a self-reinforcing way — excellence begets further excellence. Survey respondents perceived significant strength in some emerging fields such as nanoscale materials and biotechnologies, quantum informatics and humanities computing. These latter transdisciplinary fields are specialities for which future prospects are seen to be more significant than currently established strength.

Some components of the aerospace and automotive sectors were also rated as quite strong in the survey (**Figure 4**). The aerospace industry has important concentrations of excellence across the country, but the perceived S&T strengths, and especially the trend, appear to fall short of the economic importance of the industry. The Canadian automotive industry was judged reasonably strong only in respect of motor vehicles and parts. This sector is not R&D-intensive in Canada. As a result, it does not appear to have — relative to the scale of the industry here — a strong indigenous base of skills for automotive innovation.

Figure 4

Automotive, Aerospace & Related Technologies

		Percentage of Respondents			
Sub-Areas	**Mean**	**Strong**	**Weak**	**Up**	**Down**
Aerospace Products and Parts*	4.98	66	11	22	20
Aerospace Engineering	4.77	61	23	19	32
Materials Engineering	4.67	54	10	27	13
Motor Vehicles & Parts*	4.65	59	16	23	24
Advanced Industrial Materials*	4.64	59	16	41	18
Automotive Engineering	4.15	41	32	12	30

* Sub-areas of technology application; others (without asterisk) are sub-areas of scientific research.

One important cluster of technologies — those related to transportation — was identified by survey respondents as unusually weak and perhaps getting weaker (**Figure 5**). Given the importance of efficient transportation, particularly in a geography as vast as Canada's, the committee notes that the apparent technological weakness of this infrastructure could have significant implications.

Figure 5

Transportation Technologies

		Percentage of Respondents			
	Mean	Strong	Weak	Up	Down
Air Transport Technologies	4.41	50	22	15	27
Rail Transport Technologies	3.99	41	40	17	33
Road Transport Technologies	3.90	30	36	10	23
Multi-modal Transport Technologies	3.76	25	35	9	26
Marine Transport Technologies	3.38	18	57	4	46

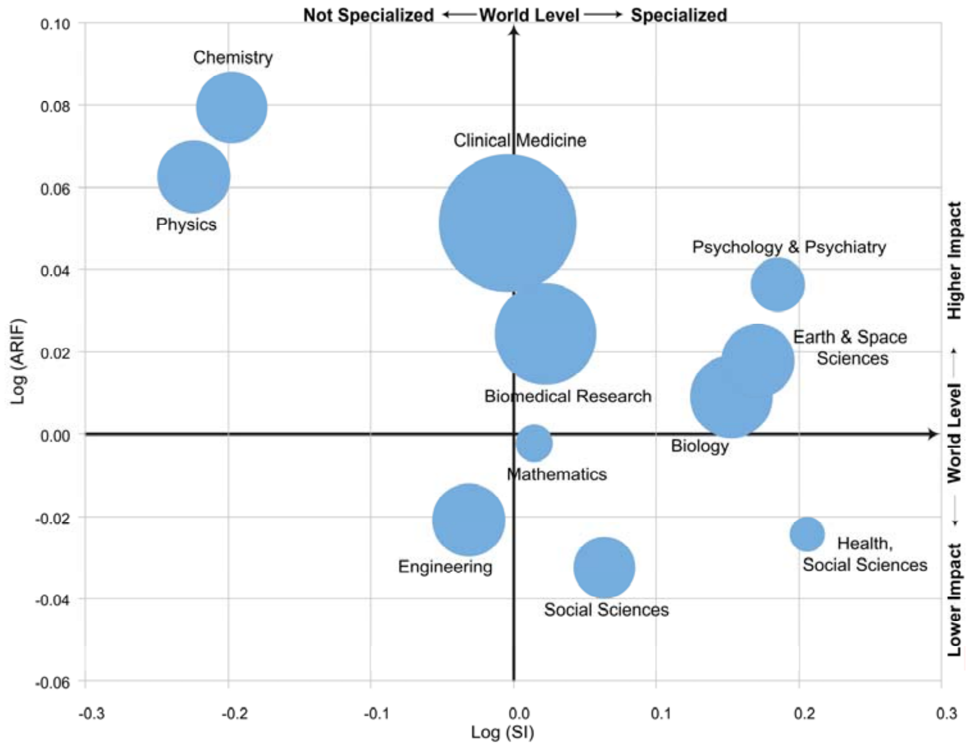
19. A Second Lens: Bibliometric Perspectives on Research Strengths – Canada currently ranks eighth in the world in total volume of scholarly publications. We have analyzed 125 fields of research (78 of which roughly matched sub-areas in the opinion survey) to determine areas of particular Canadian research specialization and publication quality, relative to the world average. The *quality* indicator — called the Average Relative Impact Factor, or ARIF — is derived from international ratings (based on citation numbers) of the journals in which Canadian researchers publish. The *intensity* of Canadian publication in various fields, relative to the world average, is measured by a Specialization Index, or SI. If the ARIF or SI is greater than 1.0 for a given field in Canada, it indicates that Canadian research in that field is of higher quality, or is pursued more intensively, than the world average. (Ratings less than 1.0 are below the world average.)

20. Bibliometric Analysis: The Big Picture – **Figure 6** depicts Canada's position relative to world science with respect to research intensity (SI on the x-axis) and research output quality (ARIF on the y-axis). The size of the circles on the chart is proportional to the number of Canadian papers published in the various fields over the eight years from 1997 through 2004. The top right quadrant contains the domains in which Canada is relatively specialized and in which it publishes in journals that are more highly cited than the world average. This is a quadrant of unambiguous relative strength for Canadian published research. The broad fields where Canada has the best overall performance are psychology and psychiatry, earth and space sciences, biomedical research and biology.

The top left quadrant identifies domains where Canada does not publish as *intensively* as the world average but where quality is high. Chemistry is clearly a field of excellence and is followed by physics. The lower quadrant on the right hand side contains those fields where Canada specializes but where it tends to publish in journals that are not cited as often as the world average. This quadrant contains many of the social sciences. We note that a significant amount of social science research deals with location- and culture-specific questions, which would explain, in part, why research in smaller countries like Canada is disproportionately published in locally specialized journals that are relatively less cited than the world average. Finally, the lower left quadrant of the figure shows that, at the aggregate level, Canada's greatest weakness is in engineering research. Of course there are important exceptions within sub-areas of engineering.

Figure 6

Position of Canada in Scientific Research Publications, 1997–2004



21. A More Detailed Perspective – In **Figure 7,** we list separately the top 30 sub-areas (out of 125 that we have analyzed) in terms of publication quality (ARIF) and publication intensity (SI). Some clear patterns emerge: a number of the top 30 areas fall into the clusters as identified from the survey results. In terms of publication quality, the top 30 includes eleven sub-areas of health and related life sciences and three in environmental science. In terms of publication intensity, there are nine sub-areas related to natural resources and the environment, and seven in health and related life sciences. A significant cluster of five psychology sub-areas appears in the list of greatest specialization, and there are 11 sub-areas of chemistry and physics in the list of highest quality as measured by ARIF.

The highlighted sub-areas in the figure are areas in which Canada publishes more intensely than the world average and also has publication quality above the world average — these are doubly strong. For example, clinical research, psychology, oceanography, forestry engineering, hydrology, geology, marine biology, environmental sciences and ecology are all areas in which Canada excels in terms of both publication quality and intensity.

Figure 7

Top 30 Sub-areas in Descending Order of ARIF and of SI (Shaded lines are fields for which both ARIF and SI are above the world average. The sub-areas indicated by asterisk are those for which there was no clear equivalent among the 197 sub-areas in the online survey.)

Top 30 ordered by ARIF

		ARIF	SI
1	Inorganic Chemistry	**1.43**	0.55
2	Clinical Research	**1.41**	1.10
3	Gastroenterology*	**1.41**	0.72
4	Psychology, Educational*	**1.40**	0.81
5	General Physics*	**1.29**	0.65
6	Pathology*	**1.26**	0.82
7	Obstetrics & Gynecology*	**1.25**	0.76
8	General Chemistry*	**1.25**	0.75
9	Nuclear Engineering	**1.25**	0.56
10	Psychology, General*	**1.23**	1.33
11	General Engineering*	**1.23**	1.10
12	Analytical Chemistry	**1.23**	0.66
13	Pharmacy*	**1.23**	0.37
14	Condensed Matter Physics	**1.22**	0.49
15	Social Sciences, Biomedical*	**1.21**	1.95
16	General Biomedical Research*	**1.21**	0.90
17	Cancer Research	**1.21**	0.88
18	Marine Biology & Hydrobiology*	**1.20**	1.87
19	Oceanography	**1.20**	1.37
20	Applied Chemistry*	**1.19**	0.84
21	Polymer Chemistry	**1.19**	0.69
22	Organic Chemistry	**1.18**	0.62
23	Dermatology*	**1.18**	0.46
24	Psychology, Mathematical*	**1.16**	2.06
25	Human Dev't & Youth Health	**1.16**	1.23
26	Circulatory & Respiratory Health	**1.16**	1.09
27	Nuclear Phys & Elem Particles	**1.15**	0.87
28	Nanoscale Physical Science	**1.15**	0.49
29	Astron, Astro Phys, Cosmol	**1.14**	0.99
30	Ecology & Evolution Biology	**1.13**	1.47

Top 30 ordered by SI

	SI	ARIF
Forestry Engineering	**3.06**	1.03
Industrial Relations & Labour*	**2.49**	0.75
Mining & Mineral Proc Eng	**2.48**	0.97
Hydrology	**2.36**	1.00
Psychology, Mathematical*	**2.06**	1.16
Kinesiology	**2.05**	1.02
Civil Engineering	**2.05**	0.83
Experimental Psychology	**1.99**	0.94
Geology	**1.98**	1.05
Operations Research*	**1.98**	1.03
Social Sciences, Biomedical*	**1.95**	1.21
Marine Biology & Hydrobiology*	**1.87**	1.20
Social Psychology	**1.86**	1.06
Earth & planetary Science*	**1.82**	0.89
Psychiatry*	**1.78**	1.05
Environmental Science*	**1.74**	1.08
Psychology, Biological*	**1.71**	0.95
Animal Biology	**1.70**	1.07
Soil Science	**1.70**	1.05
Physiology	**1.65**	0.98
Ergonomics*	**1.63**	1.05
Transport Studies*	**1.62**	1.03
Health Services & Policy	**1.61**	0.76
Women's Studies*	**1.56**	1.00
Linguistics	**1.56**	0.83
Entomology*	**1.53**	0.98
Population & Public Health	**1.53**	0.92
Psychology, Clinical*	**1.52**	1.09
Rehabilitation*	**1.48**	1.00
Ecology & Evolution Biology	**1.47**	1.13

22. Canada's Research Strength is Confirmed – When the bibliometric data are viewed in their entirety, Canada's broad strength in published research is apparent. We note that:

- For 38 percent of the 125 areas analyzed, *both* publication quality (ARIF) and intensity (SI) were above the world average. In only 10 percent of the 125 disciplines were quality and intensity both below the world average.
- Almost 70 percent of the 125 disciplines had publication quality ratings above the world average.
- In only 11 of the 125 disciplines was publication quality rated at less than 90 percent of the world average.

23. Technometrics – Analysis of Patent Data – The analysis of patents granted, using the database of the US Patent and Trademark Office (USPTO), provides insight into the intensity and significance of inventive activity in Canada, relative to the world average. (We note, however, that many inventions are never successfully commercialized, and thus patents granted do not necessarily qualify as "innovation", and, conversely, that not all innovations are patented.)

Owing to the constraints both of time and of the antiquated classification system in the USPTO database, our technometric analysis has been rather cursory. Highlights are as follows:

- Canada is particularly strong in optics and photonics (complementing research and technology strengths noted earlier) and in energy production technologies. Although patent activity has subsided in telecommunication technologies following the "dotcom" collapse in 2000, this field — together with optics and photonics — provides a strong base for future industrial growth.
- Canada produces considerable intellectual property in the pharmaceutical sector and in biotechnology, but this is not cited as often as the world average for other patents in these fields, suggesting that their technological importance, in the aggregate, is lower than the world average.
- Canada's patenting activity is relatively weak in many fields where Canada produces good science. For example, despite excellence in chemistry research, Canada's patenting metrics are below the world average in chemical products, organic chemicals and petroleum-related technologies.
- We have also computed figures for patent growth in Canada. These data show that in the past five years, Canada has been gaining share of USPTO patents granted in the ICT, health and biotechnology sectors.

