ERAWATCH COUNTRY REPORTS 2012: Canada

ERAWATCH Network – George Teather and Associates

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Executive Summary

Canada is an economically advanced country, with the ninth largest economy in the world. Canada's natural resources sectors (oil and gas, agriculture, forestry, mining) are important contributors to the economy. International trade, especially exports of natural resources, makes up an important part of Canada's economy, and as a result, Canada is reliant on imports of Canadian goods by other countries. The population in 2010 was 34.3m and the GDP was €1.185tr (CAD$1.6tr).

Canada is a federation with a federal government responsible for security, international relationships, trade and telecommunications. The ten provinces have primary responsibility for natural resources, education and health within their geographical area. In practice the federal government is responsible for setting and implementing research policy at the national level, even in areas of provincial jurisdiction. The provinces and territories focus on implementing research policies and delivering research programmes customised to their specific requirements and economic priorities.

Canada's gross domestic spending on R&D (GERD) has declined in recent years, falling from 2.1% in 2001 to 1.85% in 2008, and has declined even further during the economic crisis as business expenditures on R&D have declined. In Canada, the higher education sector performs about twice as much R&D as the OECD average (35% compared to 17%), and the business sectors less (55% compared to 70%). The Canadian resource sectors (oil and gas, agriculture, forestry and mining), all major exporters, perform relatively little R&D.

In 2007, the present government introduced an integrated set of policies that link research policies directly with higher level national economic, environmental and social objectives. These policies and programmes support the development of research capacity, creation of knowledge and the translation of research knowledge and technological developments into economic, environmental and social applications that contribute to Canada's competitiveness and quality of life.

Knowledge Triangle

The effectiveness of knowledge triangle policies needs to be understood in the context of the Canadian political system and economic drivers. Canada is unusual among advanced economies in terms of the importance of exports, particularly of resources such as oil and gas, agriculture and forestry products and minerals. Sales of these products are driven by world demand, especially from the U.S., by far Canada's largest trading partner. Exports are affected by demand in importing countries and by alternative sources. Quality and price are important factors. Traditionally, these exporting sectors carry out little R&D, measured as a percentage of revenues.

Canada is among the leading countries in terms of spending per capita on higher education and has a high percentage of population with post - secondary education. However, Canada has had relatively little success in translating knowledge into economic, environmental and social applications.

The policy document Advantage Canada, produced in 2007, provided a clear linkage between research policy and the higher level economic and social objectives of the government. This linkage was articulated in the policy document Mobilizing Science and Technology in Canada's Advantage, which provided a clear description of the contribution of the three elements of the knowledge triangle policies to the achievement of Canada's long term objectives. The Table below provides a description of the specific contribution of the three elements to the achievement of Canada's long-term success.

Knowledge Triangle

	Recent policy changes	**Assessment of strengths and weaknesses**
Research policy	Research policy of present government was first introduced in 2006. Through the government's economic policy Advantage Canada, research policy is based on the development of: a Knowledge Advantage by focusing research on areas of social and economic importance (environment, natural resources and energy, health and information and communication technologies);	A strength is the recent direct linkage of national research policy to the achievement of national social, environmental and economic objectives. One long standing weakness that remains is the low level of industrial R&D (BERD).
Innovation policy	Through the government's economic policy Advantage Canada introduced in 2006, innovation policy is directed at translating knowledge into commercial applications to generate wealth and economic advantage. Business–led Centres of Excellence is an initiative to improve linkages between research and business communities.	Policy emphasises key role of applied R&D in translating knowledge into social, environmental, health and business outcomes. Policy has yet to affect Canada's poor record in translating R&D into applications. Canada's innovation record is poor compared to other OECD countries. The continuing low level of business R&D expenditures is considered to be a major factor.
Education policy	Through the government's economic policy Advantage Canada, education policy is based on the achievement of a People Advantage, aimed at increasing the supply of highly qualified S&T graduates	Policy directly links importance of Canada's education system in develop-ping skilled workforce to meet the needs of the modern knowledge economy and contribute to meeting Canada's long term social, environmental and economic objectives. Canada has one of the highest levels of population with postsecondary education. However there is a significant mismatch between skills required by employers and those seeking employment.

Assessment of the national policies/measures

	Objectives	Main national policy changes over the last year	Assessment of national strengths and weaknesses
1	Labour market for researchers	Canada Student Grant and Canada Graduate Scholarship Programmes receive additional funding so undergraduate and graduate students can pursue their education. There are policies to attract foreign students to undergraduate and graduate programmes.	Overall attractive conditions for training researchers. Adequate supply of science and engineering graduates. Supply is enhanced by foreign born students. Canadian trained researchers in high demand worldwide, especially in U.S. Have significant "brain drain" to scientifically interesting work in other countries. Some recent success in counteracting loss of trained researchers
2	Research infrastructures	The Canada Foundation for Innovation provides funding for large capital intensive S&T infrastructure and equipment needed by researchers to carry out leading research. CANARIE develops and maintains a world class high capacity optical communications network that is connected to other national and international networks.	Canada has recognised the need for high quality physical, technical and e-infrastructure to support researchers and to enable them to attract international collaborations
3	Strengthening research institutions	Federal government funding for Higher Education R&D, has doubled since 1980, and is presently 35% of all R&D.	Provinces are responsible for funding education, including universities. Universities are suffering from serious underfunding of staff and infrastructure. The federal government funds university R&D primarily through NSERC and government departments.
4	Knowledge transfer	The Business-Led Network of Centres of Excellence is a recent initiative to increase cooperation and transform knowledge to industrial application.	Weakness in the transformation of knowledge to application and innovative new and improved processes has been an area of long term concern.
5	International R&D cooperation with EU member states	No recent changes	Canada has a number of research projects associated with Framework programmes and bilateral agreements with several EU member states.
6	International R&D cooperation with non-EU countries	No recent changes	Canada has a number of bilateral S&T Agreements with US and other countries such as India, Japan, Brazil and China Canada has good access to international research through formal and informal collaborations and communication.

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1 INTRODUCTION

The main objective of the ERAWATCH International Analytical Country Reports 2012 is to characterise and assess the evolution of the national policy mixes of the 21 countries with which the EU has a Science and Technology Agreement. The reports focus on initiatives comparable to the ERA blocks (labour market for researchers; research infrastructures; strengthening research institutions; knowledge transfer; international cooperation). They include an analysis of national R&D investment targets, the efficiency and effectiveness of national policies and investments in R&D, the articulation between research, education and innovation as well as implementation and governance issues. Particular emphasis is given to international research cooperation in each country.

2 PERFORMANCE OF THE NATIONAL RESEARCH AND INNOVATION SYSTEM AND ASSESSMENT OF RECENT POLICY CHANGES

2.1 MAIN POLICY OBJECTIVES / PRIORITIES, SOCIAL AND GLOBAL CHALLENGES

The economies of Canada and the United States are closely linked in many areas. For example, Canada is the largest supplier of oil and natural gas to the U.S. The two countries have many common interests, such as energy production and use, and global warming, including dealing with the production of GHG and other emissions from fossil fuels. Transportation is another common interest with a high degree of cross border traffic. Canada has chosen to conduct a policy of harmonisation with US policies and regulations in the areas of fuel and vehicle emission standards.

As a result, Canadian federal research groups work closely with their U.S. colleagues in areas related to transportation related policies and regulations. Canada also participates in International Energy Agency (IEA) research involving various energy and transportation topics. One example is a major project on emissions from various diesel bus technology and fuel configurations under the IEA Advanced Motor Fuels Implementing Agreement. Some Natural Resources Canada (NRCan) programmes involving improving the efficiency of coal fired electrical generation work co-operatively with China, where coal fired generation is the main source of electricity.

In addition, the National Research Council Plant Biotechnology Institute (PBI) has a long standing research programme for canola, which has surpassed wheat to become Canada's largest grain crop, and a major export. PBI researchers are working co-operatively with researchers in China and Germany as they continue to strive for increases in productivity and improved seed characteristics related to oil and protein content.

2.2 STRUCTURE OF THE NATIONAL RESEARCH AND INNOVATION SYSTEM AND ITS GOVERNANCE

Canada is an economically advanced country, with the ninth largest economy in the world. Canada's natural resources sector (oil and gas production, forestry, mining) is an important contributor to the economy. International trade, especially exports of natural resources, makes up an important part of Canada's economy, and as a result, Canada is reliant on imports of Canadian goods by other countries. The population in 2012 was 35.1m, the GDP was €1,345b ($CAD1,74b), and GDP per capita €40,700 ($CAD52,100). Due to the heavy reliance on exploitation of natural resources, Canada has a relatively low level of expenditure on R&D, ranking 15th among OECD countries in 2008. Canada had a GERD/GDP ratio of 1.74 in 2011, reduced from 1.9 in 2009. In particular, the private sector contribution to R&D is relatively low, and has dropped in recent years, due to the economic downturn. BERD, which is always lower than other countries, has also dropped with the recent economic problems to 0.88% of GDP in 2012[1]. This is largely due to the makeup of Canada's business sector and the reliance on resource extraction.

Canada is a federation with a federal government responsible for security, international relationships, trade and telecommunications. The ten provinces have primary responsibility for natural resources, education and health within their geographical area. In practice the federal government is responsible for setting and implementing research policy at the national level, even in areas of provincial jurisdiction. The provinces and territories focus on implementing research policies and delivering research programmes customised to their specific requirements.

