Analysis of Energy R&D Programs

Trends in Private Sector Energy R&D

Between 1983 and 1995, private sector energy R&D investments in Canada have remained relatively constant in real terms at an aggregate level. Despite the overall stability of private sector energy R&D, there have been significant shifts in the composition of the R&D portfolio over the past two decades.

Trends at the programmatic level reflect many of the same dynamics observed in the public and private sector energy R&D programs of other OECD countries. For example, the declining intensity of oil and gas exploration research in Canada is largely a response to the low resource prices that have persisted for several years. Similarly, electric utilities' shrinking overall R&D investments and the focus of their remaining expenditures on transmission and distribution R&D is in keeping with the behavior of electric utilities around the world that are facing an increasingly competitive and deregulated environment.[i] More detailed descriptions of trends in Canada's privately sponsored energy R&D efforts are provided below.

Private sector investments in fossil fuel R&D programs fluctuated from a high of approximately $267 million (53% of total private sector investments) in 1983 to approximately $107 million (29% of the total) in 1995. Over the period, private investments in fossil energy R&D declined by approximately 60%.

The oil, gas, and coal industries provided nearly all of the private sector investment in fossil R&D, while the electric utility industry contributed only about 1% to the total.[ii] Most oil companies have slashed their budgets for basic research, and for R&D related to refining and enhanced oil recovery. Many of the resources once devoted to R&D in these areas have been redirected to technical support. Exploration R&D has fallen from 37% ($98 million) of total fossil R&D expenditures in 1983 to 23% ($24 million) in 1995, due in large part to low world energy prices. At the same time, industry-sponsored research on oil sands (in-situ recovery and surface mining) grew significantly as a percentage of the total private sector fossil R&D investment, having risen from 30% in 1983 to 49% in 1995. However, oil sands R&D declined in real terms from about $80 million in 1983 to $52 million in 1995, reflecting the overall decrease in fossil fuel R&D spending in recent years.

Coal research has not accounted for a major share of privately funded energy R&D in Canada at any time in recent decades. Coal research peaked at approximately $9 million in 1986 and declined to a level of $1 million in 1995.

Electric utility R&D spending has increased at an average annual rate of 2% since 1983, the majority of which has been invested in the transportation[1], transmission, and

[1] "Transportation" in this context refers to the transportation of energy commodities rather than to the transportation sector per se.

distribution areas. In 1995, transportation and transmission accounted for some 29% ($119 million) of total utility investment. Continued deregulation of the electric utility industry is expected to disrupt utility companies' R&D investments, shifting them away from generation-related research and toward shorter term projects focusing on downstream components of the industry. Increasingly, utility-sponsored R&D will focus on improvements in electricity transmission and on the development of capital equipment that will help to reduce costs and improve the quality of service.[iii]

Nuclear R&D investment has fluctuated little over the 1983-1995 period, although, since 1991, the trend has been one of modest decline in real terms.[iv] Increasingly modest private investments in nuclear fission reflect growing uncertainties concerning the future viability of nuclear energy in deregulated electricity markets. Moreover, an increasing share of nuclear energy R&D resources is being directed toward waste management, nuclear safety, and reactor lifetime extension, rather than to the design of new reactors.

Private investments in energy efficiency R&D increased in real terms from $87 million in 1983 (17%) to $90 million in 1995 (24%), while renewable energy R&D investments remained flat in real terms, at $22 million, over the period. With the deregulation of the electric utility industry, which is proceeding on a province-by-province basis, R&D in the renewable energy area is expected to decrease since these technologies are regarded as unlikely to achieve wide market penetration in the near term.[v]

Canada's private sector is a world leader in fuel cell and hydrogen energy technology. Several Canadian companies, such as Ballard Power Systems, ASA Automated Systems, Stuart Energy Systems, Nexcel, Statpower, and Global Thermoelectric, are currently supporting research, development, and commercialization of fuel cell technologies. Ballard Power System's position as an industry leader has been bolstered through Daimler Chrysler's and Ford Motor Company's investments of nearly $1 billion for the development of proton exchange membrane fuel cells for the transportation sector.[vi]