24. Metrics and the Survey Compared – We were able to create bibliometric categories that reasonably overlap almost 90 percent of the research sub-areas included in the online survey. The two bibliometric dimensions of strength — i.e., publication quality (ARIF) and intensity (SI) — can not really be combined into a single strength indicator that can be directly compared with the survey's single seven-point scale. Instead we compared the survey results with both ARIF and SI separately. We found some areas of clear divergence between the bibliometric and survey measures. For example, the bibliometric analysis reveals the exceptionally high quality of Canadian published research in many domains of chemistry and physics, areas less highly rated in the survey. Conversely, in some of the newer transdisciplinary fields — e.g., communications, media and cultural sciences — the survey results suggest greater Canadian strength than bibliometric data show. Notwithstanding examples like these, the areas of divergence do not appear to fit any systematic pattern and certainly would not invalidate the identification of four clusters of Canadian S&T strength derived from the survey responses.

On the contrary, the bibliometric analysis shows that Canada publishes intensively, and often of high quality, in areas related to natural resources and the environment. Canada is somewhat less intensively represented in health and related life sciences but the quality tends to be high overall. The ICT cluster does not show prominently in the bibliometric analysis, in part because of the limitations of sub-field classification but primarily because of the more technological orientation of ICT. Canada's strength in the latter was demonstrated in the technometric data. Overall, the results indicate that the survey and bibliometric lenses are both reinforcing and complementary.

25. A View from Abroad – A foreign perspective on Canada's S&T strengths is an important complement to the survey and bibliometric analysis. We were unable, in the time available, to canvas systematically a substantial and informed body of foreign views on Canada's S&T strengths. There is, at present, no formal database that lists all Canada's international agreements in respect of S&T, let alone the multitude of informal and semi-formal collaborations between scientists in Canada and colleagues around the world. Based on information provided by Canada's S&T Counsellors and Trade Commissioners, we have reviewed a number of S&T Memoranda of Understanding and formal agreements with several countries. The agreements concur reasonably well with the four clusters of strength that have been identified. Many of these agreements, for example, are related to health and life sciences, to natural resources and to ICT.

26. Canada's S&T Infrastructure – Research facilities and laboratories across the country constitute the tangible infrastructure needed to undertake leading-edge research and to train the next generation of Canadian scientists and technologists. Complementing this is *soft* infrastructure that includes a wide array of government programs and policies, as well as other intangibles such as the regulatory procedures that both use, and have an impact on, S&T. We identified three major categories of infrastructure that underpin Canada's S&T capacity:

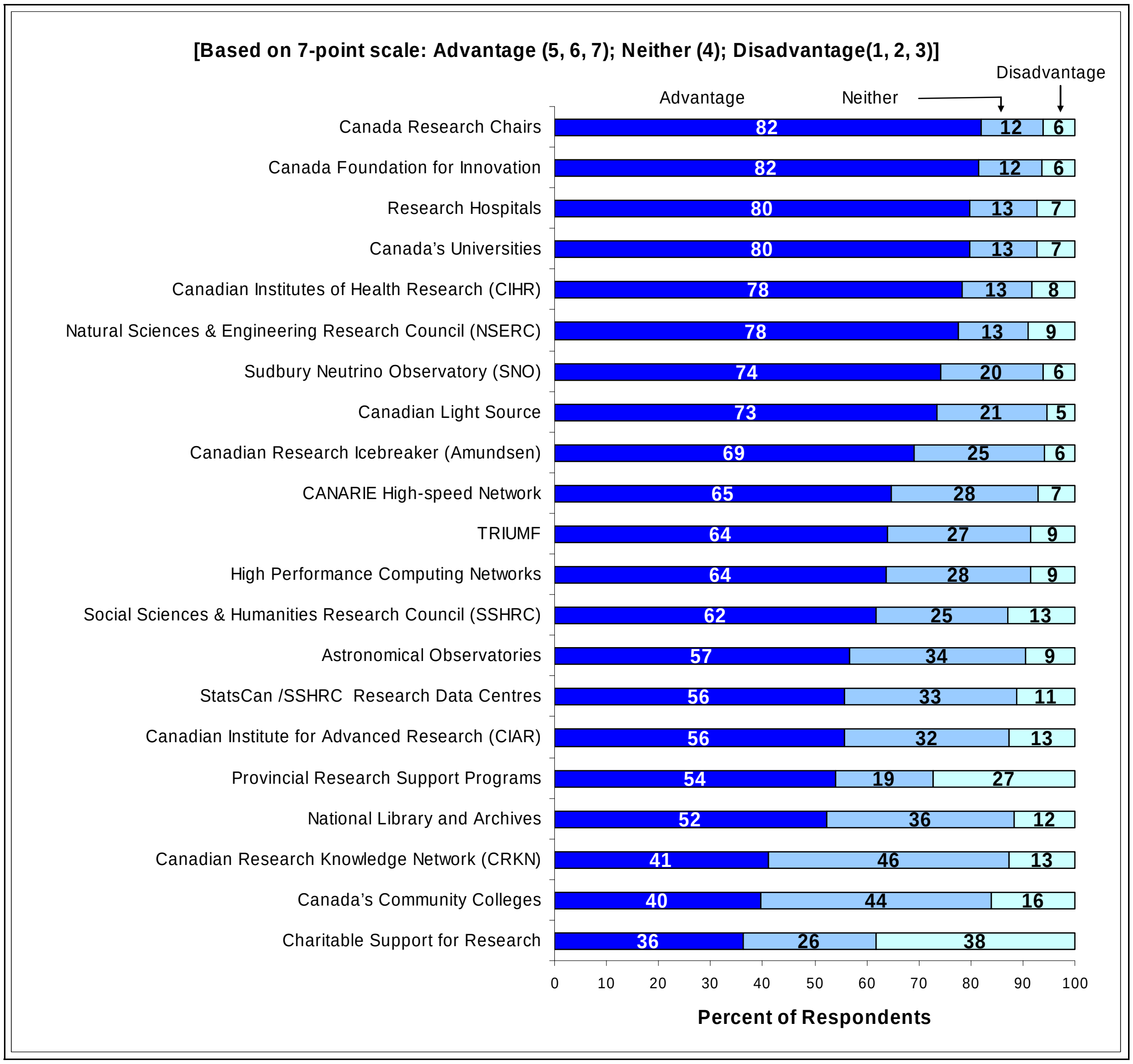
- Infrastructure that facilitates the production of knowledge — e.g., universities and research granting agencies;
- Infrastructure that promotes the commercialization and translation of research results — e.g., industrial research support programs and tax incentives; and
- Infrastructure that supports other public policy objectives that draw upon, or significantly affect, S&T activity — e.g., related to health, public safety, national data collection and analysis, and various regulatory systems.

The online survey canvassed the opinion of the S&T expert community as to the degree of advantage Canada derives (relative to other advanced countries) from 48 specific components of infrastructure belonging to the three major categories.

27. Knowledge Production and Support – Among 21 specific infrastructure components surveyed in this category, respondents of all affiliations and in all regions gave very high marks to the main national institutions that support research and advanced training — i.e., Canada Research Chairs, the Canada Foundation for Innovation, research hospitals, universities, and the granting agencies (particularly NSERC and CIHR). The ratings were among the highest recorded in the entire survey (**Figure 8**).

Figure 8

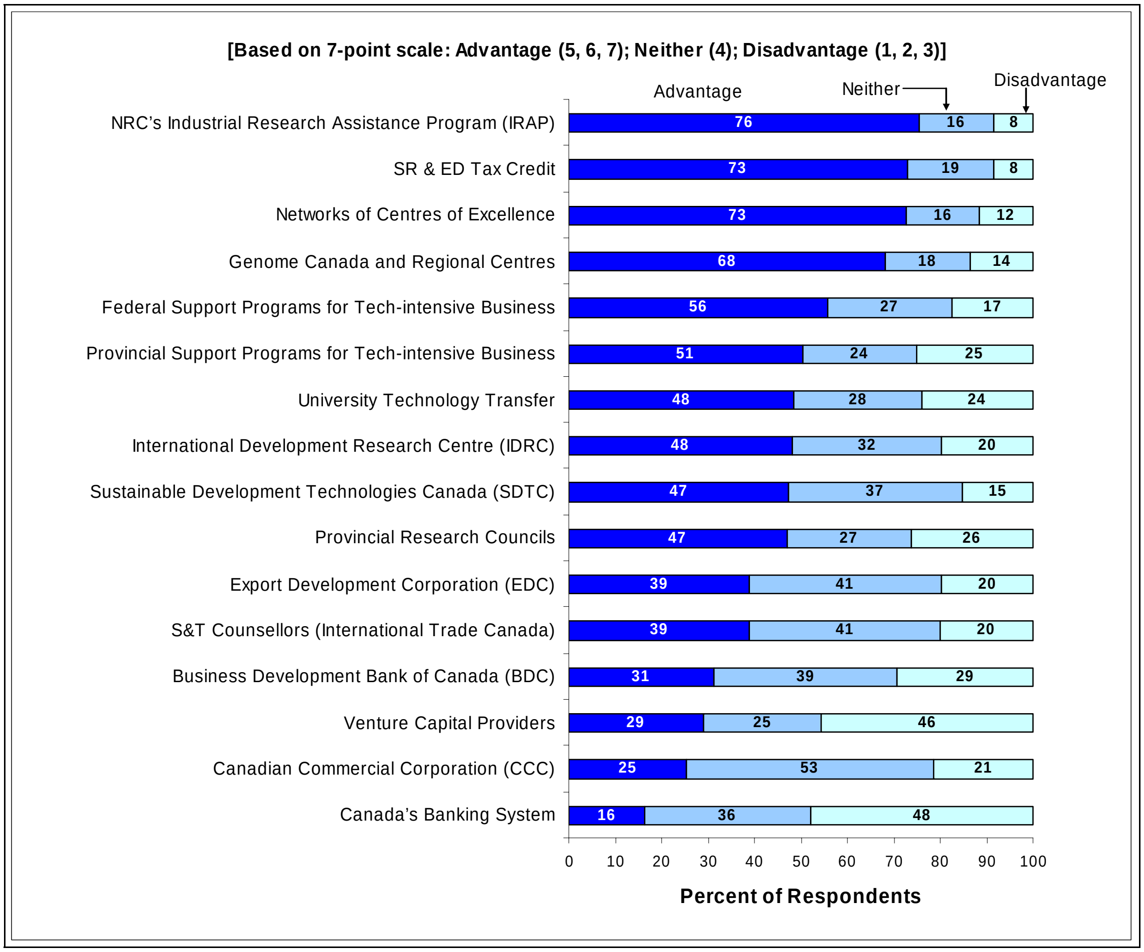
S&T Knowledge Production and Support



28. Support for Commercialization / Translation of S&T – Of the 16 specific components in this category (**Figure 9**), the highest ratings were accorded to four programs: the Industrial Research Assistance Program (IRAP), which promotes technology development in small and medium enterprises; the Scientific Research and Experimental Development tax credit (SR&ED); the Networks of Centres of Excellence program, which supports cross-Canada collaboration in significant areas of applied research; and Genome Canada, which supports research and applications in genomics and proteomics. These ratings were also among the highest recorded throughout the survey.

Figure 9

Support for Commercialization / Translation of S&T



Response rates for individual components of the infrastructure survey ranged from a low of 470 respondents to more than 1,400. This permits cross-tabulations by affiliation status — e.g., university, business, government — and by region across Canada. **Figure 10** does this for all 16 components of commercialization / translation support infrastructure. It is apparent, though hardly surprising, that respondents tend to rate infrastructure more highly when it serves their interest more directly — e.g., the exceptionally high rating of the SR&ED tax credit by those with business affiliation. Also notable is the unusually favourable rating given to provincial research councils by Quebec-based respondents.