Main actors and institutions in research governance

For the current federal government first elected in 2006, research policy has been integrated into the overall federal government plan to achieve broad, long range economic and social objectives, first articulated by the Minister of Finance in the government economic document **Advantage Canada**. Industry Canada is the government department responsible for developing research and innovation policy within the framework of the economic plan. The document **Mobilizing Science and Technology to Canada's Advantage** outlines the main elements of Canada's current research policy. Other federal departments and agencies with a large science component are known as Science-Based Departments and Agencies (SBDAs)[2]. SBDAs develop department / agency level research policies specific to their mandate and objectives based on the high level policies. These SBDAs share responsibility with Industry Canada for development and delivery of science policies and programmes. The **Science Technology and Innovation Council** (STIC) is made up of representatives of business, academia and other organisations and is responsible for providing the government with external advice on R&D and innovation issues critical to Canada's economic development and social well-being. STIC has produced several reports describing Canada's S&T and innovation performance compared to other industrialized countries[3].

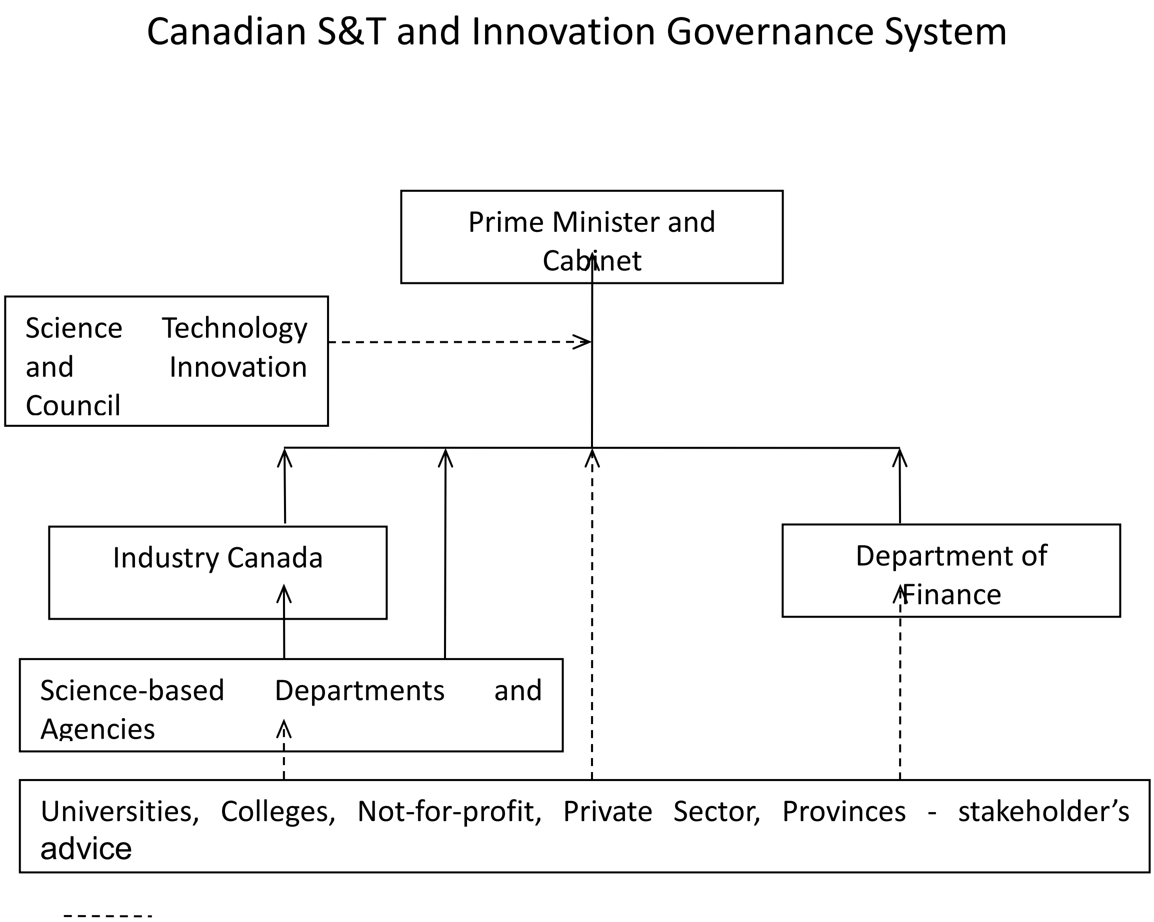
The arrows in Figure 1 indicate the flow of advice for decision making. Solid lines indicate formal channels for advice and dotted lines indicate informal methods. Governance and funding flow in the opposite direction. The Prime Minister and Cabinet have the highest level of responsibility for the Canadian federal research system in terms of both policy and funding levels. The Department of Finance allocates funding levels to all federal agencies, including SBDAs annually, based on direction from the Prime Minister and Cabinet. While the **Minister of Industry** has theoretical responsibility for overall research policy, in practice, responsibility is shared with the Ministers responsible for the other SBDAs. Each Minister is responsible for interpreting the overall research policy in the context of their Departmental mandate.

[1] Statcan data, preliminary estimate

[2] SBDAs include: Agriculture Canada, Canada Institutes for Health Research, Environment Canada, Fisheries and Oceans, Health Canada, Natural Resources Canada, Natural Sciences and Engineering Research Council, National Research Council of Canada, Social Sciences and Humanities Research Council, Statistics Canada

[3] The most recent STIC report was "2010 State of the Nation- Canada's Science, Technology and Innovation System" found at http://www.stic-csti.ca/eic/site/stic-csti.nsf/eng/h_0038.html

Figure 1: Overview of Canada's research system governance structure



Several federal organisations have a mandate to fund research, performed mainly at universities. These include Departments such as the **Natural Science and Engineering Research Council (NSERC)** and the **Social Sciences and Humanities Research Council (SSHRC).** The **Canada Foundation for Innovation (CFI)** provides funding for major capital infrastructure and equipment that supports research carried out in universities and research hospitals. Some federally funded agencies, such as **Sustainable Development Technology Canada (SDTC)** co-fund R&D projects carried out by industry that are at the advanced development or pilot stage and are strong candidates for commercial application. Research is carried out in business enterprises, universities, government laboratories, and a range of public, not-for-profit and private research institutes. Most research institutes receive funding from both government and business. Most other SBDAs both carry out intramural research and fund extramural research at universities and other research organisations. The governance and delivery structures have been relatively stable for many years. The roles of Industry Canada, SBDAs, NSERC and SSHRC have been consistent for decades. From time to time, new agencies are created in response to government priorities and identified needs. For example, CFI was created over a decade ago to address the need for funding major scientific infrastructure in universities and hospitals. SDRC was created a number of years ago in response to the increased focus on improving environmental sustainability through the development of new and improved technologies.

The institutional role of regions in research governance

As Canada is a federation, the provinces are important actors in the areas of research and higher education. Provinces are responsible for education under the Constitution, including the universities within their borders. In general, provinces contribute funding towards the salary of professors and university infrastructure and the federal government funds the research and stipends for graduate students. However, compared to the business sector and the federal government, the provinces are relatively small funders of R&D. In 2012, provinces funded 5.7 of R&D, compared to 19.5% by the federal government and 46.7% for the business sector[4].

Each province has a political governance system similar to the federal government and has departments and agencies similar to those of the federal government. Provinces develop and fund R&D and innovation policies and programmes that are focused on those areas most important to their regional economy. For example, Quebec, which has large aerospace and pharmaceutical sectors, has programmes and funding to support research in these areas, carried out both by business and universities. British Columbia carries out research on forestry and Alberta and Saskatchewan on production and refinement of fossil fuels from conventional and oil sands. Ontario and other provinces have major programs to translate research knowledge into innovative applications and commercial products. Some provinces have a provincial research organisation that conducts research in areas related to the economic interests of the province. For example, with the increasing concern about the environmental effects of the oil sands, Alberta and Saskatchewan both have research programmes aimed at reducing the energy costs and emissions associated with producing and upgrading oil produced from the oil sands and heavy oil deposits. The Alberta Research Council has large programmes linked to production of oil from the oil sands and remediation of the residual sand and waste products from production. The Council also has programmes supporting the improve of the efficiency of production of valued added forest products such as oriented strand board used as a lower cost substitute for plywood. A new area of research in Alberta and the US has recently opened up associated with the discovery of oil deposits tightly held in rock formations, that can be reached through “fracking” which is the use of high pressure fluids to open up the rock formations.

In many cases, the federal and provincial governments co-fund research initiatives that are in their mutual interest. For example, the federal government co-funds genomics related research with specific provinces related to their interests under a generic federal genomics program. Western Canada genomics research projects focus on agricultural products such as canola and other grains, which are major crops out West. The federal and provincial governments, along with the private sector, also fund Forintek, Canada’s primary forest products research organisation.

Ontario has the largest share of Canada’s GDP, and has the most universities, and firms, as well as federal government laboratories. As a result R&D is heavily concentrated in Ontario, which in 2010 performed 45% of all R&D. Quebec at 26%, British Columbia at 10%, and Alberta at 9.5%are the next largest performers.

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[4] Statcan preliminary data

Canada has a major research programme on arctic issues, particularly the effects of global warming on flora and fauna. Because of the limited resources in the north, the federal government is the primary funder and performer.

Main research performer groups

The private sector is the larger performer of research, at 52% of GERD in 2011, with a total of €1.15b (CAD$15.5b)[5]. Firms in the several of the resource sectors, including forestry and fossil fuel production, perform relatively little R&D in proportion to sales. Until recently, Nortel, one of Canada's largest IT firms, was a major R&D performer. Unfortunately, Nortel declared bankruptcy in 2010. Canada's other major IT firm, RIM, the maker of the Blackberry, continues to be among the largest private sector R&D performers

The higher education sector is the next largest performer of research, accounting for about 38% of GERD, with €8.5b (CAD$11.5b) in expenditures[6] in 2012. Each province has at least one university and Ontario, the largest and most populous, has ten. Provinces also have colleges that deliver applied programmes.