Canada's federal and provincial governments are also helping to maintain and augment the private sector's leading role in this key emerging technology area through a variety of direct-funding and public-private partnership arrangements. The federal government has invested almost $100 million in fuel cell system development through the National Research Council's National Fuel Cell Research and Innovation Initiative and the Natural Sciences and Engineering Research Council's Research Partnership Program. The government of British Columbia has provided a total of some $21 million in support to Ballard, ASA Automated Systems, Statpower, and Nexcel, while the government of Quebec has jointly funded hydrogen projects involving the federal government and private industry.[vii]

Through its Technology Partnership Canada (TPC) investment fund, Industry Canada has also invested in projects directly or indirectly supporting the commercial viability of fuel cell technology.[viii] For example, in 1999 the government provided approximately $4 million to Stuart Energy Systems Inc. for a $13 million project to develop an improved hydrogen refueling system for fuel cell buses such as those designed by Ballard Power

Systems. Similarly, the government recently invested $3.8 million in Questor Industries to develop a unique gas separation technology that strips nitrogen and other gases from an air stream leaving pure oxygen. Advancements in separation technologies such as this would potentially improve the performance of fuel cells, bringing them closer to market viability.[ix]

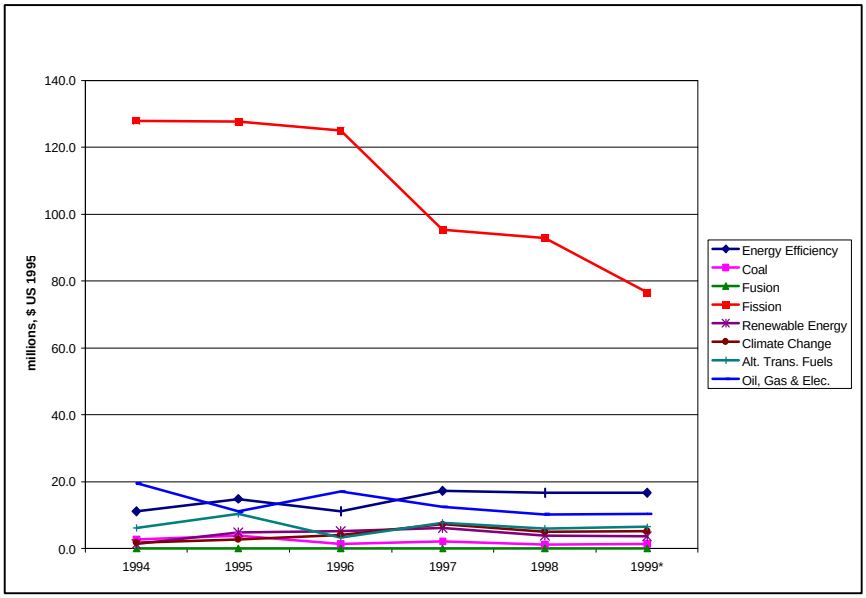
Government Energy R&D Performers and Programs

Canada's combined federal and provincial energy R&D expenditures peaked in 1984 at approximately $686 million. Since then, the funding profile of energy R&D has changed considerably. For example, while in 1983 the federal government accounted for 46% of energy R&D funding; by 1994 it accounted for 33%. Federal investments have also been directed increasingly to shorter term projects. Federal and provincial investments fell to a level of $198 million in 1995—a real decline of 71% from the 1984 level.[x]

At the same time, provincial funding for energy R&D has also declined (from 11% of total energy R&D funding in 1984 to 4.9% in 1995).[xi] The provinces spent $32 million on energy R&D in 1995. It is important to note that almost 70% of provincial energy R&D was performed by the province of Alberta, primarily in the fossil fuel area.[xii]

Support for Canada's federally sponsored Program of Energy Research and Development (PERD), described in detail below, has declined by 75% since 1984 to its 1998 level of $46 million. Research funded by Atomic Energy of Canada Limited, a government-owned corporation that performs the majority of Canada's fission R&D, has remained essentially flat, falling by 3% in real terms since 1989 to $111 million. Even though federal energy R&D funding fell by 18% between 1995 and 1999 alone, in fiscal 1999 energy R&D still accounted for about 7% of the total federal R&D budget—slightly more than defense R&D. Non-PERD federal energy R&D has declined from $171 million to $120 million between 1994 and 1999—a 30% reduction, as Figure 4 shows.[xiii]

Figure 4. Non-PERD Federal Energy R&D Expenditures, 1994-1999



The Office of Energy Research and Development (OERD) of NRCan[xiv] is the coordinator of energy research and development activities (with the exception of nuclear R&D) for the federal government. OERD is responsible for overall strategy development of the PERD, its planning, budgetary and review process, the assessment of its impacts and effectiveness, its communication and liaison activities, and the overall management of PERD, which constitutes Canada's largest, integrated public energy R&D program.[xv] In addition, OERD coordinates Canada's participation in international energy R&D activities and organizations (such as the International Energy Agency) and serves as one of the government's main internal science advisory bodies.