Figure 10

Support for Commercialization/Translation of S&T — Affiliation and Regional Perspectives

	Percentage Rating Strong Advantage (Ratings 5, 6 or 7)										
Infrastructure	**Total**	**Univ**	**Bus**	**Gov**	**BC**	**AB**	**M/S**	**ON**	**QC**	**ATL**	**INTL**
IRAP	76	**71**	**82**	**82**	80	84	80	76	**66**	82	70
SR&ED	73	**66**	**84**	78	74	72	71	74	78	63	67
NCE	73	73	69	79	76	71	72	75	72	65	66
Genome Canada	68	65	65	74	75	67	67	66	71	60	76
Fed Supp for Tech Bus	56	**48**	**64**	59	61	52	59	52	61	53	63
Prov Supp for Tech Bus	51	48	57	52	48	48	38	51	60	40	52
Univ Tech Transfer	48	51	46	45	**61**	46	42	46	50	42	54
IDRC	48	47	42	46	48	36	50	52	46	48	48
Sust. Dev. Tech Cda.	47	46	47	45	44	46	43	46	56	52	32
Prov Resh. Councils	47	49	48	44	40	50	36	42	**65**	40	52
Export Dev Corp	39	**31**	**48**	43	38	40	41	38	43	36	23
S&T Counsellors	39	**28**	**46**	45	44	39	33	35	41	33	52
Bus Dev Bank	31	26	36	35	22	30	34	27	**43**	27	41
Venture Capital	29	26	30	28	22	33	33	28	31	25	39
Cdn Commercial Corp	25	18	**33**	27	17	27	24	26	32	22	14
Commercial Banks	16	14	16	16	10	11	21	15	18	18	37

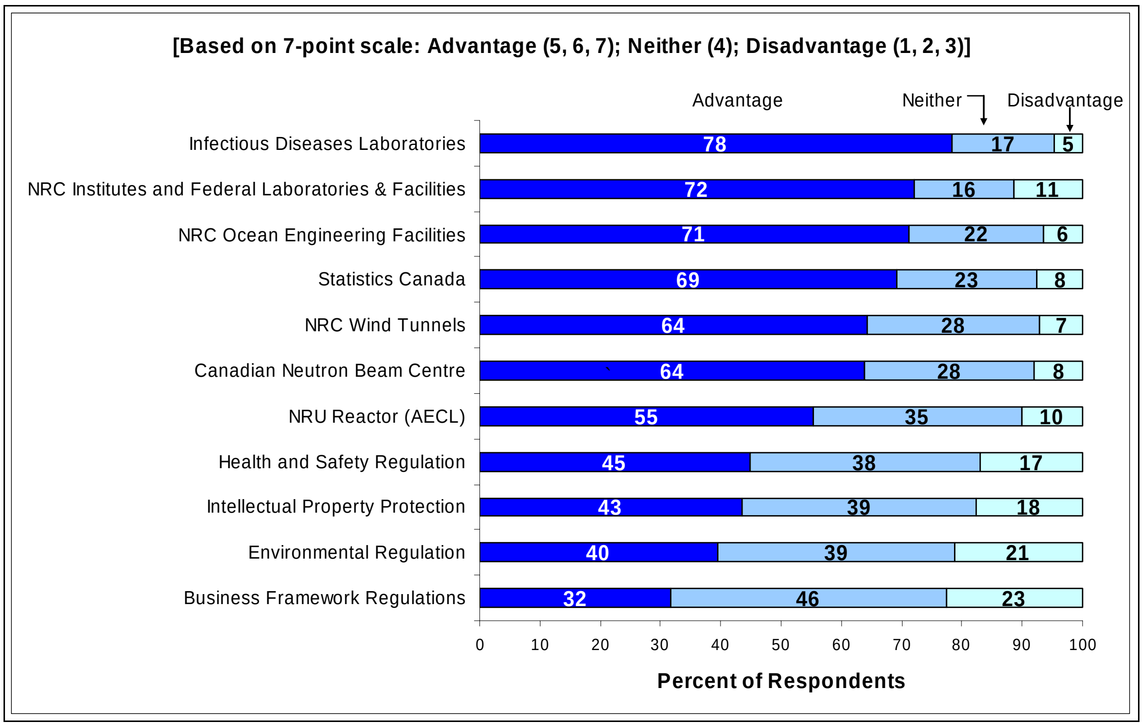
Note: Bolded figures indicate statistically significant variations from the overall rating — i.e., less than one percent probability that the difference was due simply to chance.

29. Commercial Financing of S&T – One finding that may be surprising is the relatively low rating given to Canada's financial support infrastructure for S&T (see bottom several rows in **Figure 10**). For example, fewer than 30 percent of survey respondents cited venture capital providers as a strongly advantageous element of Canada's infrastructure — among the lowest ratings of any element in the entire survey. Further study is required to fully understand the widespread negative perceptions held by the S&T community, not only of venture capital providers but also of commercial banks and of the government institutions engaged in the funding of commercial activity in Canada.

30. Government S&T Infrastructure – The committee notes that the S&T capacity of the government of Canada is a valuable national asset, since the government is often the only feasible provider of many important services — e.g., standards setting; public goods such as the meteorological service and the geological survey; national statistical services; science in support of regulatory functions; and maintenance of long series of observational data (e.g., to support climate science). **Figure 11** shows that survey respondents gave high ratings to three major federal institutions: the infectious diseases laboratories; NRC Institutes and other federal labs; and Statistics Canada. A number of specific facilities — e.g., NRC's ocean engineering facilities, wind tunnels, and the Canadian Neutron Beam Centre — were also well regarded.

Figure 11

Federal S&T Infrastructure and Regulatory System



31. The Regulatory System as Infrastructure – The regulatory system can be regarded as an element of soft infrastructure that has a significant impact on, and relationship to, S&T. Good science is needed to inform wise and effective regulation — e.g., in fisheries and other environmental areas, or in respect of health and safety. Intellectual property regulation (e.g., the patent and copyright systems) has important implications for the incentives to innovate in Canada, while business framework regulations (relating for example to business start-up, competition and bankruptcy) can either enhance or degrade the environment for entrepreneurial activity.

The four regulatory elements in the survey — health and safety, intellectual property, environment, and business framework — nevertheless received remarkably low support compared with the great majority of infrastructure rankings (**Figure 11)**. Fewer than half of respondents rated them as providing a relative advantage for Canada. Regulation is often perceived as an inhibitor. The challenge is to design regulations that achieve their objectives while minimizing unintended negative consequences — i.e., *smart* regulations. The survey results suggest that, from the perspective of a significant proportion of S&T stakeholders, Canada's regulatory frameworks are falling short. Detailed analysis confirms that these views are broadly held irrespective of affiliation or region.

32. Areas of Potential S&T Strength for Canada – Our findings with respect to the question "what are the scientific disciplines and technological applications that have the potential to emerge as areas of prominent strength for Canada and generate significant economic and social benefits?" are more speculative than those described elsewhere in the report. This is because, first, we have not had the opportunity to carry out a thorough foresight analysis; and second, because of the substantial uncertainties in our understanding of how, and over what time period, particular strengths in S&T lead to "significant economic or social benefits".

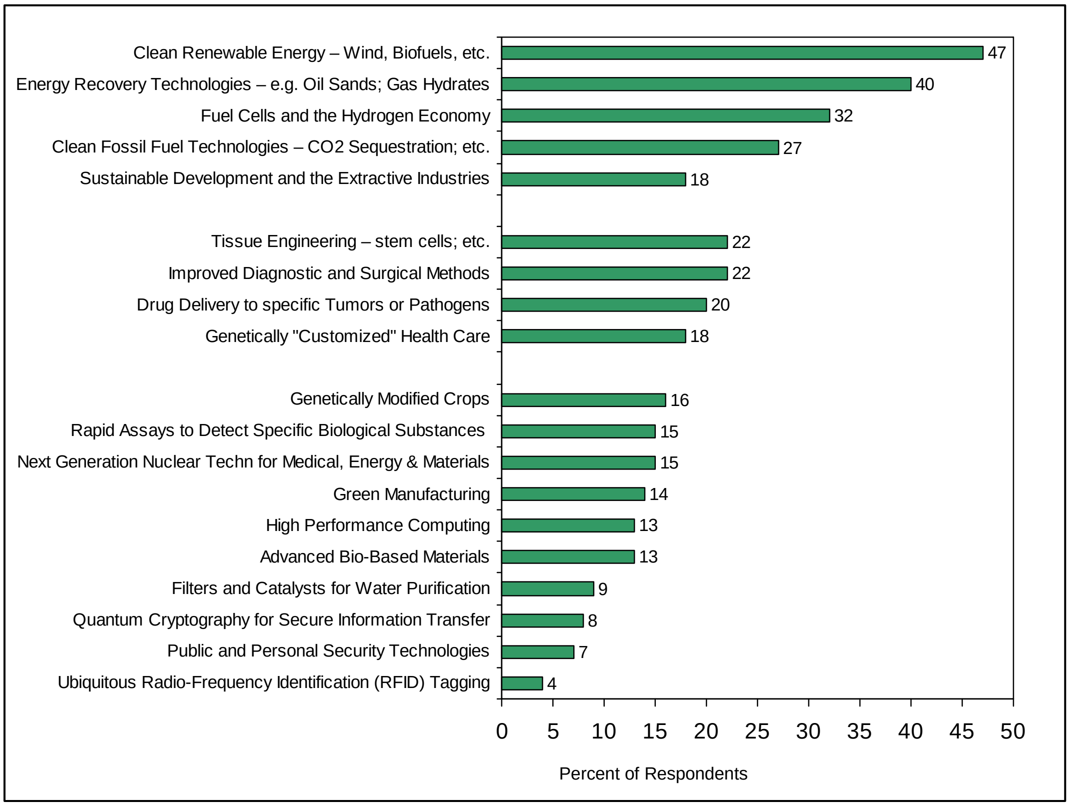
We have relied primarily on the online survey, which presented participants with a list of 19 areas of research or technological application that are thought likely to be of increasing significance over the next 10 to 15 years. (The selection of the menu of 19 areas was based on an extensive analysis by the RAND Corporation, augmented with items of more particular relevance to Canada.) Respondents were asked to choose up to *five* areas in which they believed "Canada is best-placed to be among the global leaders in development and/or application."

33. Clean Energy Technologies Lead the List – By a wide margin, survey respondents identified energy technologies as the area where Canada is best positioned to develop prominent strength in the future (**Figure 12**). The four top-ranked emerging areas all fell into the energy category, and three of them related to sustainable energy. In second place was a set of healthcare technologies — including tissue engineering (e.g., use of stem cells), targeted drug delivery, and genetically customized healthcare — that were viewed as having great potential for Canada.

34. A Caveat – The committee notes that the top ranking given to clean energy as an emerging area of potential Canadian leadership is inconsistent with respondents' assessment that Canada does not *currently* have much strength in the field of "green energy". This calls into question whether the survey responses reported above reflect a hard-headed assessment of where Canada is *best positioned* to be a global leader, or whether the responses reveal a powerful aspiration as to where Canada *ought* to be a leader. In any event, there is a significant gap between aspiration and current reality. If Canada is to become an international leader in clean energy, there is much work to be done.

Figure 12

Survey Results on Emerging Opportunities — Percent of Respondents Including the Listed Areas in Their Top Five



35. Diverse Perspectives on Future Opportunities – The more than 1,500 survey responses as to the most promising emerging opportunities provide a rich statistical base for cross-tabulation (**Figure 13**). This reveals some significant regional variations around the survey averages. For example, BC respondents were significantly more likely than the average to select "fuel cells and the hydrogen economy" in the top five; Albertans were far more likely to select "energy recovery technologies" and "clean fossil fuel technologies", while Quebecers were significantly less likely than the average to name these. Respondents from Manitoba and Saskatchewan were much more likely than the average to see opportunity in "genetically modified crops". In all these cases, one can see the strong influence of existing regional specialization on the perception of future opportunity.