The public sector is the third largest research performer, accounting for about 9.6% of GERD or €2.1b (CAD $2.9b) in 2010. The federal government is the largest performer accounting for about 86% of public sector R&D. Federal government SBDAs carry out and fund research related to their mandates. For example, Natural Resources Canada conducts research on improving the efficiency of coal fired electrical power generation and renewable power generation in order to support the effective use of Canada's large coal reserves and on improving the fuel efficiency of vehicles in order to support the efficient use of fossil fuels and reduce greenhouse gas (GHG) and other emissions. Agriculture Canada conducts research on improving crop yields and animal husbandry.

2.3 RESOURCE MOBILISATION

2.3.1 Financial resource provision for research activities (national and regional mechanisms)

Canada has no specific targets for R&D investment. While there is a general desire to increase GERD, the GERD/GDP ratio has in fact declined in recent years, from 2.1% in 2001 to 1.74% in 2011. Even though the government has attempted to increase industrial R&D investments through a very generous R&D tax credit programme, BERD/GDP remains low in Canada by international standards. From a high of 1.25% in 2001, BERD declined to 0.9% in 2009. While the government has challenged the business sector to increase its spending on R&D, the recent economic crisis has affected business spending.

[5] Statistics Canada preliminary 2012 data

[6] *ibid*

Canada's R&D investments are based on the country's societal and economic challenges and political objectives. Canada's economy relies heavily on exports, and the country needs to ensure a competitive marketplace so companies can compete on the world stage. For example, Canada needs to develop new technologies to reduce the costs and environmental effects of oil production from the oil sands. To reduce delays in decision making, in 2011, the government improved the efficiency of regulatory processes and cut back on environmental studies associated approval of major resource related projects such as pipelines or mines. The government also helps maintain the competitiveness of Canada's aerospace industry by funding the development of new and improved technologies to increase the energy efficiency and reduce the environment footprint of Canada's next generation aircraft.

Like other countries, Canada has major environmental challenges related to reduced energy use and greenhouse gases generated by fossil fuels that contribute to global warming. With an aging population, Canada also has challenges related to the health of Canadians and minimising the costs of health care. As stated in the federal policy document, Mobilizing Science and Technology to Canada's Advantage, "*Science and technology are essential to … building a prosperous economy and promoting a better quality of life across the country*." The challenge is to translate S&T knowledge into public and private sector applications that provide socio-economic benefits.

Canada's current long term policies regarding R&D activities are directly linked to the economic policy Advantage Canada, and are based on the 2007 policy document **Mobilizing Science and Technology to Canada's Advantage**. The goals are to utilise science and technology to create innovation applications that help improve Canada's economic competitiveness and provide solutions to environmental, health and other social challenges. The 2007 report sets out an S&T strategy to achieve these goals, built around three pillars, Entrepreneurial Advantage, Knowledge Advantage and People Advantage, described below:

- Canada will create an **Entrepreneurial Advantage** by translating knowledge into commercial applications that generate wealth and support the quality of life of Canadians.
- A **Knowledge Advantage** will be created by focusing on research in areas of national importance from a social and economic perspective. These are: environmental science and technologies; natural resources and energy; health and related life science and technologies; and information and communications technologies.
- In order to create a P**eople Advantage**, Canada will attract and retain the highly skilled workers necessary to foster innovation and growth. This goal will be accomplished through enhancing Canada's immigration system, fostering excellence in and access to post-secondary education, and reducing barriers to labour mobility.

As articulated, Canada's science policy is vertically integrated, beginning with education and R&D to develop highly qualified personnel (HQP), leading to the development of new knowledge that will be applied to achieve economic, environmental and social objectives. There have been updates, but the broad strategy has not changed.

The recent economic crisis has affected R&D funding in several ways. The federal government response to the crisis has been two fold. On one hand, as part of the Economic Action Plan in 2008-2009, the focus was to provide additional financial assistance to help the large industries most affected, such as forest products and automotive, and SMEs to invest in modern innovative technologies to improve competitiveness. The government instituted additional programmes to help industry develop innovative technologies through university / business partnerships and support for the venture capital industry. However, more recently, in the 2012 budget, as the economic crisis abates for Canada, and the Economic Action Plan comes to a close, the focus has been on reducing government expenditures in all areas, including R&D in an effort to return to a balanced budget. Funding for environmental and fisheries research has been particularly affected. Business funding of R&D has also been negatively affected since the economic downturn in 2008. Canada's biggest single private sector R&D spender for many years, Nortel, went into bankruptcy during the crisis and has been wound up. Other business R&D spending has also declined.

Canada has a number of federal organisations that manage and distribute R&D funding. There are three agencies, Natural Science and Engineering Research Council, Social Sciences and Humanities Research Council and Canada Institute for Health Research that deliver programmes that provide funding support to carry out R&D in universities and colleges in natural sciences and engineering, social sciences and humanities and medicine and health sciences respectively. Much of the funding from these three agencies is provided for research projects on a competitive basis. The Canada Foundation for Innovation provides funding for major capital equipment and infrastructure required to carry out front line research. The science-based departments and agencies carry out and fund R&D related to their specific mandates. For example, Natural Resources Canada carries out and supports research in forestry, oil and gas production, energy and mining. In addition, there are a number of specific programmes that fund specific initiatives such as Genome Canada and National Centres of Excellence in various fields. There are also several programmes that support private sector R&D carried out to develop new and improved technologies, products and processes to improve their competitive position. The programme Strategic Aerospace and Defence Initiatives (SADI) provides funding for major projects in those sectors, and the Industrial Research Assistance Program provides technical advice and financial assistance to SMEs through a network of over 200 Industrial Technology Advisors. In 2010, federal funding of R&D totalled €4.5b ($CAD6.0 b), 21% of the total, divided about equally between federal departments and universities.

Canada's provinces funded about €1.2b ($CAD1.6 b) in R&D, 5% of the total, with the majority going to higher education. Ontario, Quebec and Alberta are the largest funders of R&D. Funding by Alberta has grown rapidly in recent years, increasing by 70% between 2004/2005 and 2008/2009. In addition to funding higher education, provinces also support applied R&D in areas of economic importance. For example, Quebec R&D funding is focused on biotechnology, aerospace and forestry, industrial sectors with large employment. British Columbia funds forestry and forest products related research through the public/privately supported Forintek, Canada's primary forest products research centre. The Alberta Heritage Fund, established in the 1970s to collect and invest a portion of Alberta's non-renewable resource revenue for future generations, is being used to fund R&D in medicine and health care and support training through fellowships.

2.3.2 Providing qualified human resources

As noted above, under the **People Advantage** policy, Canada has supported excellence in and improved access to post-secondary education. Canada is near the top among OECD countries in terms of per cent of GDP going to Higher Education R&D

The supply of researchers in Canada comes from two sources. The first and largest is the Canadian University system. Students receive training at the undergraduate and graduate level from university professors. For undergraduates, the training is primarily through course work. For postgraduate students, the training is a combination of course work and participation in research projects. The second is the recruitment of researchers from abroad. Canadian trained researchers are in high demand and many are attracted to opportunities in other countries. To counteract this “brain drain” and attract excellent researchers, there are programmes such as the Canada Research Chairs Programme to attract and retain world-class researchers, including expatriates.

The 2007 Canadian federal science policy report Mobilizing Science and Technology has a specific objective, aimed at increasing the supply of highly qualified science and technology graduates, including providing students with business experience to improve their job readiness. Specific initiatives include an expanded Canada Graduate Scholarship programme to support an additional 1000 graduate students and an Industrial R&D Internship programme to provide 1000 science graduate interns with business experience. The government has also introduced measures to make it easier for foreign workers to come to Canada.

Canada has a well educated population, with 49% of adults between 25-64 having tertiary education (STI Council 2010), compared to about half that level for the EU average. This is consistent with the high level of expenditures for higher education. In terms of S&T degrees, Canada ranks about average among OECD countries and fifth among G7 countries, with about 21% of total degrees in S&T. However, Canada ranks poorly in terms of the number of Doctoral degrees granted, being well below the OECD average and last among G7 countries.

Canada had about 214,000 personnel employed in R&D in 2006, with 45% in Ontario and 30% in Quebec, the two largest and most industrialised provinces. There were about 6,600 in the federal government, with the largest number, 1475, at the National Research Council of Canada.

Canada has higher levels of unemployment among doctorate holders than other countries (STI Council 2010). While research is a relatively attractive career after obtaining permanent employment, there are a number of impediments. One is the number of years to achieve a postgraduate degree compared to the potential for entering the workforce earlier with a good salary. This is particularly true for engineers. As a result, there is a lack of Canadian students for postgraduate studies.

To compensate, foreign students are hired. In addition, there are a number of other careers that have greater salaries than research.

2.3.3 Evolution towards the national R&D&I targets

In 2011, the federal government undertook a major policy review and produced a Review of Federal Support to R&D, known as the Jenkins Report, aimed at a more focused approach to federal R&D spending. The report has seven major recommendations, including:

- Creation of an Industrial Research and Innovation Council to deliver federal business innovation programmes;
- Simplification of the federal tax credit system supporting small and medium sized businesses;
- Link federal procurement policies to business innovation;
- Transform the National Research Council Institutes into large scale collaborative centres involving business, universities and province;
- Help high growth innovative forms access risk capital through the Business Development bank; and
- Establish a clear federal voice for innovations and work more closely with the provinces.