In addition to its coordinative role in the interagency PERD program, NRCan is home to a network of research institutions that constitute the Canadian Centre for Mineral and Energy Technology (CANMET). CANMET is the main applied research and technology development arm of Natural Resources Canada. CANMET employs more than 550 scientists, engineers and technicians, and has research facilities in Quebec, Ontario, and Alberta. Through exploratory research, commercial and cost-shared R&D, product testing and technology transfer, CANMET assists Canada's minerals, metals and energy industries. Under its mandate, CANMET works in partnership with these industries to enhance their competitiveness, to improve and develop energy efficiency and alternative energy technologies, to improve health, safety and environmental control in client industries, and to support government policy initiatives. CANMET operates three major federal energy research institutions, described briefly below.[xvi]

The CANMET Energy Technology Centre (CETC), located in Nepean, Ontario, seeks to accelerate the development and use of clean, energy efficient conventional, alternative and renewable energy technologies, domestically and in the global marketplace. The Centre works on a fee-for-service or cost-sharing basis with a wide range of clients, including small and medium-sized enterprises, and large industrial concerns from several countries. CETC's major program areas include advanced combustion technologies, buildings energy technologies, community energy systems, renewable energy, and transportation energy technologies.[xvii]

The CANMET Western Research Centre (CWRC) in Devon, Alberta, is the federal government's primary research group for the development of hydrocarbon supply technologies and related environmental technologies, with an emphasis on oil sands and heavy oil. Canada's oil sands and heavy oil deposits represent one-third of the world's useful petroleum resources. Like other CANMET research centers, CWRC conducts fee-for-service, cost-shared, and task-shared S&T activities and performs exploratory, public-good research in strategic areas such as environmental technologies. CWRC focuses on the development of hydrocarbon technologies that are less energy-intensive and that have smaller environmental impacts.[xviii]

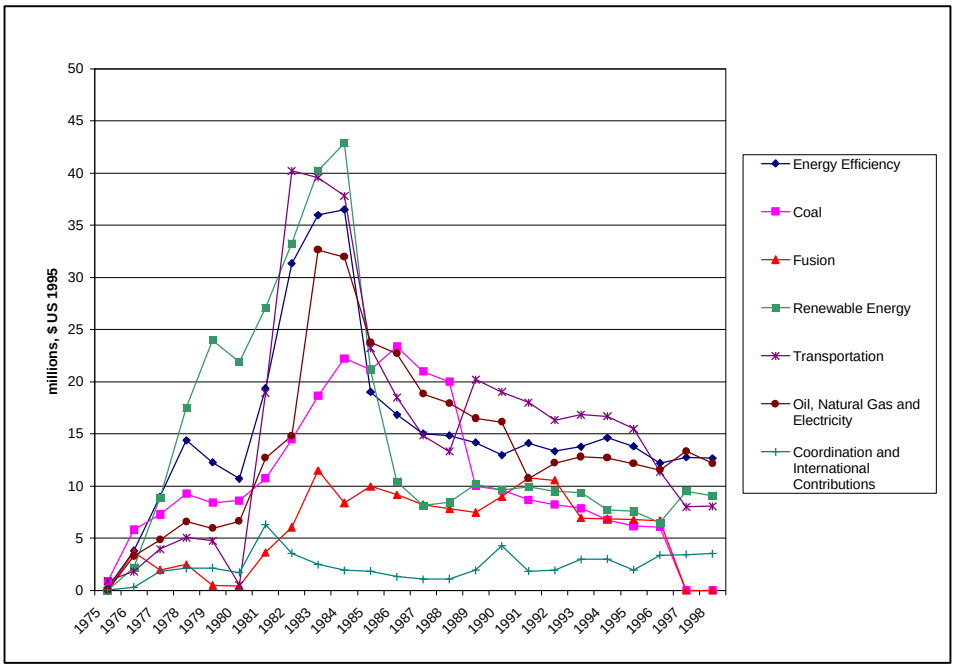
A third CANMET research institution is the Energy Diversification Research Laboratory (CEDRL) in Varennes, Quebec. CEDRL is a network of energy and mining laboratories managed by NRCan that provides clients with technologies designed to improve industrial competitiveness by reducing energy intensity. CEDRL focuses principally on the development and promotion of innovative technologies in the fields of energy efficiency and renewable energy. Working closely with industry and other partners, the Center carries out applied R&D in the areas of heat management as well as renewable energy and hybrid systems.[xix]