Figure 13

Various Perspectives of Survey Respondents on Emerging Opportunities

	Percentage of Respondents Including Item in Top Five												
Item	**Total**	**Univ**	**Bus**	**Gov**	**<35**	**>55**	**BC**	**AB**	**M/S**	**ON**	**QC**	**ATL**	**INT**
Clean Renewable Energy — Wind, Biofuels, etc.	47	**44**	**58**	49	55	**42**	52	50	57	**41**	53	49	45
Energy Recovery Technologies — e.g. Oilsands; Gas Hydrates	40	**36**	**51**	**51**	29	**47**	34	**62**	47	42	**30**	41	36
Fuel Cells and the Hydrogen Economy	32	**27**	**39**	**40**	35	31	**45**	26	25	32	30	32	30
Clean Fossil Fuel Technologies — CO2 Sequestration; etc.	27	25	32	31	25	28	29	**55**	28	25	**18**	27	28
Tissue Engineering — stem cells; etc.	22	25	21	22	22	22	18	18	16	24	**29**	**12**	20
Improved Diagnostic and Surgical Methods	22	21	23	22	16	24	17	27	14	**26**	24	**10**	16
Drug Delivery to Specific Tumours or Pathogens	20	22	21	16	22	20	27	18	14	18	**29**	15	13
Sustainable Development and the Extractive Industries	18	15	21	22	16	17	21	18	27	16	15	20	19
Genetically "Customized" Health Care	18	19	**14**	21	17	20	23	16	12	18	22	11	23
Genetically Modified Crops	16	14	14	**24**	15	19	13	**24**	**39**	16	**9**	17	17
Rapid Assays to Detect Specific Biological Substances	15	17	17	16	10	13	13	13	24	14	18	12	13
Next Generation Nuclear Technologies for Medical, Energy and Materials	15	14	17	19	13	**20**	11	14	23	**19**	11	11	9
Green Manufacturing	14	14	15	14	**23**	12	20	11	11	12	15	16	25
High Performance Computing	13	13	11	16	14	14	15	11	7	13	15	14	14
Advanced Bio-Based Materials	13	13	16	16	14	13	10	9	**25**	14	14	14	14
Filters and Catalysts for Water Purification	9	8	12	12	8	10	7	11	10	11	6	11	6
Quantum Cryptography for Secure Information Transfer	8	7	4	9	10	9	6	11	4	8	7	3	12
Public and Personal Security Technologies	7	6	8	**13**	6	8	5	6	1	8	8	10	7
Ubiquitous Radio-Frequency Identification (RFID) Tagging Products	4	3	**7**	5	2	3	2	4	4	3	5	5	3

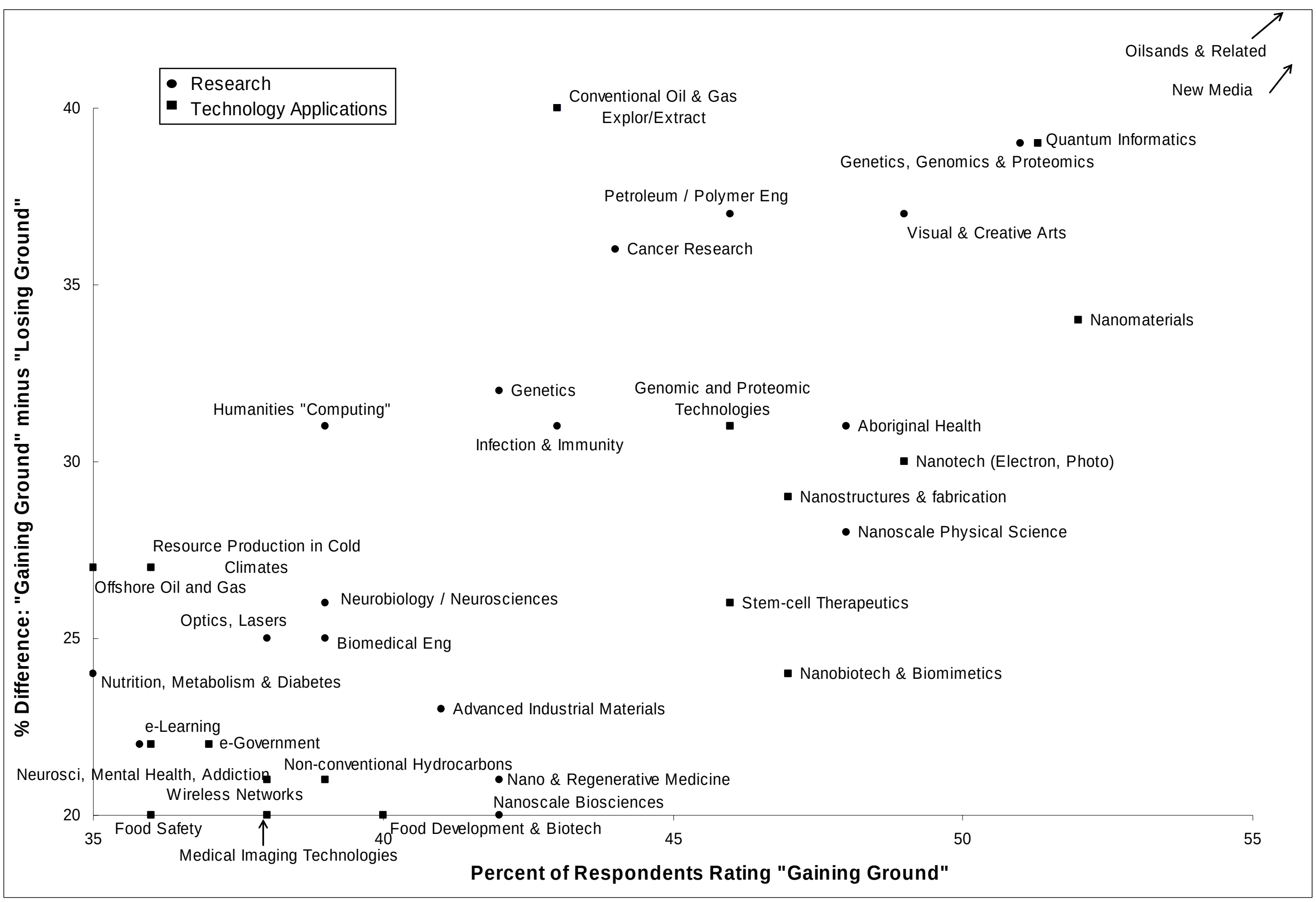
Note: Bolded figures are statistically significant deviations from the total – i.e., less than one percent probability that the difference was due simply to chance.

36. Where Upward Momentum Appears to be Strongest – A final perspective on areas of future promise for Canada can be gleaned from the trend ratings assigned by survey respondents to the 197 sub-areas of research and technology application discussed earlier. **Figure 14** maps the areas for which respondents were most united in their view that Canada has been gaining ground. (The sub-areas plotted are those for which two conditions were met: (i) at least 35 percent of respondents believe the area is gaining ground in Canada; and (ii) the *net* trend – i.e., percent who see an uptrend minus the percent who see a downtrend – is at least 20 percent.)

It is notable that almost all the disciplines and technologies in the figure are associated with ICT and its applications, the bio-based and health sciences, various applications of nanotechnology, and natural resources. There are no representatives of the newer breed of environmental sciences and technologies needed to fulfill the aspirations so forcefully expressed by survey respondents when they selected their top five future opportunities for Canada.

Figure 14

Areas Judged to Have the Highest Growth Prospects

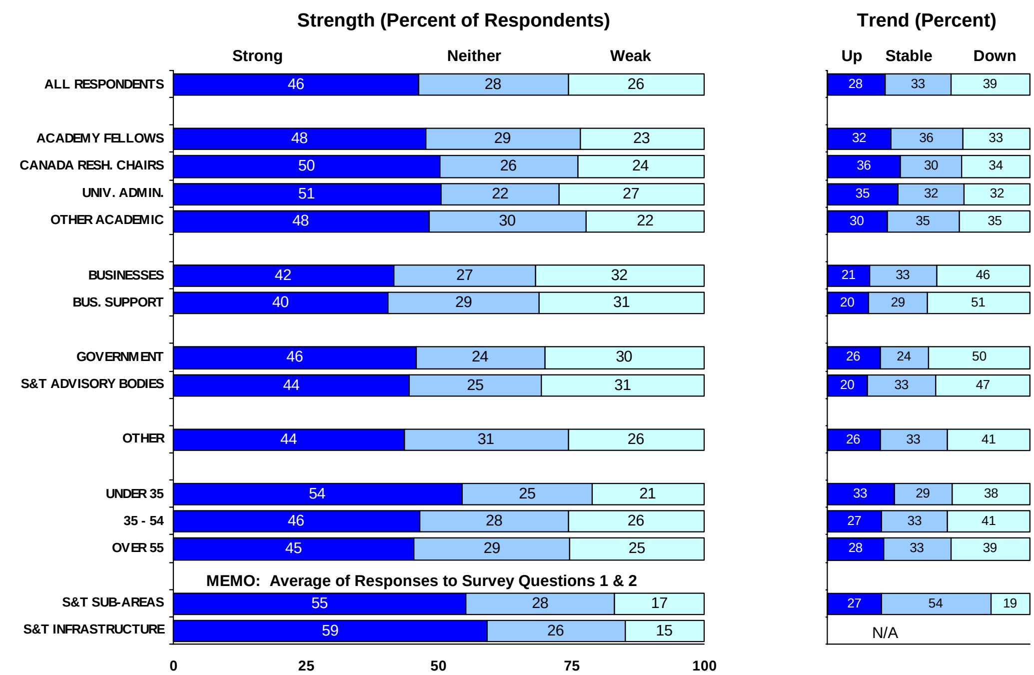


37. Canada's S&T Strength, Overall – Participants in the online survey were asked to rate Canada's strength in S&T, and its trend, overall. The results, reflecting 1,490 responses, are depicted in **Figure 15**, disaggregated by age and affiliation. The integrated view of Canada's strength in science and technology is somewhat more pessimistic than survey respondents' opinion of S&T strengths in *specific* areas of research, technology application, and infrastructure. Fewer than half of respondents ranked Canada strong overall in S&T (ratings 5, 6, 7) and roughly a quarter believe we are weak relative to the average of other economically advanced countries. The perception of overall trend is rather pessimistic – almost 40% believe Canada is losing ground, while only 28% see us gaining. The net trend, again, is considerably more pessimistic than is the case for the (average) outlook in the specific areas of research and technology application (see bottom of **Figure 15**).

Figure 15

Perspective on Canada's S&T Strength Overall

Responses to the Survey Question: "Taking into account all aspects of S&T – knowledge generation and application; supporting infrastructure; and positioning for the future – what is your opinion of Canada's current overall strength in S&T relative to other advanced countries – and the overall trend …?"



38. Looking Forward: Implications of Findings – The survey results, in addition to providing a detailed map of where Canada's S&T strengths are perceived to lie, pointed to some potentially significant challenges including: the perceived shortcoming of the financial institution infrastructure to support S&T; the state of Canada's capabilities related to transportation technologies; perceived weaknesses in important components of the forest products industry, as well as in the pharmaceutical sector; and the guarded view of survey respondents concerning the S&T benefits, or otherwise, of Canada's regulatory systems. We express no view on any of these questions but simply raise them here as an agenda for others to consider.

The committee made very few attempts to interpret what lies behind the survey results. They contain a wealth of information that can be further analysed and interpreted by the various stakeholder communities. We believe that one of the most useful aspects of our report is the foundation it provides to develop a much deeper, and more broadly shared, understanding of Canada's S&T system. To this end, the set of Strength vs. Trend charts for the 197 sub-disciplines in **Appendix B** might stimulate a number of dialogs within and between expert communities as to why the survey respondents, collectively, placed the various disciplines and technologies where they did.

39. Looking Forward: Still to be Addressed – This report leaves two large issues unresolved – one implicit, the other explicit. The explicit question, raised by the survey, is the gap between an aspiration to develop a leading capability in clean energy technologies, and the current reality. This is a significant challenge that has clearly been identified.

The second, and much broader issue, is the difficulty of knowledge transfer from researchers in universities to innovators in industry. A central conclusion from the evidence in this report is that Canada has built significant strength in many fields of research and there is optimism that we are gaining ground in several of the newer areas. Based on survey commentaries, and in the view of the committee, we do less well in converting strength in basic science into sustained commercial success. This is a long-standing deficiency in Canada's innovation system which requires resolution for the full benefit of Canada's considerable S&T strengths to be realized. An in-depth study of Canadian weaknesses and strengths, their causes and possible remedies, could build on the current study by first focusing on the areas of S&T where Canada is currently strong. Where are the hurdles in translating Canadian strengths in S&T into innovation and wealth creation that will enhance the quality of life of Canadians? How can those barriers be overcome?