One major science policy objective is for the private sector to invest more in R&D. As stated in **Mobilizing Science and Technology to Canada's Advantage,** "*At a time when Canada`s overall productivity gains are below those of other trading nations with whom we compete, the need to encourage greater private-sector S&T investment is a priority*." This policy directive is intended to address the long-standing concern about relatively low levels of BERD. While there is no specific target, government has encouraged business to increase R&D spending through various means, including increasing the funding for programmes that co-fund R&D joint projects between government departments and industrial partners. Canada carries out relatively little industrial R&D, as it has a large resource based industrial sector, that traditionally carries out relatively little R&D. The industrial downturn has exacerbated the problem. The Science Technology and Innovation Council Report entitled "2012 State of the Nation" described the decline in Canada's R&D investments over the past five years. Canada has dropped from 16th in the world in 2006 to 23 in 2011. Recent government programmes are focused on encouraging the knowledge –based industrial sectors, such as ICT, to undertake additional R&D and for sectors that can apply R&D to participate in joint projects to commercialise and apply R&D. The federal government also provided funding to the venture capital sector. While there are examples of individual firms and sectors increasing R&D, at the national level there has been little success. Canada ranked 18th among OECD countries in 2008 in terms of BERD/GDP. In 2008 Canada's BERD/GDP ratio was 1.0% compared to the OECD average of 1.6%. Canada's BERD/GDP reached a peak in 2001 of 1.25% when the IT sector was flourishing and has declined since then, as that sector declined. During the economic crisis, business spending on R&D declined even further to 0.9% in 2010. This is of major concern, as business R&D is closer to the market and the development of innovative new products that improve Canada's competitive position in the knowledge economy.

There are a number of reasons for the low rate of business R&D. One major reason has been the Canada/US Auto pact, whereby the Canadian automotive sector carried out almost no R&D, focusing on production of models that were developed in the US. The Canadian automotive sector continues to be primarily focused on manufacturing and assembly. Canada also has many firms in the resource sectors (oil and gas, mining, and forestry), which are largely involved in extraction and carry out relatively little R&D. To encourage more private sectors R&D, government policies and programmes are focused on supporting those sectors in the knowledge-based economy that carry out and utilise R&D. These include pharmaceuticals, aerospace, IT, and renewable energy. In the past, the IT sector was a major performer of R&D. Since the dot-com crash in 2001, Canada's IT sector has declined, and has been spending less on R&D.

Policy Mix towards increasing private R&D investment

Stimulating greater investment in R&D performing firms: The government has instituted a number of programmes aimed at stimulating R&D investment in private firms, with a focus on transforming knowledge into commercial products and wealth. These programmes are in support of a policy objective identified under Entrepreneurial Advantage to translate knowledge into innovative applications that help improve Canada's economic competitiveness and provide solutions to environmental, health and other social challenges. Canada has a number of programmes, each one designed to support a specific industrial sector or area of technology. Several programmes co-fund R&D projects in strategic areas of the knowledge-based economy where Canada has some significant strength and/or competitive advantage that involve private sector firms working co-operatively with universities and government R&D laboratories. The Business–Led Networks of Centres of Excellence (BL-NCE) initiative is an example of a recent government programme in this area. The BL-NCE four year funding (2009-2013) for four major business led programmes aimed at:

- reducing the environmental impact of aircraft and air travel and increasing the competitiveness of Canadian aerospace firms;
- enhancing oil recovery;
- developing value-added forestry products; and
- creation of pharmaceutical products.

This funding was recently extended.

Another example is the Strategic Aerospace and Defence Initiative (SADI), which provides financial support for R&D carried out within the aerospace and defence sector. SADI is targeted at relatively large firms. Canada also supports SMEs through the Industrial Research Assistance Program (IRAP) which provides technical and financial support to SMEs for R&D projects associated with product and process development that improve competitiveness.

Promoting the establishment of new indigenous R&D performing firms; The Industrial Research Assistance Program (IRAP) provides technical and financial support to help grow SMEs. Many of the firms assisted are very small start-ups with less than 10 employees, with a focus on R&D and new products. During the economic crisis (2008-2010), IRAP received an additional €150 m ($CAD 200m) to help firms improve their competitive position. Recently this additional funding was confirmed for an additional term.

Stimulating firms that do not perform R&D yet: IRAP also helps firms develop R&D capability to support the development of new and improved products, and increased competitiveness.

Attracting R&D performing firms from abroad: Canada has a very generous Scientific Research and Experimental Development tax credit to encourage firms to carry out R&D. The government has also reduced corporate tax rates and provided funding to support employee training. While these initiatives provide an encouraging environment for firms to come to Canada, there are no specific programmes to attract R&D performing firms from abroad.

Increasing extramural R&D carried out in co-operation with the public sector: Most of the programmes described in the section describing ways that Canada is stimulating greater R&D investment in the private sector involves partnerships with university and or government researchers who contribute their own expertise. Many of the programmes are intended to transfer public sector knowledge to the private sector and transform it into economic wealth.

Increasing R&D in the public sector: Current government policy does not include increasing overall public sector R&D. During the 2009-2011 periods, during the economic crisis, the government instituted an Economic Action Plan that spent €38b ($CAD50b) to mitigate the economic downturn. This year, the government is reducing spending in almost all areas in order to return to a balanced budget from the major deficit during the last two years. These reductions are affecting spending in R&D.

Innovation oriented procurement policies

The federal government does not have any explicit R&D oriented procurement policies

Other policies that affect R&D investments

Canada has a number of other policies that affect R&D investments. For example, the Province of Ontario has a policy of encouraging the use of renewable energy in the form of solar and wind power as a means to support an emerging green energy sector. The government is providing major long term subsidies to individuals and firms that install renewable power generation equipment. This policy has attracted late stage development of new and improved technologies. However, this policy is being challenged at the World Trade Organization by several other countries.

The federal government has also provided funding to support the venture capital sector, which is vital to the successful development and production of new and improved technologies.

As mentioned previously, the federal government has policies and programmes in place that support the development, retention and import of highly qualified personnel, an important element of successful R&D performing firms. The government has also reduced personal and corporate tax rates to encourage researchers to stay in Canada and firms to grow their Canadian operations.

2.4 KNOWLEDGE DEMAND

This section focuses on structure of knowledge demand drivers and analysis of recent policy changes.
The majority of Canada's economy is linked to natural resources including oil and gas production, mining, forestry and agriculture. However there are a number of strategically important industrial sectors and firms that rely on R&D and innovation. These include:

- Information technology and communications (many firms including Blackberry
- Aircraft and jet engines (Bombardier, Pratt and Whitney Canada, and other small aerospace firms)
- Pharmaceuticals (several international pharmaceutical firms);
- Plant biochemistry and genomics (Monsanto and other international agricultural firms)

The oil and gas sector is another important strategic sector with a need for innovative approaches to oil sands extraction and refinement that consumes less energy, produces less GHGs and is more environmentally sustainable. Many government R&D policies and programmes support industrial R&D in these strategic areas with direct funding and co-funding of research with government agencies.

It is important to realise that often many years of basic and applied research and testing are required as the foundation for commercialisation, application and widespread implementation of new technology. Resource limitations and focus on the short term and immediate needs may affect the ability to conduct research to support emerging and longer term challenges, such as development of Canada's arctic resources.

2.5 KNOWLEDGE PRODUCTION

The production of scientific and technological knowledge is the core function that a research system must fulfil. While different aspects may be included in the analysis of this function, the assessment provided in this section focuses on the quality of the knowledge production, the exploitability of the knowledge creation and policy measures aiming to improve the creation of knowledge.

2.5.1 Quality and excellence of knowledge production

The primary source of knowledge production in Canada as measured by scientific publications is through scientific research at the universities. However researchers at Canadian SBDAs also make a significant contribution to knowledge production. In 2009, Canada placed sixth among OECD countries, with 2,500 articles per million population[7].This is higher than the US, UK and Germany. Canada has the largest fraction of research publications in the fields of biology, agriculture, geology, the environment and mathematics. The overall quality of Canadian research, is generally good, with 54% of articles published in top quartile journals, third among G7 countries. The fields with the highest number of citations are clinical medicine, chemistry, and biomedical research. The recent report on the State of Science and Technology in Canada 2012, by the Expert Panel on the State of Science and Technology in Canada showed that Canada remains strong in terms of the production and impact of scientific research, as measured by publication analysis. However, experts consider that Canada's strength has declined in recent years. However, Canada's record in terms patents is not strong. In 2010, Canada had a negative balance of nearly €3.7m (CAD$5m) in royalties and licencing revenues.

Canadian universities also rank quite high by international standards. In the field of natural sciences, Canada has seven universities among the top 100 in the world. However, by international standards, Canadian students do not view an S&T education as a preferred option. The number of S&T degrees as a percentage of the total number of new degrees is relatively low in Canada, 21st among OECD countries (STI Council 2008).

Canada ranks poorly in translation of knowledge into application and commercial products. For example, in terms of patenting, Canada ranks 14th among the 17 nation comparison group. The report State of the Nation 2012, produced by the Science Technology and Innovation Council also identified development and application of knowledge by industry as a serious weakness for Canada.

2.5.2 Policy aiming at improving the quality and excellence of knowledge production

There is no overriding national policy or initiative aimed at monitoring or improving the quality and excellence of knowledge production. There are however, periodic studies that examine the quality and amount of knowledge production in Canada compared to other countries. As described in Section 2.2, the Science Technology and Innovation Council is responsible for providing external advice and guidance on Canada's R&D and innovation policies to the federal government. In 2012 the Council produced the latest update of the State of the Nation, Canada's Science, Technology and Innovation System, that provided an overview of Canada's innovation performance including world ranking in science and engineering. The government takes reports such as this into account in developing innovation policies. The government also has provided annual updates to the 2007 major policy document Mobilizing Science and Technology to Canada's Advantage. These updates describe progress in achieving policy goals, including the quality and relevance of knowledge production and its transformation into social and economic impacts.

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[7] Statistics Canada 2012 Report

2.6 KNOWLEDGE CIRCULATION

This section will provide an assessment of the actions at national level aimed at allowing an efficient flow of knowledge between different R&D actors and across borders.

2.6.1 Knowledge circulation between the universities, PROs and business sectors

The 2006 report The State of Science and Technology in Canada by the Committee on the State of Science and Technology in Canada cited "*the difficulty of knowledge transfer from researchers in universities to innovators in industry*" as a long-standing problem in Canada. Solutions to the problems were considered to include a need for investment in technology development and demonstration, as well as dealing with broader economic, financial and cultural issues. In Advantage Canada, the 2007 economic policy statement, there is a section called Entrepreneurial Advantage that emphasises the need to translate knowledge into commercial applications that generate economic benefit and support quality of life of Canadians.

Canada has always had a number of programmes to bridge academic and business interests, including several Natural Sciences and Engineering Research Council funded joint university-industry initiatives. However, there has been an increased focus and funding since the present government was elected in 2007, for programmes directly linking universities and businesses. As one example, the Business–Led Network of Centres of Excellence Programme (BL-NCE) introduced in 2009 provided €30.1m (CAD$40m) over 4 years to four business led initiatives to develop technology relevant to business in four areas of national interest. There is one network in each of the following areas:

- Heavy oil production;
- Environmentally friendly next generation aircraft;
- Pharmaceuticals; and
- New value-added products from the forestry sector.

Each of these initiatives receives matching funding from industry and other sources, and carries out research projects selected by industry. In the aerospace network, industry is also managing and carrying out the research projects.

2.7 OVERALL ASSESSMENT

Canada has a well-developed research system, involving many federal and provincial departments and agencies, and not-for-profit organizations. Some are carrying out research intramural and with partners to help achieve their own objectives, while others focus on funding research carried out in universities and colleges as well as industry.

With a GERD/GDP ratio of 1.74 in 2010, Canada has a relatively low level of expenditure on R&D, ranking 15th among OECD countries. Canada is also low among OECD countries in terms of business spending on R&D, with a BERD/GDP ratio of 0.9% in 2010 compared to the OECD average of 1.6%.

Linked to the relatively low level of business R&D is Canada's poor performance in transforming knowledge created through R&D to applications. This weakness has been identified in several recent studies and a number of programmes have been put in place to try to overcome the problem. These include the Business–Led National Centres of Excellence, which funds business led research with university involvement that supports the development of commercial applications in Canada's strategic priorities (energy, health, natural resources and IT). In spite of the recent transformative policies identified in the previous sections, Canada has had not yet succeeding in improving R&D performance, according to most indicators, in fact performance has declined significantly. The State of the Nation 2012 report on Canada's Science, Technology and Innovation System describes the change in a number of R&D indicators since the last report in 20108. There were declines in the level of R&D expenditures by the public, private and higher education sectors. Expenditures by the Higher Education Sector declines to 0.66% of GDP in 2011, reducing Canada's rank to ninth in 2011, compared to fourth in 2008. Business Expenditures also continued to decline, dropping to 0.89% of GDP in 2011, ranking Canada 25th of 41 countries.

Table 1: Changes in R&D Indicators as Reported in State of the Nation Reports

Indicator	2008 Report	2010 Report[8]	2011
GERD as % of GDP	1.97%	1.85%	1.74%
GERD by federal gov't	CAD$2.2b	CAD $2.15b	
BERD as% of GDP	1.10% 15th	1.0% 18th	0.9%
Venture Capital	0.12%	0.08%	
HERD as % of GDP	0.66%	0.64%	
% of BERD carried out by Higher Education	5.7%	6.3%	
Intramural Gov't R&D as % of GDP	0.20%	0.19%	

[8] The data are earlier, not 2010

3 NATIONAL POLICIES FOR R&D&I

3.1 LABOUR MARKET FOR RESEARCHERS

3.1.1 Stocks of researchers

Canada has just less than 0.1% of the population engaged in natural sciences and engineering R&D in 2008, a total of 242,700 out of a population of 30 million (Statistics Canada 2010). The largest fraction, 65% were in the business sector. In 2008, Canada had 5 business researchers per 1000 total employment, just above the OECD average of 4.7. About 26% of researchers are in the higher education and 8% in the government sector, respectively. Universities have a larger share of researchers with PhDs, with fewer Masters and undergraduate level researchers. PhD students and post - Doctoral Fellows are also concentrated at universities. The demand for newly trained researchers varies with the economic climate. As a result of the recent economic downturn, many firms were not hiring and were in fact lying off some researchers. To address the major deficit, governments are now downsizing with a similar effect on employment for researchers. Canada`s relatively low level of GERD is another factor. One result is that unemployment among science-based PhD graduates was higher in Canada than other OECD countries (2006 data).

As stated in the Policy Document **People Advantage**, Canada's recent S&T strategy includes the goal of attracting and retaining highly skilled workers and researchers, and a number of programmes have been put in place to achieve this objective. Canada has a number of programmes to train researchers. These include the Canada Student Grant and Canada Graduate Scholarship Programmes that have recently received additional funding. Canadian trained researchers are in high demand and many are attracted to opportunities in other countries. To counteract this "brain drain", there are programmes in place to attract and retain world class researchers. These include the Canada Research Chairs Programme, which funds almost 2000 university appointments across Canada in areas of strategic importance. The Canada Excellence Research Chairs and the Canada Industrial Research Programmes are also designed to attract world class expatriate and foreign researchers to Canada. Through the Canada Foundation for Innovation (CFI), Canada provides new research equipment and facilities that help retain Canadian researchers and attract high quality foreign researchers. In 2006-2007, over 2100 new researchers were recruited to CFI sponsored projects, almost half (44%) came from outside Canada.

Data from 2007 show that Canada is relatively good at training scientists; less so for engineers. About 13% of Canadian university graduates have science degrees, higher than the OECD average of 10%, however only 9% have engineering degrees, lower than the OCECD average of 12%[9]. To enhance the supply of highly trained personnel, including researchers, Canada has adjusted the immigration system to make it easier for foreign students and trained workers to come to Canada and stay. Specific initiatives include the Temporary Foreign Worker program and the new Canadian

[9] Ibid

Experience Class, which makes it easier for skilled temporary foreign–trained workers and students to stay in Canada as permanent residents.

3.1.2 Providing attractive employment and working conditions

In Canada, employment in the private sector is attractive, as researchers have a relatively high level of income. In some sectors such as IT, they may receive additional income in the form of options. However, security can be an issue, and there have been some cutbacks during the recent economic downturn. There are relatively few PhDs working in the private sector, as work is generally close to market, involving mostly undergraduate and master level researchers.

University tenured professors have attractive positions and working conditions, with good salaries, security, and benefits. They generally combine teaching and research. However they must compete for access to funding for their research. Salaries in colleges are generally lower, however, positions are secure. All permanent university and college employees, including professors and some other research and technical staff have benefit packages that include health and medical insurance, holidays and sick leave. However, graduate and post-graduate students have lower income and less security, as they occupy term positions that are dependent on research grants and projects with two or three year funding. Post -doctoral fellowships provide an interim position, while seeking permanent positions.

Many university professors have a percentage to time available beyond their regular duties for consulting which brings additional income. As discussed in Section 3.1.1, there are several federal programmes to attract and retain high quality researchers at Canadian universities.

Canada has an overall goal of employment equity, with four designated groups (women, visible minorities, people with disabilities and aboriginals). The Canada Research Chairs Programme, which has an objective to promote equity, has 25 % women Chair holders, and is striving to develop gender targets linked to increasing the proportion of women researchers. Public and private sector science-based organizations all have programmes to provide funded maternity leave of up to one year, similar to all others.

Since 2006, the newly elected government has taken additional measures to improve the competitive position of Canada for the retention and attraction of highly skilled people by reducing personal taxes, allowing people to retain a higher percentage of their income.

Since the economic downturn in 2008, there has been less opportunity for employment in the US and the brain drain has been reduced. There have been a number of cases recently of well -known Canadian and international researchers coming to Canada.

3.1.3 Open recruitment and portability of grants

Recruitment policies in Canada favour the hiring of Canadian nationals. In general, to hire a foreign worker, the employer must demonstrate that there is no Canadian with the required mix of skills available. In addition, many degrees and professional qualifications from other jurisdictions, such as engineering are not generally recognised in Canada. Individuals have to take pass qualifications from Canadian professional associations to demonstrate that their training meets Canadian standards. It can be difficult to qualify, as it is often necessary to have Canadian experience, which is difficult to obtain without the qualifications. However, the government is taking steps to reduce the barriers and expedite recognition of foreign credentials. As discussed in Section 3.1.1, there are a number of other incentives to attract foreign researchers and enable them to take up positions in Canada.
Research grants can be made either to the institution or the researcher, depending on the terms of reference of the project. Those research grants from NSERC and other funding agencies made to the researcher are portable.

3.1.4 Enhancing the training, skills and experience of researchers

Canada has a well -developed system for training for post graduate researchers at university. All major universities have postgraduate programmes at the Masters and PhD level for postgraduate training. Many funded research projects also employ Post-doctoral Fellows as members of the research team. The federal government recently expanded the Canada Graduate Student Scholarship programme to support an additional 1000 students. The government has also introduced an Industrial R&D Internship programme to provide science graduate interns with an opportunity to gain business experience.

Canada has a number of programmes to enhance the scientific, technical and business skills of young researchers by allowing for training outside Canada. For example, some of the NSERC programmes permit graduate students taking a PhD to undertake some or all of their research outside Canada. Many research projects involve collaborators from other countries such as the US, or Europe, which also provides international exposure.

Canada has policies to repatriate high quality researchers who have gained experience in other countries. As mentioned previously, there are now programmes that provide funding to encourage high quality researchers who left Canada after graduation to return to Canadian universities to lead research teams involved in priority research topics. There are also several programmes to help graduate students develop business skills. One is the Industrial Research and Development internship programme that funds internships for graduate students and post-doctoral fellows to apply their knowledge to address the needs of participating businesses. Other programmes, such as the Business-Led National Centres of Excellence, provide funding for professors and graduate students to carry out research directly linked to an identified business need in the aerospace, oil production, pharmaceutical or forestry sector.