40. Looking Forward – We leave the final word to our survey respondents.

Thoughts on S&T Strategy – Voices of the Survey

- We have transformed the country since 1997 from a mediocre performer (broadly speaking) on the R&D stage internationally to a country that is perceived to be on the rise in terms of basic-research investment and output. But, we've only built some momentum. We MUST continue to invest nationally to harvest the fruits of that momentum. *Fellow, RSC Academy of Sciences*

- We spend a lot of money on discovery research, and we are globally competitive there. Where we are very weak is in the translation either to commercial applications or public good. *Fellow, RSC Academy of Sciences*

- Canada has a significant advantage in some areas of basic science and needs to ensure that this is preserved as it attempts to develop strength in applications. *Program Member, Canadian Institute for Advanced Research*

- It is important to support humanities and social science research in conjunction with 'pure' S&T to make sure we are pursuing socially valuable programs and that we know how to integrate the products that emerge in a complex, diverse, society. *Fellow, RSC Academy of the Arts and Humanities*

- Canada desperately needs a science strategy based upon our strengths and the commercial opportunities that will arise. *Fellow, RSC Academy of Sciences*

- I would hope that a possible outcome of this survey and others that may follow is the development of a research strategy or philosophy. Where do we see Canadian S&T in 5 or 10 years? How can we improve the current situation? How can we foster collaborations between government labs, universities and industry? There has to be an open dialogue that addresses these issues. *Canada Research Chair*

Appendix A: Survey Results on 197 Sub-Areas – Table

	Sub-Areas*	Numb. Resps.	Mean[1]	Percentage of Respondents Strong[2]	Weak[3]	Up[4]	Down[5]	Cluster
1	Oilsands and Related*	316	6.41	97	1	77	2	Nat Res
2	Conventional Oil & Gas Exploration/Extraction*	305	5.66	84	1	43	3	Nat Res
3	Hydroelectric Power*	291	5.56	79	2	22	9	Nat Res
4	Resource Production in Cold Climates*	254	5.48	86	5	36	9	Nat Res
5	Geology	234	5.44	81	4	21	18	Nat Res
6	Mining Exploration*	249	5.35	77	3	24	8	Nat Res
7	Mineral Extraction & Primary Processing*	237	5.34	77	3	23	10	Nat Res
8	Aluminium Production*	120	5.34	76	3	34	12	Nat Res
9	Physical Geography, Remote Sensing	247	5.32	80	4	30	14	Nat Res/ Environ
10	Petroleum / Polymer Eng	244	5.24	78	7	46	9	Nat Res
11	Genetics (Medical)	381	5.24	75	6	42	10	Health & Rel
12	Geochem & Geochronology	170	5.23	74	5	21	16	Nat Res/ Environ
13	Mining & Mineral Processing	218	5.22	78	4	30	12	Nat Res
14	Offshore Oil and Gas*	287	5.21	74	6	35	8	Nat Res
15	Comms & Network Eng	233	5.20	76	7	27	19	ICT
16	New Media, Multimedia, Animation, Gaming*	169	5.19	77	10	59	8	ICT
17	Geophysics & Seismology	198	5.19	71	8	20	14	Nat Res
18	Genetics, Genomics & Proteomics	474	5.18	74	9	51	12	Health & Rel
19	Hydrology	208	5.17	75	4	25	14	Environ
20	Telecom Equipment*	313	5.17	75	9	25	32	ICT
21	Broadband Networks*	302	5.16	71	8	31	16	ICT
22	Oceanography	241	5.15	73	7	25	27	Environ
23	Cancer Research	441	5.14	73	6	44	9	Health & Rel
24	Pipelines*	260	5.12	68	4	22	4	Nat Res
25	Climate Science	265	5.11	72	7	26	19	Environ

* Sub-areas of technology application; others (without asterisk) are sub-areas of scientific research
[1] Mean = Weighted average of seven-point scale ratings
[2] Strong = Percentage of survey respondents rating the sub-area as "Strong" (rating 5, 6, 7)
[3] Weak = Percentage rating the sub-area as "Weak" (rating 1, 2, 3)
[4] Up = Percentage rating the sub-area as "Gaining Ground"
[5] Down = Percentage rating the sub-area as "Losing Ground"

	Sub-Areas*	Numb. Resps.	Mean[1]	Percentage of Respondents				Cluster
				Strong[2]	Weak[3]	Up[4]	Down[5]	
26	Wireless Networks*	330	5.09	72	11	38	16	ICT
27	Cold Climate Construction*	217	5.08	75	11	28	11	
28	Optics, Lasers	188	5.05	68	11	38	13	ICT
29	Astronomy, Astrophysics, Cosmology	207	5.05	67	12	25	13	
30	Neurobiology / Neurosciences	331	5.02	67	11	39	14	Health & Rel
31	Computer Software Development & Theory	258	5.00	68	9	27	16	ICT
32	Telecom Services*	277	5.00	68	10	25	18	ICT
33	Aerospace Products and Parts*	184	4.98	66	11	22	20	
34	Electricity Distribution*	246	4.96	64	11	19	18	
35	Forestry Engineering	208	4.95	67	11	23	18	Nat Res
36	Genomic and Proteomic Technologies*	408	4.94	67	12	46	15	Health & Rel
37	Circulatory & Respiratory	337	4.93	63	6	27	10	Health & Rel
38	Infection & Immunity	384	4.91	65	10	43	13	Health & Rel
39	Artificial Intell, Robotics	262	4.91	64	15	31	18	ICT
40	Electronic & Photonic Eng	240	4.90	64	11	27	17	ICT
41	Meteorology	208	4.90	58	5	12	12	Environ
42	Visual & Creative Arts	126	4.89	67	16	49	12	
43	Neuroscience, Mental Health, Addiction	340	4.89	64	12	36	14	Health & Rel
44	Quantum Informatics	167	4.89	60	17	51	12	ICT
45	Electrical Engineering	231	4.89	58	9	17	20	
46	Satellite-based Systems and Services*	270	4.88	62	14	23	20	ICT
47	Fuel Cell & Hydrogen*	241	4.87	65	18	32	24	Environ
48	Geography; Urban & Environmental Planning	165	4.85	67	13	31	21	Environ
49	Computer Databases, Information Systems	234	4.85	63	12	27	13	ICT
50	Pulp & Paper*	129	4.85	61	12	10	36	Nat Res
51	Timber Harvesting Technols*	262	4.84	64	15	14	22	Nat Res
52	Library & Archive Science	107	4.83	60	12	34	14	
53	Software Development*	336	4.82	58	12	26	17	ICT
54	Communications, Media & Cultural Sciences	171	4.81	63	15	37	19	
55	Nuclear Power*	292	4.81	60	14	10	42	
56	Humanities "Computing"	100	4.81	59	10	39	7	

	Sub-Areas*	Numb. Resps.	Mean[1]	Percentage of Respondents Strong[2]	Weak[3]	Up[4]	Down[5]	Cluster
57	Soil Science	177	4.81	58	8	8	15	Nat Res/ Envir
58	Building Construction*	150	4.80	63	7	22	10	
59	Food Safety Assurance Technologies*	157	4.80	63	11	36	17	
60	Organic Chemistry	150	4.79	59	10	16	17	
61	Language & Literature	134	4.78	60	14	22	18	
62	Aerospace Engineering	284	4.77	61	23	19	32	
63	Civil Engineering	233	4.77	57	7	17	16	
64	Hydrocarbon Refining*	232	4.77	53	9	18	11	Nat Res
65	Medical Imaging Technols*	401	4.76	60	17	38	17	Health & Rel
66	Other Non-conventional Hydrocarbons*	252	4.75	62	17	39	18	Nat Res
67	Environmental Engineering	239	4.75	59	14	27	25	Environ
68	ICT Systems Engineering*	233	4.72	55	10	21	14	ICT
69	Plant Biotechnologies*	316	4.71	59	13	27	13	
70	Cell Biology	380	4.71	55	11	22	14	Health & Rel
71	Nutrition, Metabolism & Diabetes	314	4.70	57	13	35	10	Health & Rel
72	Biomedical Engineering	225	4.69	62	15	39	14	Health & Rel
73	Polymer Chemistry	163	4.69	54	15	19	18	
74	Aquaculture*	166	4.67	60	16	30	24	
75	Agricultural Engineering	179	4.67	56	14	21	17	
76	e-Learning*	177	4.67	55	16	36	14	ICT
77	Materials Engineering & Sci	234	4.67	54	10	27	13	
78	Physical Chemistry	165	4.67	52	10	15	11	
79	e-Government*	175	4.66	57	18	37	15	ICT
80	Clean Water Technologies*	253	4.66	56	16	36	20	Environ
81	Motor Vehicle Parts/Products	181	4.65	59	16	23	24	
82	Nuclear Engineering	210	4.65	58	16	12	34	
83	Ecology & Evolutionary Biology	331	4.65	50	14	22	15	Environ
84	Advanced Industrial Materials*	159	4.64	59	16	41	18	
85	Forest Conservation*	268	4.64	58	19	24	34	Nat Res/ Envir
86	Stem-cell Therapeutics*	406	4.64	56	20	46	20	Health & Rel
87	Biochemistry	389	4.64	48	10	10	13	

	Sub-Areas*	Numb. Resps.	Mean[1]	Percentage of Respondents				Cluster
				Strong[2]	Weak[3]	Up[4]	Down[5]	
88	Robotics, Automation & AI*	290	4.63	57	19	29	22	ICT
89	Law & Criminology	142	4.63	53	14	23	11	
90	Inorganic Chemistry	147	4.63	48	10	13	13	
91	Population & Public Health	339	4.62	56	16	33	16	Health & Rel
92	Condensed Matter Physics	166	4.61	48	16	21	20	
93	Nanotechnology (Electronics, Photonics)*	181	4.60	57	24	49	19	ICT
94	Political Sci & Public Admin	168	4.59	52	13	20	15	
95	Data - Architecture, Processing Security*	251	4.59	49	15	25	12	ICT
96	Microbiology	342	4.58	49	13	19	13	Health & Rel
97	Aging	375	4.57	53	14	32	13	Health & Rel
98	Computer - Human Interfaces	221	4.57	53	18	24	14	ICT
99	Plant Biology	321	4.57	51	15	18	14	
100	Applied Math	207	4.56	51	14	24	11	
101	ICT-enabled Commercial Services*	155	4.56	51	15	33	11	ICT
102	Other Chemical Engineering	192	4.56	49	11	12	12	
103	Sawmills/Primary Processing*	220	4.56	49	16	11	26	Nat Res
104	Animal Biology	317	4.56	48	13	12	16	
105	Food Processing Technols*	144	4.56	48	15	20	16	
106	Business & Management Sci	170	4.55	52	19	30	17	
107	New Food Development & Food Biotechnologies*	164	4.54	56	20	40	20	
108	Nuclear Physics	169	4.54	54	20	13	31	
109	Clinical Research	357	4.54	47	19	25	26	Health & Rel
110	Nanomaterials*	192	4.53	57	24	52	19	
111	Economics	187	4.53	48	13	14	16	
112	Human Development, Child & Youth Health	317	4.53	47	14	25	14	Health & Rel
113	Gender & Health	307	4.53	46	14	33	12	Health & Rel
114	Environmental Monitoring & Systems*	239	4.52	50	21	28	19	Environ
115	Pure Math	190	4.52	47	18	20	17	
116	Systems Biology & Bioinformatics	373	4.51	54	21	40	23	Health & Rel
117	Demography	131	4.51	50	14	16	15	

	Sub-Areas*	Numb. Resps.	Mean[1]	Percentage of Respondents				Cluster
				Strong[2]	Weak[3]	Up[4]	Down[5]	
118	Musculoskeletal Health & Arthritis	299	4.51	46	11	19	9	Health & Rel
119	Analytical Chemistry	149	4.51	46	12	10	14	
120	Catalytic Processes*	105	4.50	55	14	21	24	
121	Fish Harvesting & Processing*	153	4.50	52	20	14	31	Nat Res
122	Computer Engineering	253	4.50	51	19	14	29	ICT
123	Aboriginal Health	362	4.49	54	22	48	17	Health & Rel
124	Food Handling & Marketing*	131	4.49	44	15	18	15	
125	Education	172	4.48	53	19	21	32	
126	Health Services & Policy	353	4.48	51	21	30	22	Health & Rel
127	Infrastructure Construction *	140	4.48	49	17	19	19	
128	e-Commerce*	175	4.48	49	19	29	19	ICT
129	Polymer Synthesis, Plastics*	122	4.47	52	20	18	24	
130	Nanoscale Physical Science	200	4.47	51	23	48	20	
131	Elementary Particle Physics	158	4.44	48	23	19	21	
132	Social Psychology	136	4.44	46	17	21	13	
133	Kinesiology	242	4.44	40	13	16	9	Health & Rel
134	Microelectronics Components & Systems*	270	4.43	47	21	20	32	ICT
135	Veterinary Science	254	4.43	41	13	16	14	
136	Global Health	346	4.42	49	23	31	19	Health & Rel
137	Math Statistics	173	4.42	42	14	15	12	
138	Experimental Psychology	238	4.42	40	18	13	12	
139	Air Transport Technologies*	130	4.41	50	22	15	27	
140	Nanobiotech & Biomimetics*	64	4.41	50	27	47	23	Health & Rel
141	Bioinformatics*	335	4.41	49	21	36	18	Health & Rel
142	Nano and Regenerative Med	282	4.41	48	20	42	21	Health & Rel
143	History	124	4.41	45	18	16	17	
144	Metal Products*	136	4.41	43	18	15	27	Nat Res
145	Physiology	295	4.40	41	16	10	19	Health & Rel
146	Linguistics	131	4.39	49	21	25	16	
147	Space Science	223	4.37	50	30	19	29	
148	Architecture (Design)	105	4.37	45	18	31	13	
149	Animal Biotechnologies*	280	4.35	41	17	20	14	
150	Nanostructures & Fabrication*	176	4.34	51	28	47	18	