3.2 RESEARCH INFRASTRUCTURES

Research infrastructures (RIs) are a key instrument in the creation of new knowledge and, by implication, innovation, in bringing together a wide diversity of stakeholders, helping to create a new research environment in which researchers have shared access to scientific facilities.

Canada has no National Roadmap that examines access to research facilities. However, the Canada Foundation for Innovation is the federal agency responsible for providing funding for large, expensive scientific equipment for universities and teaching hospitals.

As a federation, with power for education vested in the provinces, there are only a few situations with shared access to and/or use of scientific facilities among research organisations in Canada. In the case of radio astronomy, the capital costs of building new scientific facilities are beyond most countries, as such, Canada is a partner in radio astronomy observatories in Hawaii, and Chile (under construction). Access to these sites for Canadian researchers in universities and the Herzberg Institute of Astronomy at the National Research Council of Canada is managed co-operatively, to ensure the most productive use of Canada's allotment of viewing time.

Canada is also a member of an international high capacity fibre optic communications network used to send large data sets between researchers in different countries. In Canada, this network is operated by CANARIE, which provides the main high capacity backbone that links researchers across Canada and has connections to other national and international networks. All Canadian universities and many other research laboratories are connected to this network. For example, Canadian nuclear scientists participating in experiments at CERN use this network to send large amounts of data between CERN and their own laboratories in Canada.

3.3 STRENGTHENING RESEARCH INSTITUTIONS

3.3.1 Quality of National Higher Education System

Canada has over 40 universities across the ten provinces. Ontario, the largest province, has 12 universities. Education is the responsibility of the provinces, which provide basic funding to the universities that complements tuition fees. In many provinces, universities are significantly underfunded. Universities are governed by provincial legislation, which is similar across the 10 provinces. In order to grant degrees in a particular area, universities must meet standards for academic course content. Each university is governed by a Board of Governors made up of representatives from the community, industry and public sectors.

The primary mission of universities is to deliver high level academic programmes that produce educated graduates in a variety of fields, from the humanities and social sciences to the natural sciences, engineering. University courses and degrees include both general topics of broad interest and specific topics aligned with regional and local interest. For example, universities in Alberta provide science and engineering courses linked to the province's oil and gas production and refining industries. All

Canadian publically funded universities have undergraduate and graduate programmes and over half have professional programmes in business, law and /or medicine. There are only a few small private universities that have undergraduate programmes.

Canadian spending on Higher Education R&D (HERD) has grown over the past 20 years, doubling since 1980. In 2010, the Higher Education sector carried out 38% of R&D performed in Canada. Canada ranked first among the G7 in 2009 in spending on higher education at 0.7% of GDP. Business funds only 8.4% of HERD. As a result of the high level of spending, Canada has a high percentage of the population with tertiary level education, 45% in 2006. However, the focus of education is not primarily on science and engineering, as Canada ranks only fifth among G7 countries in terms of science and engineering degrees as a percentage of all new degrees. Canada has a low level of PhD graduates compared to other countries and is well below the OECD average.

Canada is generally considered to have a good higher education system and some of Canada's universities are among the best. In terms of overall ranking (quality of education, quality of faculty, research output and size), Canada had four universities among the top 100 in the world in the 2008 rankings. Canada did even better in specific categories, with 7 or 8 universities among the top 100 in the fields of natural sciences, technology and life sciences and medicine.

3.3.2 Academic autonomy

Under Canada's federal system, the provinces are responsible for education, including the basic funding for universities. Each province has a Department of Education, and controls the number of universities within its boundaries and influences the educational priorities. Universities must meet accreditation standards in terms of faculty and curriculum.

Each university follows a general governance model, which includes a Board of Directors made up of business, community and academic representatives that provide strategic direction and oversight to the President, who is responsible for delivering the overall programme. Each faculty (Engineering, Science, Business, etc.) has a Dean who is responsible for oversight of that group, assisted by Department Heads.

While the province provides funding to support the salaries of permanent staff, each professor has general autonomy in deciding what topics to pursue, as they have to find their own funding sources to support their research interests. Most research funding is provided by the federal government through the Natural Sciences and Engineering Research Council and the Social Sciences and Humanities Research Council. Other sources include business, provincial governments and federal departments which fund research of specific relevance to their needs.
Professors have a high degree of autonomy, as they can be dismissed only for major issues of misconduct.

3.3.3 Academic funding

Core funding for universities is provided by the provinces, which are responsible for education under the Constitution. This core funding, together with tuition fees, makes up the majority of general operational funding to support teaching. Each province provides funding for both general programmes and specific programmes related to provincial priorities. For example, Saskatchewan provides funding for agricultural studies linked to provincial crops such as canola and legumes. Most research funding is provided by the federal government on a competitive basis.

The federal government has three funding agencies, Natural Sciences and Engineering Research Council (NSERC), Social Sciences and Humanities Research Canada (SSHRC) and the Canada Institute for Health Research (CIHR) that provide funding to carry out research in the natural sciences and engineering, social sciences and humanities and medicine respectively. These agencies have specific programmes aligned with a number of government priorities as well as general support for developing and maintaining expertise. These funds are distributed on a competitive basis usually involving peer review. The Canada Foundation for Innovation provides funding to purchase up to date the major capital equipment and infrastructure needed to carry out world class research.

3.4 KNOWLEDGE TRANSFER

3.4.1 Intellectual Property Policies

In almost all universities in Canada, the university controls the intellectual property (IP) arising from university research. All universities with active S&T research programmes have an Industrial Liaison Office or Technology Transfer Office to manage IP issues, including patent applications, and negotiation of licencing agreements. Because this function is controlled by each individual university, there are a variety of practices and policies

As research institutions, universities are a major source of intellectual property, a 2010 AUTM survey of licensing activity report covering 40 Canadian research institutions identified the following for the year:

- 986 new US patent applications, up 6% from 2009;
- 143 new U.S. patents issues, up by 19%;
- 449 licenses granted, down 28%; and
- €43.5m (CAD$58.7m) in licensing revenue in 2010.

3.4.2 Other policy measures aiming to promote public-private knowledge transfer

Spin-offs

As discussed in Section 3.4.1, universities have Technology Transfer Offices that promote the licensing of university research results. In a number of cases, university researchers have created companies based on the technology developed within the university.

The 2010 AUTM survey also reported that 50 new start-ups were formed in 2010 by participating universities, and that there were 632 start-ups still operating in 2010. In recent years, the most successful has been the University of Waterloo in Ontario, which has a number of successful start-up firms based on technology developed by university professors. The National Research Council of Canada actively promotes spin-offs of commercially relevant technology. There have been a number of spin-offs, with varying degrees of success. In a few cases, the spin-off has grown to a successful SME.

Inter-sectorial mobility

There is no specific policy related to inter-sectorial mobility. Many scientists in SBDAs have an adjunct professorship at a university. In recent years, there have been a number of cases where senior industry researchers have joined university faculty either as full time staff or as adjunct professor. Most universities allow faculty to spend up to 30% of their time outside the university. Many scientific and engineering staff also have consulting practices with business. In some cases, members of staff are partners in scientific or technology start-up businesses associated with their field of research.

Promoting research institutions – SME interactions

Canada has a number of programmes that promote interactions between SMEs and research institutions. The Industrial Research Assistance Programme (IRAP) of the National Research Council of Canada is a well - known long standing programme that provides technical and financial assistance to SMEs to solve technical problems. IRAP is delivered by experienced Industrial Technology Advisors who provide diagnostic services to identify how best to help the company and then help find the best source of assistance. In many cases, this is a researcher at a university of government laboratory with specialised knowledge and equipment that can be applied.

Another programme that links university researchers with firms in the private sector is the Business-Led National Centres of Excellence (BL-NCE). For example in GARDN, one of the BL-NCE initiatives, large and small firms in the aerospace sector work in joint partnership with university researchers in projects related to reducing the environmental foot print of next generation aircraft.

Involvement of private sectors in the governance bodies of HEIs and PROs

The Board of Directors of all Canadian universities includes a mix of senior representatives from business, academia and the community. The Board of Directors provides strategic oversight and advice, but is not directly involved in transferring specific knowledge.

Regional Development Policy

Canada has several federal government regional development agencies (RDAs), each responsible for economic development in a geographical area that is considered to require special attention. These include the Atlantic Canada Opportunities Agency (ACOA), Community Economic Development Quebec (CEDQ), federal government economic development agency for Northern Ontario (Fed Nor) and Western Economic Diversification (WED). These agencies have a number of programmes including support for innovation and R&D, which are an integral part of the broad suite of initiatives that implement research policy. For example, the Atlantic Innovation Fund managed by ACOA supports R&D projects among public / private partnerships that that lead to the development of new products, processes and services that can become commercially successful. Other RDAs have similar programmes that support applied R&D and innovation, leading to economic growth and job creation.

3.5 ASSESSMENT

Canada's spending on Higher Education R&D in 2010 was 0.68% of GDP; the highest among the G7. Canada is generally considered to have a good higher education system and some of Canada's universities are among the best, and Canada has four universities among the top 100 in the 2008 world ranking. However, Canada has relatively few science and engineering graduates compared to other G7 countries. About two thirds of Canada's science and engineering workers are in the private sector and the number of researchers in the business sector in Canada is just above the average for the OECD at 5 per 1000 of total employment.

Canada's economic and S&T policies both recognise the need for a well trained workforce as an essential contributor to Canada's competitive position in the world. This is articulated in People Advantage. Canada has long had a "brain drain" problem with researchers and other S&T workers educated in Canada being attracted to the US and other countries. To counteract this trend, Canada's S&T strategy, includes the goal of adding to the stock of highly skilled workers being educated and trained in Canada by attracting and retaining additional workers and researchers. The recent downturn in economic activity in the US has also reduced the brain drain as there have been fewer opportunities. Several recent programmes have been successful by providing funding to attract world class expatriate and other researchers to come to Canadian universities to carry out their research programs.

4 INTERNATIONAL R&D&I COOPERATION

4.1 MAIN FEATURES OF INTERNATIONAL COOPERATION POLICY

While Canada has no formal written overall policy for international cooperation in conducting R&D&I, there are a number of agreements to carry out research in partnership with other countries in areas of mutual interest For example, Canada works cooperatively with Russia and the Nordic countries on polar research and with China on agricultural and electrical power generation issues. The general approach is to work with other countries in areas of mutual interest Canada collaborates multilaterally with many other counties on transportation and energy related issues through the International Energy Agency. Other research priorities include frontier science, health, the environment and the north as well as support for less developed countries. In addition to addressing national priorities, individual departments and agencies each carry out cooperative research with external partners according to their mandate.

Specific objectives for cooperation with other organisations include:

- Development of research partnerships;
- Leveraging of investment;
- Access to needed expertise; and
- Development of research knowledge and capacity in areas of mutual interest.

In many cases, co-operation is based on long standing relationships between countries and research groups.

Because of proximity, strong economic linkages and common geographical factors, Canada's major partner in scientific cooperation is the U.S. In 2009, almost half (47%) of internationally co-authored publications involved an American co-author. Because of common interests and Canada-US linkages of policies and regulations in the areas of transportation, energy, air quality and the environment, Canadian and U.S. researchers have strong ties in these areas. Canada has also had strong linkages with the European Union for a number of years through the various Framework Programmes, and has had a formal agreement for scientific and technological cooperation since 1996. Canada also has strong research relationships with the United Kingdom, France and China, which have the next highest percentage of co-authorships, with 14%, 11% and 10% respectively.

Because the high cost of constructing and operating major astronomical facilities, Canada has a policy of sharing the cost with other countries where possible. Canada is a partner in two international telescopes, one in Hawaii and one in Chile.

4.2 NATIONAL PARTICIPATION IN INTERGOVERNMENTAL ORGANISATIONS AND SCHEMES

Canada is a member of many international and intergovernmental organisations and initiatives. These include a number of international regulatory agencies such as the International Standards Organization (ISO), and the World Organization for Animal Health (OIE) which regulates various aspects of international trade in animals. All these organisations have scientific subcommittees in which Canadian scientists participate to share knowledge and develop improved research and measurement strategies. Canada also participates in a number of international agencies that share knowledge of international importance, such as the International Energy Agency. For example, Natural Resources Canada leads a major project supported by the International Energy Agency Greenhouse Gas R&D Programme (IEA GHG), an international collaboration investigating technologies to reduce GHG emissions. Canada, the US. Department of Energy, other countries, and a number of research organisations and private sector firms are participating in a field trial injecting CO_2 into the Weyburne-Midale producing oil field in Western Canada to examine long term storage of CO_2 while enhancing oil recovery.

In addition to the Framework Programmes, Canada participates in a number of European Union initiatives. These include the European Strategy Forum for Research Infrastructure. Canada also is involved in a number of projects of the European Space Agency and other European organisations, such as CERN, the European Nuclear Research Agency. Canada participates in other European programming, including several ERA-NET programmes that support networking and coordination of research activities among the European Union Member States and other countries.

These include:

- ERA-AGE2, on aging that involves 16 countries;
- ERA-Neuron, related to neuroscience research that involves 13 countries; and
- ERA-SAGE, which has been completed, related to genomics research that involved 9 countries.

Another example of cooperation is the International Nuclear Energy Initiative, under which, Canada and the U.S. Department of Energy (DOE) are collaborating on the development of a next generation power generation system for use with either nuclear or fossil fuelled electrical generation. Canadian high energy physics scientists also participate in a number of experiments being carried out at CERN.

4.3 COOPERATION WITH THE EU

4.3.1 Participation in EU Framework Programmes

Canada has been a participant in many European Union initiatives, including the various Framework Programmes. Canada's participation has grown steadily, from 70 projects in FP4 to 108 projects involving 119 organisations in FP6. This trend has continued, and Canada is a major participant in the current FP 7 programme.

Table 2: Canada Participations in FP7

		All submitted		Mainlisted			
Proposal SP Description2	Proposal Program	Number of Proposals	Number of Applicants	Number of Proposals	Number of Applicants	Proposal Total Cost	Success Rate: applicants in mainlisted proposal / applicants in all submitted proposals
CIP	CIP-ICT-PSP	1	1				
Not_Available	N/A	3	3				
Research Fund for Coal and Steel	RFCS	2	2				
SP1-Cooperation	ENERGY	22	24	7	8	31.117.545	33,33%
SP1-Cooperation	ENV	32	38	11	15	59.801.758	39,47%
SP1-Cooperation	HEALTH	56	66	21	28	118.416.599	42,42%
SP1-Cooperation	ICT	128	149	21	21	232.739.578	14,09%
SP1-Cooperation	KBBE	78	90	22	29	149.216.378	32,22%
SP1-Cooperation	NMP	28	32	9	12	67.516.272	37,50%
SP1-Cooperation	SEC	8	8	3	3	14.851.250	37,50%
SP1-Cooperation	SP1-JTI	4	4	2	2	74.267.579	50,00%
SP1-Cooperation	SPA	37	39	5	5	89.470.718	12,82%
SP1-Cooperation	SSH	36	38	5	5	8.135.621	13,16%
SP1-Cooperation	TPT	42	53	19	28	136.428.996	52,83%
SP2-Ideas	ERC	49	56	1	1	1.300.000	1,79%
SP3-People	PEOPLE	509	520	113	118		22,69%
SP4-Capacities	COH	1	1				
SP4-Capacities	INCO	7	14	3	8	3.027.284	57,14%
SP4-Capacities	INFRA	12	14	6	8	37.881.532	57,14%
SP4-Capacities	SiS	13	13	4	4	9.727.829	30,77%
SP4-Capacities	SME	4	4				
SP5-Euratom	Fission	4	4	3	3	41.598.245	75,00%
	Sum:	**1.076**	**1.173**	**255**	**298**	**1.075.497.184**	**25,40%**

The above table describes Canadian participation in FP7 in terms of the Proposal Description and Programme, and the number of proposals submitted and accepted.[10]

[10] Up to and including 2012

As can be seen, Canada has submitted a total of 1,076 proposals. Submissions were generally of high quality, with success ratios up to 50% in several categories, and an overall success ratio of 25%.A total of 255 proposals have been accepted, with a budget of €1,075 m (CAD $1,451m). Canadian participation in FP7 is mainly in terms of training and career development of young researchers and small and medium scale focused research projects. Canadian groups participating include universities, federal and provincial government departments and agencies, hospital research groups and private sector firms.

Table 3 Canada's FP7 projects in terms of type of contract.

Proposal Sub Funding Description	Number of Proposals submitted	Number of Proposals mainlested
Collaborative project for specific cooperation actions dedicated to international cooperation partner countries (SICA)	15	6
Collaborative project (generic)	38	11
Collaborative Project targeted to a special group (such as SMEs)	20	4
Combined Collaborative Project and Coordination and Support Action	3	1
Coordinating action	41	19
ERC Starting Grant	33	1
Industry-Academia Partnerships and Pathways (IAPP)	7	2
Initial Training Networks (ITN)	17	1
Integrating Activities / e-Infrastructures	8	4
International Incoming Fellowships (IIF)	9	2
International Outgoing Fellowships (IOF)	402	61
International Research Staff Exchange Scheme (IRSES)	73	47
Joint Technology Initiatives - Collaborative Project (FCH)	3	2
Large-scale integrating project	91	26
Network of Excellence	6	3
Research for Civil Society Organisations (CSOs)	1	1
Small or medium-scale focused research project	170	46
Small or medium-scale focused research project INFSO (STREP)	81	7
Supporting action	30	11
Other	28	
Sum:	**1.076**	**255**

As can be seen, the largest number of projects submitted and mainlisted are International Outgoing Partnerships. The most successful types of projects are International Research Staff Exchange Scheme (RSES) and Collaborative Project for specific cooperation actions dedicated to international cooperation partner countries (SICA), and at52% and 40% respectively.

ERA-Can is a joint initiative of the European Union and the Government of Canada, which facilitates and encourages Canadian researchers and research organizations to collaborate with European researchers under the FP7 programme. ERA-Can holds information sessions to inform Canadian researchers of the opportunities within the FP7 programme and how to apply for participation. However, ERA-Can does not provide programme funding.

Through FP7, Canada participates in mobility and training initiatives through the Marie Curie Actions International Outgoing Fellowships and International Incoming Fellowships which provide opportunities for European researchers to carry out research at a Canadian organization, and for Canadian researchers to carry out research at a European research organization respectively. Canadian researchers participate in a range of FP7 funded research programs, including Emerging Science and Technology (seismic oceanography), MOBI-KIDS (cell phone safety), and Winner (wireless connectivity),among others.

4.3.2 Bi- and multilateral agreements with EU countries

While there are no specific budgets, Canada has broad bilateral science and technology agreements with France, Germany and the European Union as a whole. In the case of the EU, there is a formal Agreement for Scientific and Technical Cooperation between Canada and the European Community, first signed in 1996. The Agreement covers:

- agriculture and fisheries;
- medical and health research;
- non-nuclear energy;
- environment, including earth observation;
- forestry;
- information technologies;
- communications technologies;
- telematics for economic and social development; and'
- Mineral processing.