	Sub-Areas*	Numb. Resps.	Mean[1]	Percentage of Respondents				Cluster
				Strong[2]	Weak[3]	Up[4]	Down[5]	
151	Industrial & Environ Biotech*	311	4.32	45	23	32	19	Environ
152	e-Health*	165	4.30	52	27	43	26	ICT/Health
153	Steel-making*	119	4.30	45	24	8	34	
154	Other Medical Devices*	146	4.30	42	21	21	22	Health & Rel
155	Anthropology	150	4.28	35	17	16	18	
156	Sociology	164	4.27	40	22	13	20	
157	Philosophy	105	4.26	42	27	12	24	
158	Agro-Chemical Technologies*	149	4.25	39	22	11	23	
159	Industrial Engineering	212	4.24	35	19	10	21	
160	Other Mechanical Eng	226	4.23	33	17	7	17	
161	"Green Building" Technologies*	238	4.22	46	32	35	24	Environ
162	Printing Technologies*	89	4.22	31	18	8	19	
163	Clean Air*	221	4.20	40	27	26	28	Environ
164	Nursing Science	263	4.19	32	23	22	20	Health & Rel
165	Pharmaceutical Development*	433	4.18	42	34	19	35	Health & Rel
166	Computer & Related Equipment*	287	4.18	37	29	14	31	ICT
167	Other Transportation Equipment*	125	4.17	30	22	9	22	
168	Automotive Engineering	255	4.15	41	32	12	30	
169	Nanoscale Biosciences	267	4.14	39	31	42	23	
170	Archaeology	91	4.14	36	27	14	18	
171	"Clean" Hydrocarbons*	231	4.13	44	36	33	34	Nat Res/ Envir
172	Religious Studies	87	4.13	34	26	8	19	
173	Agricultural Machinery*	131	4.09	32	27	7	39	
174	Dental Science	243	4.09	26	19	6	17	Health & Rel
175	Smart Energy & Conservation*	250	4.08	38	33	29	30	Environ
176	Medical Nanotech*	152	4.07	44	32	44	29	Health & Rel
177	Recycling & Recovery*	249	4.06	39	35	25	29	Environ
178	Energy Cogeneration*	229	4.06	36	32	29	28	Environ
179	Computer Hardware	92	4.03	37	36	13	40	ICT
180	Plasma Physics	125	4.02	30	28	9	29	
181	Architectural Eng	160	4.01	29	26	8	21	
182	Biofuels*	259	4.00	39	37	36	25	Environ
183	Rail Transport Technologies*	148	3.99	41	40	17	33	
184	Solid Waste Management*	239	3.96	34	36	19	32	Environ

	Sub-Areas*	Numb. Resps.	Mean[1]	Percentage of Respondents				Cluster
				Strong[2]	Weak[3]	Up[4]	Down[5]	
185	Road Transport Technologies*	137	3.90	30	36	10	23	
186	Furniture & Related Products*	124	3.88	27	33	3	48	
187	Classics	103	3.86	27	38	10	36	
188	Machinery (Electric)*	124	3.84	21	31	6	30	
189	Machinery (Non-electric)*	119	3.81	19	32	5	23	
190	Microfabrication*	109	3.80	28	42	23	33	
191	Advanced Textiles*	95	3.76	27	43	15	40	
192	Multi-modal Transport*	101	3.76	25	35	9	26	
193	Wind Power Technologies*	274	3.62	28	55	38	34	Environ
194	Solar Power Technologies*	244	3.40	20	58	20	40	Environ
195	Marine Transport*	112	3.38	18	57	4	46	
196	Clothing*	118	3.34	15	58	4	60	
197	Shipbuilding*	145	3.06	12	63	2	72	