Under this Agreement, cooperation in identifying and undertaking S&T activities has grown, particularly in the areas of energy, environment, food, agriculture and fisheries and biotechnology. In some cases, Canadian and European groups carry out parallel research programmes that benefit from formal and informal relationships. For example, the Environment Canada Strategic Plan focuses on climate change topics such as polar research and marine ecosystems which are also included under FP7. In another example, the European Commission's Directorate-General for Research and Innovation, Directorate for Biotechnology, Agriculture and Food, and Agriculture and Agri-food Canada have “twinned” complementary projects in the field of agricultural bio products.

The agreement includes a Joint Science and Technology Cooperation Committee which reviews progress and provides future direction. A Road Map was developed in 2009 to identify the areas of cooperation and identify future opportunities.

Canada is a member of the European Space Agency, the only non-European country involved. Since 1979, Canada has participated in ESA programmes in satellite telecommunications, Earth Observation, space exploration and generic technology. Over the last 10 years, Canadian companies have been awarded over € 140m (CAD $200m) in contracts to develop space related technologies.

Canada has had formal science and technology agreements for many years with a number of European Union countries, including France, Germany and the United Kingdom. These agreements provide a broad umbrella for the development of more specific initiatives in areas of mutual interest.

Many government programmes encourage the participation of non-national firms and research organisations in Canadian initiatives; however, there is no specific funding for their participation. In many cases, joint projects are carried out with each partner funding their share of the work. A fraction of NSERC funding for graduate and postgraduate students and other university researchers is available for research carried out in other countries. However, there is no national programme to fund other researchers to carry out work in other countries.

4.4 COOPERATION WITH NON-EU COUNTRIES OR REGIONS

4.4.1 Main Countries

Because of the geographic proximity and close economic ties, Canada has many common scientific interests with the U.S. While energy, transportation and the environment are the primary areas of co-operation, Canada also has similar interests in areas related to health and other topics. For example, Canadian researchers co-operate with researchers in the US Department of Energy (energy), the Environmental Protection Agency (environment) and the National Institutes of Health (health). Canada also collaborates with a number of other countries on a wide range of R&D topics, including China (energy production and agriculture), India (agriculture), Brazil (renewable energy, biofuels) and Israel (sustainable energy).

In some cases, Canadian researchers receive funding from other countries or participate in projects led by researchers in other countries. For example, several Canadian research groups receive funding from the US National Institutes of Health. In 2008, Canada received €2,040m (CAD$2,754m in R&D funding from foreign sources, primarily the US.

Canada participates in a number of multinational science initiatives. Some involve joint funding and operation of high cost scientific infrastructure, such as the new radio astronomical facilities (Atacama Large MM Wave Array) in Chile, jointly funded by Canada, the US, Europe, China and East Asia.

Canada also has broad Science, Technology and Innovation Agreements with a number on non-European countries, including Brazil, Chile, China, India, Israel, Japan, Russia, and Sweden which provide a framework for the development of more specific initiatives of mutual interest. For example, Canada has joint projects with China in coal fired electricity production and with China and India in genomics related agriculture.

Many government programmes encourage the participation of non-national firms and research organisations in Canadian initiatives; however, there is no specific funding for their participation. A fraction of NSERC funding for graduate and postgraduate students and other university researchers is available for research carried out in other countries. However, there is no national programme to fund other researchers to carry out work in other countries.

4.4.2 Main instruments

The main instruments for scientific cooperation are specific agreements, MOUs and programmes, such as the International Science and Technology Partnerships Programme. ISTPP was renewed in 2010 with a $20 CAD m budget over five years to promote bilateral research and development projects with Israel, India, China and Brazil with the potential for commercialisation. Other instruments are programmes funded by science based departments and agencies, and postgraduate training of students from Canada funded through NSERC. There are also similar programmes from other countries funding postgraduate training of foreign students in Canada.

Canadian researchers also interact with their international colleagues through participation on international scientific and regulatory committees such as the International Energy Agency and the International Standards Organization (ISO). Through these committees Canadian researchers contribute to and learn from international fore.

4.5 OPENING UP OF NATIONAL R&D PROGRAMMES

In general, other countries can participate in Canadian federal R&D initiatives as team members, however their contributions cannot be subsidised by Canadian government funding. One project led by Canada is sponsored by the International Energy Agency with international partners is the field trial examining long term storage of CO_2 in the Weyburne-Midale oil field , which involves U.S. and Japanese participation.

4.6 RESEARCHER MOBILITY

4.6.1 Mobility schemes for researchers from abroad

Canada has several programmes to encourage world class researchers from other countries to come to Canada to carry out their research programmes. The Canada Research Chairs (CRC) programme, with funding of €230m (CAD$300m)/ year, established 2000 Chair positions at Canadian universities in engineering and the natural sciences, humanities and social sciences. CRC's objective is to attract and retain skilled researchers. At present, CRC positions are help by 256 expatriates who have returned to Canada, and 290 international researchers who have come to Canada to carry out their research. In 2010, Canada established the Canada Excellence Research Chairs, which provides 20 positions with funding of up to €7.7m (CAD $10m) over seven years to attract leading Canadian and international scientists to Canadian universities to carry out long term research programmes in areas of national importance (environmental sciences and technologies, natural resources and energy, health and related life sciences, and information and communications technologies).

Canada also encourages graduate students from other countries to come to Canada to continue their scientific careers and stay in Canada.

4.6.2 Mobility schemes for national researchers

There is no specific policy related to mobility for researchers. However, many of the programmes discussed in Section 4.6.1 allows researchers to move from one university to another where there is funding for their research interests. Also, many scientists in government laboratories have an adjunct professorship at university. In recent years, there have been a number of cases where senior industry researchers have joined university faculty either as full time staff or as adjunct professor.

Most universities allow faculty to spend up to 30% of their time outside the university. Many scientific and engineering staff also has consulting practices with business. In some cases, members of staff are partners in scientific or technology start-up businesses associated with their field of research.

5 CONCLUSIONS

The effectiveness of Canada's R&D policies needs to be understood in the context of the Canadian political system and economic drivers. Canada is unusual among advanced economies in terms of the importance of exports, particularly of resources such as oil and gas, forestry products and minerals. Sales of these products are driven by world demand, especially from the U.S., by far Canada's largest trading partner. Exports are affected by demand in importing countries and by alternative sources. Quality and price are important factors. Traditionally, these exporting sectors carry out little R&D, measured as a percentage of revenues.

Canada is among the leading countries in terms of spending per capita on higher education and has a high percentage of population with post - secondary education. However, Canada has had relatively poor success in translating knowledge into economic, environmental and social applications.

Canada participates in multinational and international initiatives based on their contribution to the achievement of Canadian national objectives. There are a number of agreements with other countries to conduct research related to the Arctic, energy, the environment and frontier science. Canada participates in order to develop research partnerships, leverage investments, obtain access to expertise and develop scientific knowledge and expertise. The US is the main partner as a result of proximity and strong economic ties. Canada has strong research collaborations with the US in transportation, energy and health. Canada also has a long standing agreement for science and technology cooperation with the European Union and has strong research ties with the European Union through the FP programmes.

Table 4: Linkage of Science and Policy Objectives to National Social and Economic Objectives

Science and Technology Policy Objectives	Contribution to Economic and Social Objectives
Entrepreneurial Advantage	Translation of scientific and technical knowledge into commercial applications that generate wealth and support improved quality of life
Knowledge Advantage	Through research, generate knowledge in areas of national social and economic importance (environmental science and technologies, natural resources and energy, health and related life sciences, and information and communication technologies
People Advantage	Educate, attract and retain highly skilled workers to support innovation and growth

The policy document Advantage Canada, produced in 2007, provided a clear linkage between research policy and the higher level economic and social objectives of the government. This linkage was articulated in the policy document Mobilizing Science and Technology in Canada's Advantage, which provided a clear description of the contribution of the three elements of the knowledge triangle policies to the achievement of Canada's long term objectives. Table 4 provides a description of the specific contribution of the three elements to the achievement of Canada's long-term success.

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7 LIST OF ABBREVIATIONS

ACOA	Atlantic Canada Opportunities Agency
BERD	Business Expenditures for Research and Development
BL-NCE	Business Led National Centres of Excellence
CAD	Canadian Dollars
CERN	European Organisation for Nuclear Research
CIHR	Canada Institutes for Health Research
CFI	Canadian Foundation for Innovation
CRC	Canada Research Chairs
DOE	Department of Energy
ERA	European Research Area
COST	European Cooperation in Science and Technology
ERA-NET	European Research Area Network
ERP Fund	European Recovery Programme Fund
FP	European Framework Programme for Research and Technology Development
EU-27	European Union including 27 Member States
FDI	Foreign Direct Investments
FP7	7th Framework Programme
GBAORD	Government Budget Appropriations or Outlays on R&D
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
GHG	Green House Gases
GOVERD	Government Intramural Expenditure on R&D
GUF	General University Funds
HEI	Higher education institutions
HERD	Higher Education Expenditure on R&D
HES	Higher education sector
HQP	Highly Qualified Personnel
ICT	Information and Communications Technologies
IEA	International Energy Agency
IRAP	Industrial Research Assistance Programme
IP	Intellectual Property
ISO	International Standards Association
IT	Information Technology
NSERC	Natural Sciences and Engineering Research Council
PRO	Public Research Organisations
OECD	Organisation for Economic Co-operation and Development
OIE	World Organization for Animal Health
R&D	Research and development
RI	Research Infrastructures
RTDI	Research Technological Development and Innovation
SBDAs	Science-based Departments and Agencies
SF	Structural Funds
SDTC	Sustainable Development Technologies Canada
SME	Small and Medium Sized Establishments
SSHRC	Social Sciences and Humanities Research Council
S&T	Science and technology

VC	Venture Capital
WED	Western Economic Development
WTO	World Trade Organisation