Appendix B: Survey Results on 197 Sub-Areas – Strength vs. Trend Charts

Figure B.1

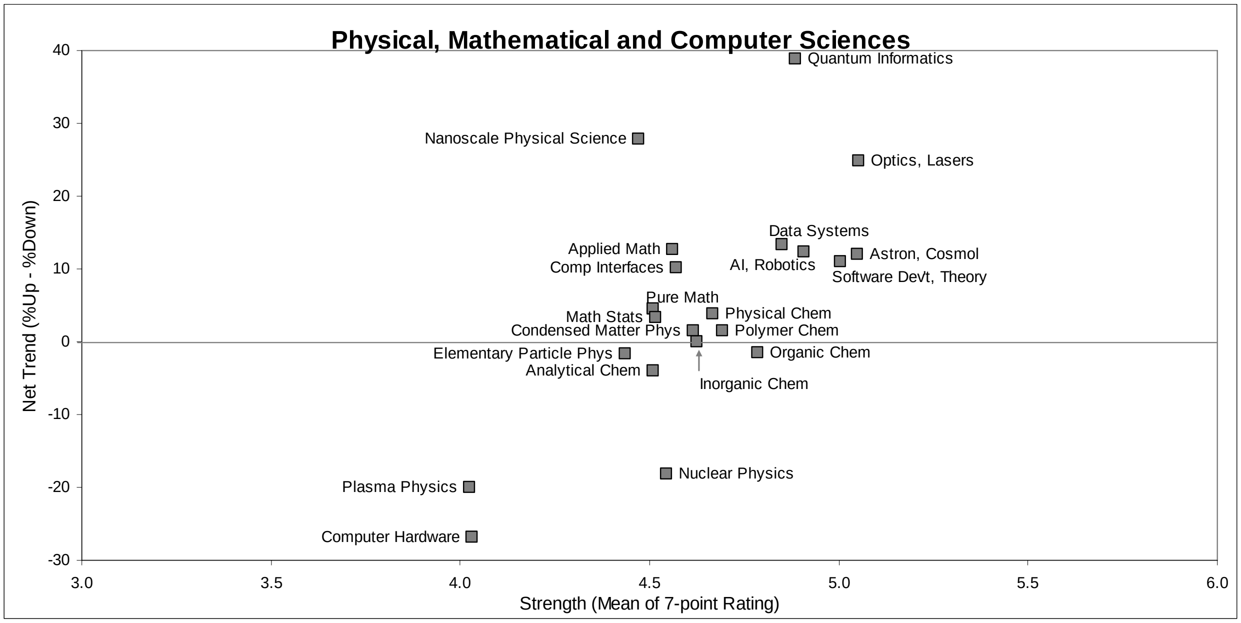


Figure B.2

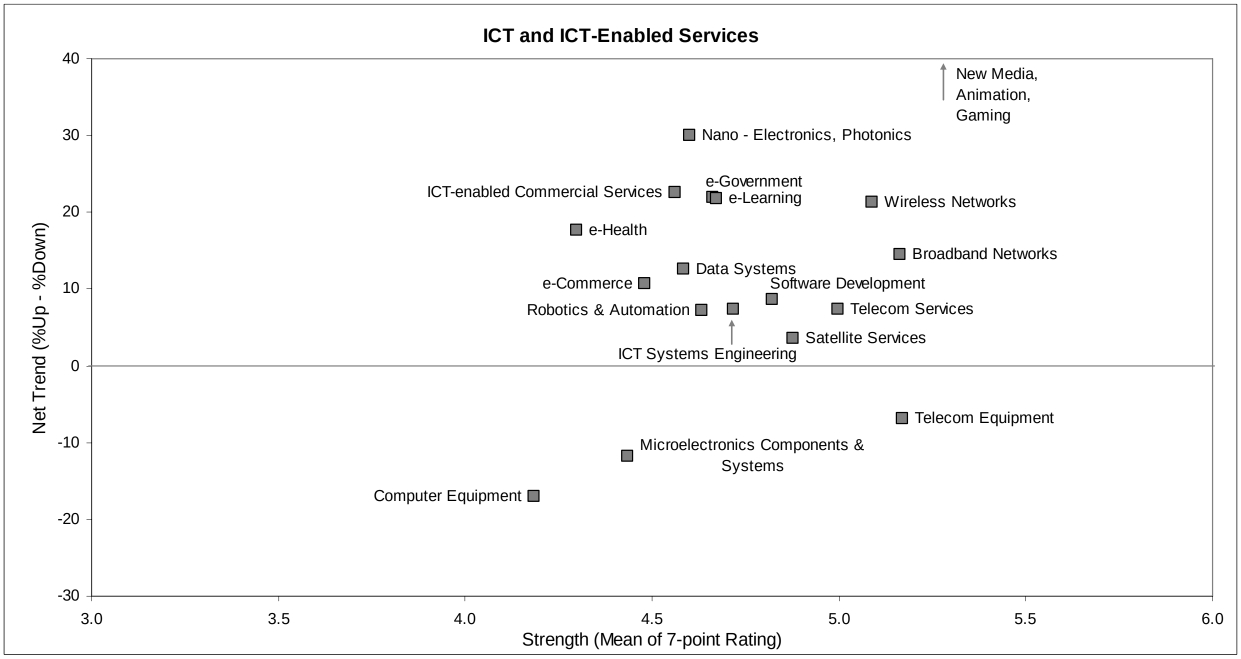


Figure B.3

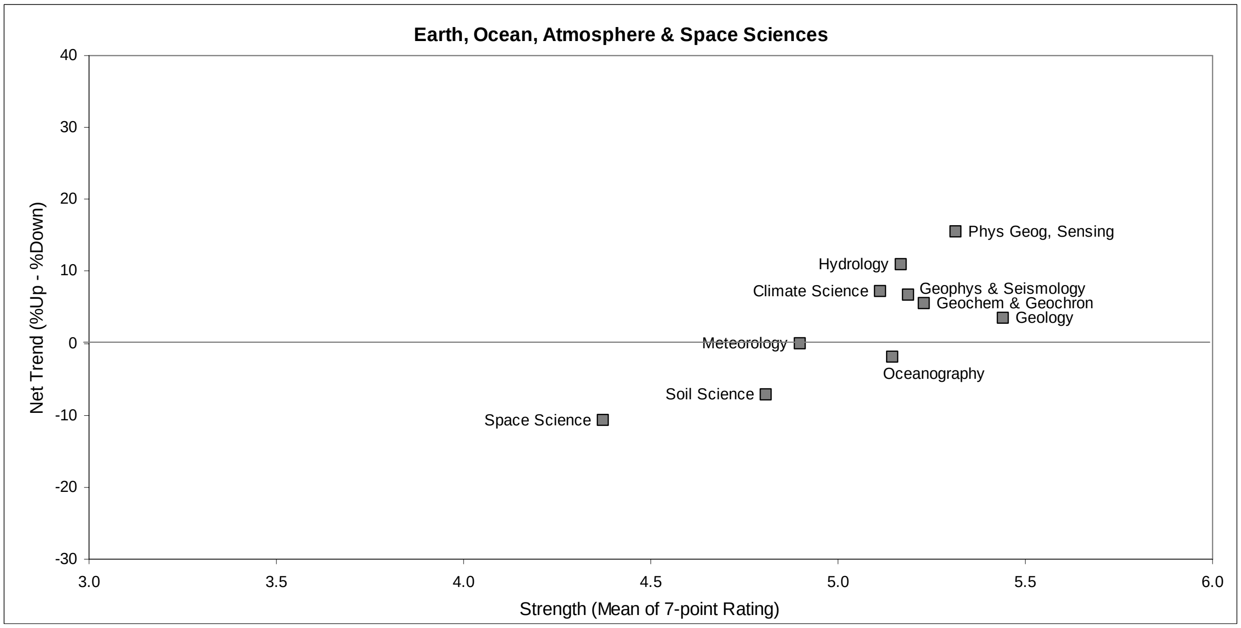


Figure B.4

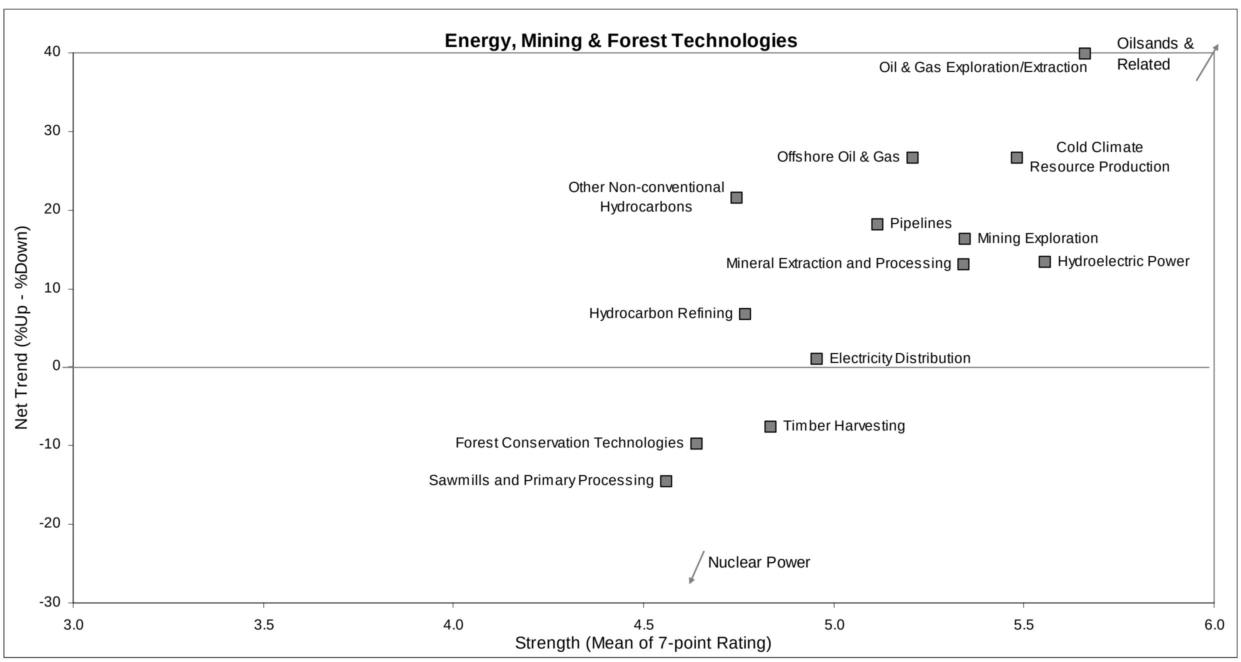


Figure B.5

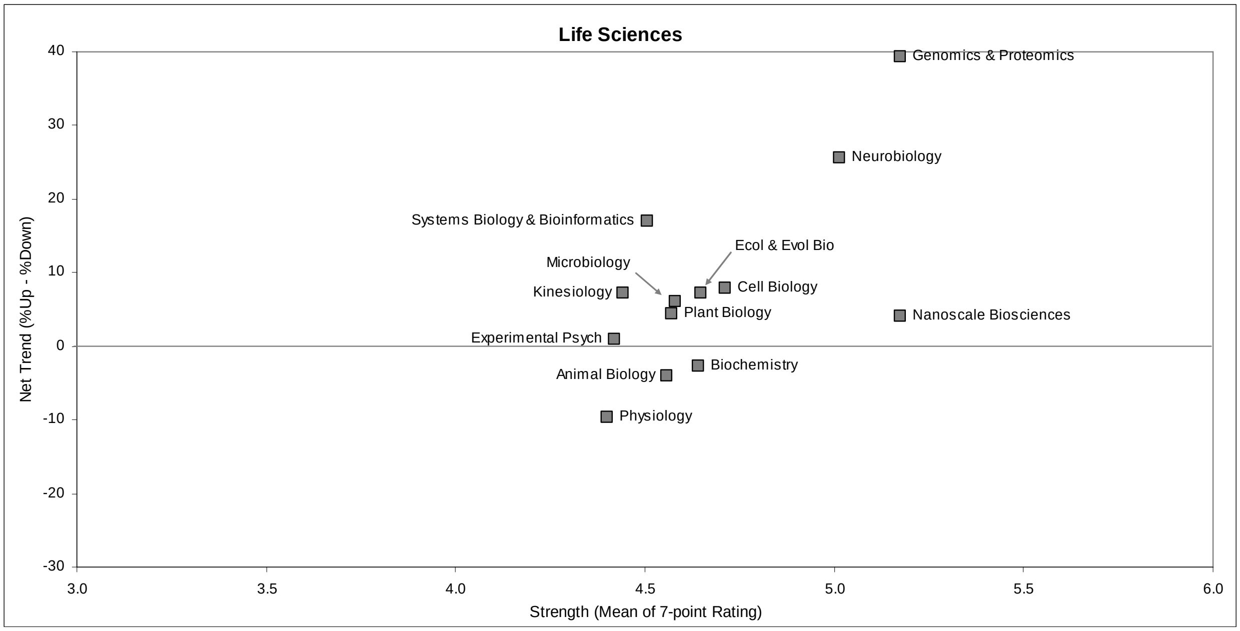


Figure B.6

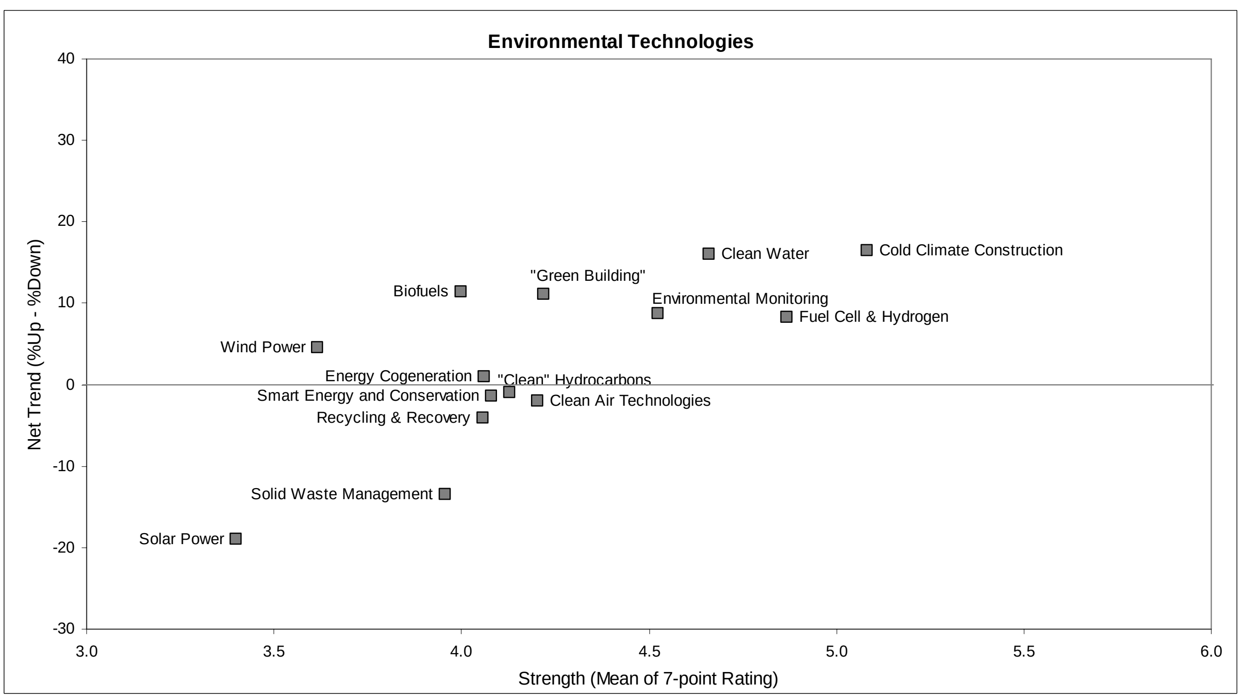


Figure B.7

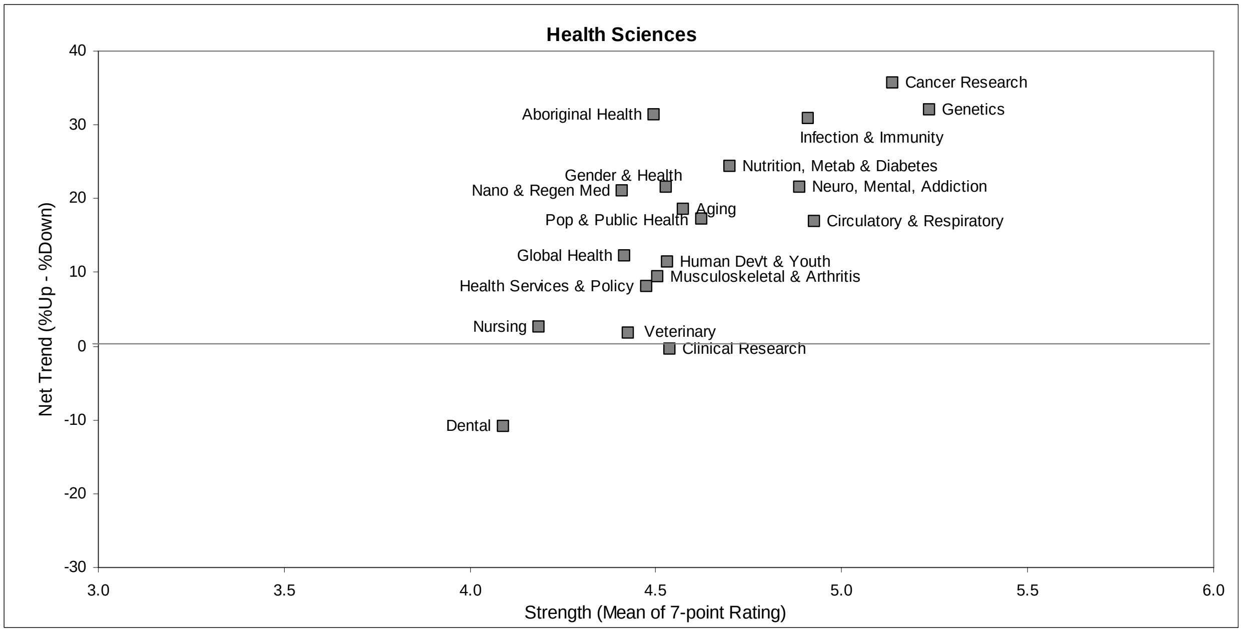


Figure B.8

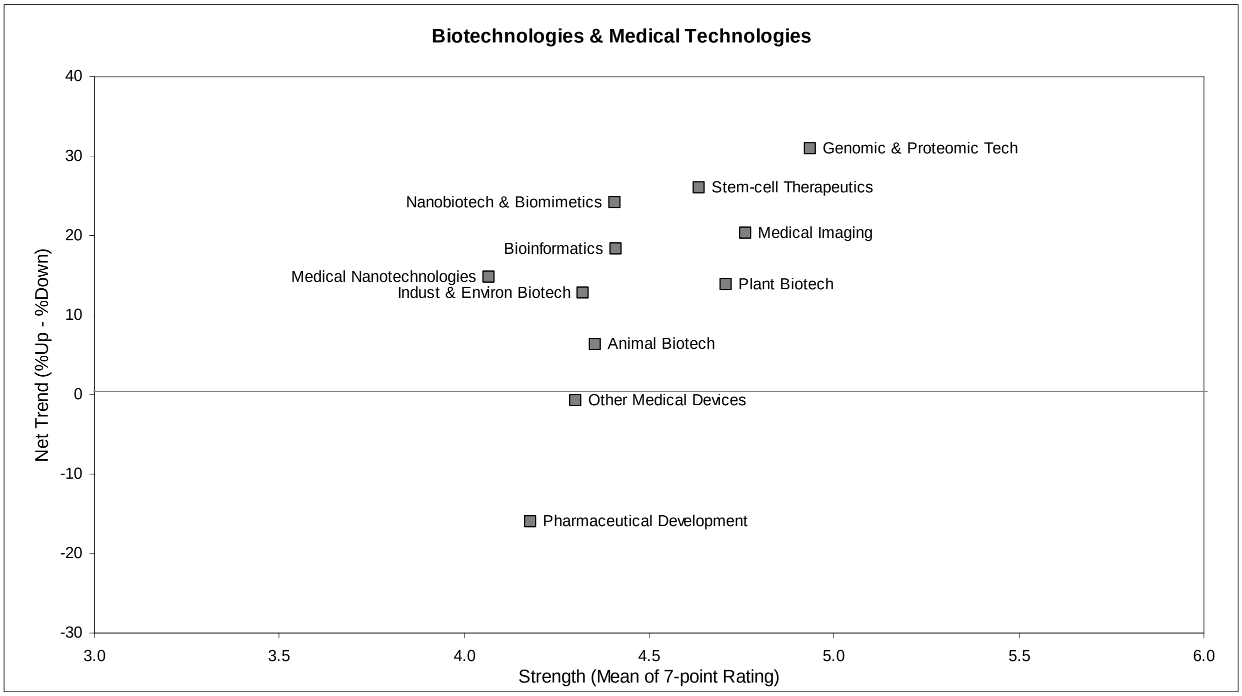


Figure B.9

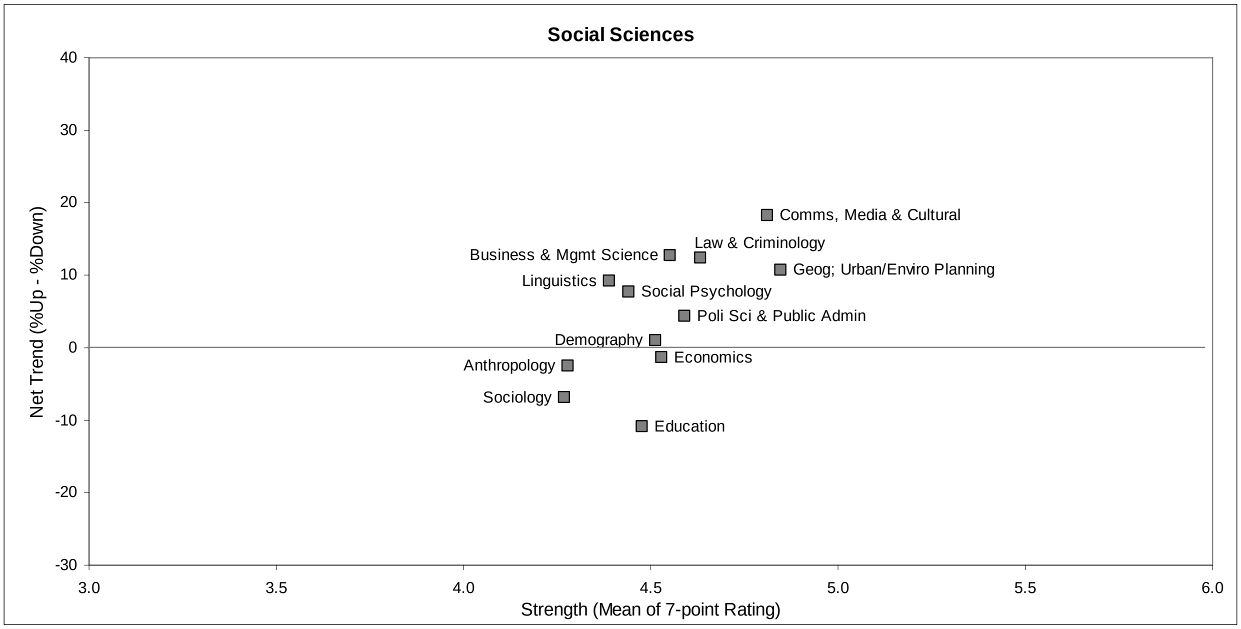


Figure B.10

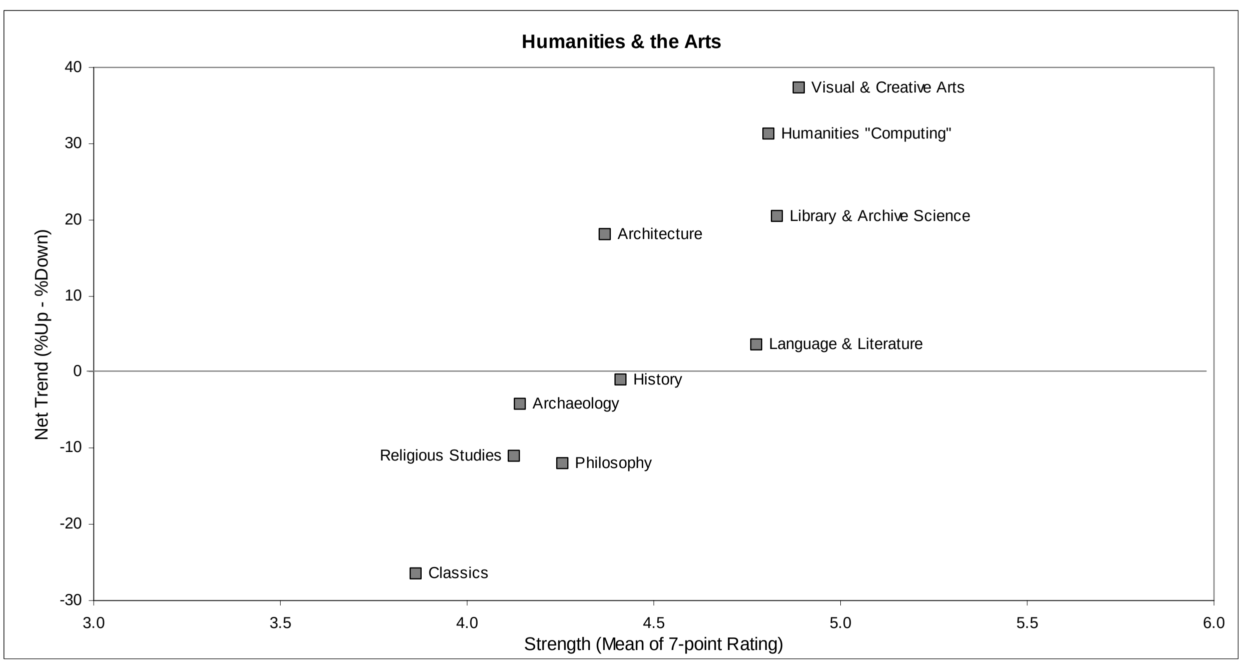


Figure B.11

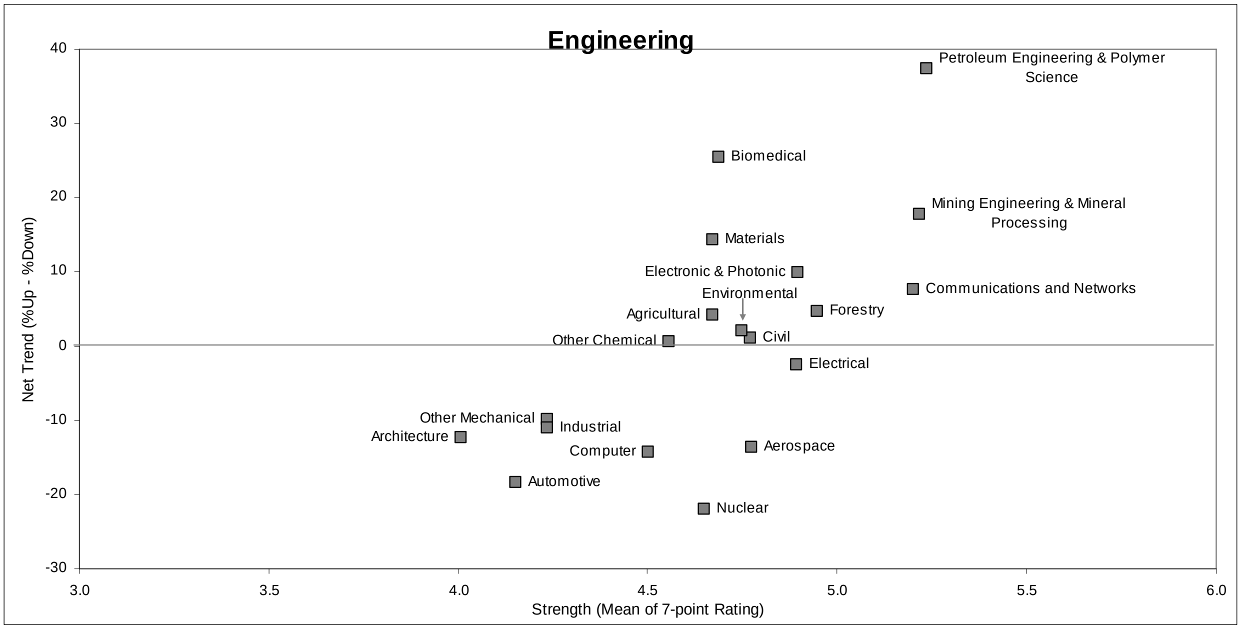


Figure B.12

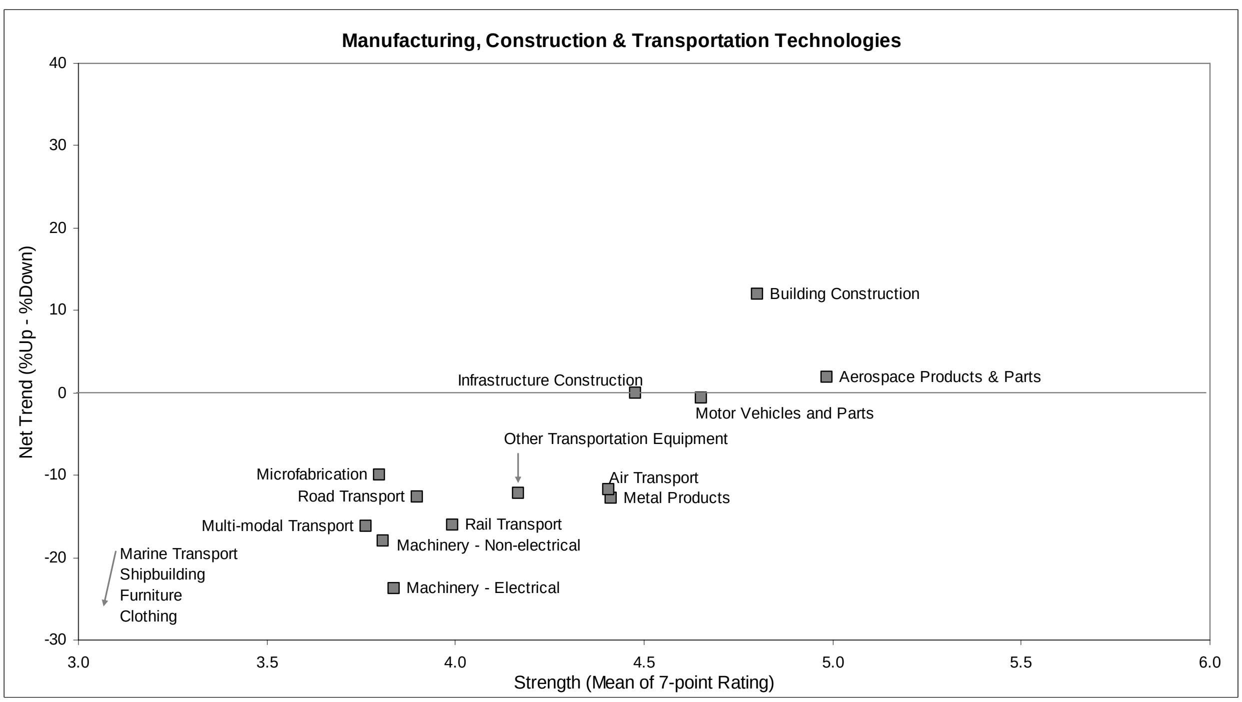


Figure B.13

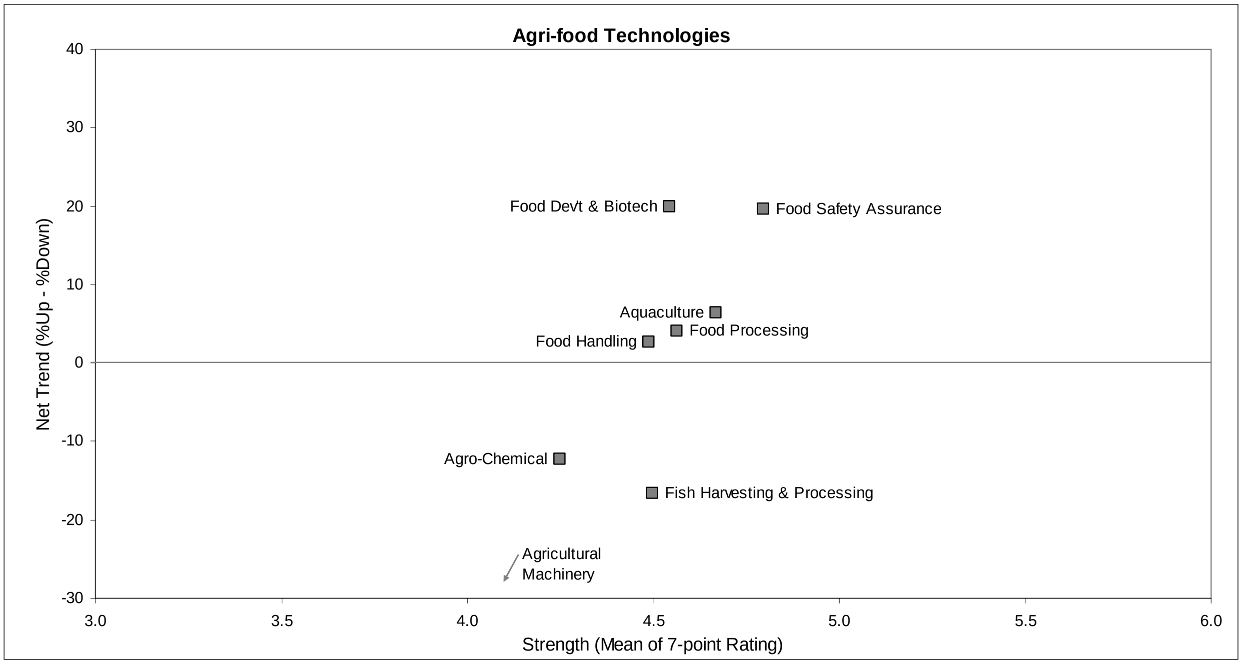


Figure B.14