The Program of Energy Research and Development (PERD)

Much of the federal government's sponsorship of energy R&D activities falls under the PERD, a federal effort focusing entirely on energy research and development in non-nuclear areas. Major PERD research areas include energy efficiency, renewable energy, energy and climate change, transportation, and hydrocarbons. PERD is an interdepartmental program that addresses energy production, distribution, and use in all economic sectors. Eleven federal departments and agencies are involved in the program. In 1994, the government conducted a comprehensive review of PERD's role and strategic direction, resulting in a stronger emphasis on energy efficiency, renewable energy, and energy issues related to climate change. This shift has reduced the program's emphasis on supply aspects of conventional fossil fuels, while increasing its focus on environmental, safety, and health aspects of energy production and use, and on oil sands and heavy oils.[xx] Ongoing project activities in each of these areas and nuclear energy are discussed below.

Like all other federal activities, PERD's budget was reduced substantially following the government-wide Program Review that began in 1994, as Figure 5 shows. Between 1994 and 1998, the PERD budget was reduced by approximately 28% to a level of approximately $46 million, while decisions from a recent review of the program, effective in fiscal year 1999, have cut PERD funds by an additional 3%.[xxi] Trends in Canada's major federally-sponsored energy R&D programs are discussed below.

Figure 5. PERD Expenditures by Program Area, 1975-1998



Energy Efficiency **($13 million, FY1998-99)**

Compared with many other countries, Canada is a large energy consumer. This can be attributed in part to its large landmass and cold climate, in part to the central role of energy-intensive extractive and primary industrial operations in the national economy, and in part to its abundant supplies of low-cost energy resources. The government recognizes that improvements in energy efficiency are among the most cost-effective ways of reducing pollution and minimizing environmental impacts associated with energy use. That said, PERD energy efficiency activities are organized around three major themes: buildings efficiency, efficiency in the resource industries, and cross-cutting technologies.

Buildings Efficiency

The buildings energy efficiency program has three main components. Housing R&D addresses main energy elements of residential building such as housing structure, insulation, furnaces, appliances, lighting, ventilation and water heating, considering the impacts of each of these elements on total energy use, indoor air quality, productivity of residents and affordability. Large Buildings R&D looks at similar issues to the housing program but focuses on commercial/institutional buildings such as retail stores, office buildings, restaurants, hotels, government buildings, places of worship, schools, hospitals, and prisons. Community Energy Systems R&D focuses on energy R&D projects that aim to exploit opportunities available only through an integrated systems approach to energy efficiency. For example, projects have sought to use waste energy from electric utilities or industries to heat office buildings or other commercial structures.

Resource Industries Efficiency

R&D in the resource industry efficiency program aims to improve the energy productivity of Canada's extractive industries, which account for a significant portion of GDP. R&D in the agriculture, food production, and fisheries industries are also included in this program area. PERD projects in this area also aim to improve agricultural energy efficiency through direct measures such as optimization of direct energy use in farming operations and indirectly through improvements in the manufacture and use of fertilizers and pesticides.

Cross-Cutting Technologies

Key technology areas in this program include:

Combustion. R&D focuses on improvements in furnace design, burner and stack technologies; process design; expert systems and model development; catalytic combustion of natural gas; biomass combustion; and residential/commercial liquid, solid and gas combustion technologies.

Heat Management Technologies. R&D efforts concentrate on the development of absorption heat pumps, evaporative desiccant systems, diagnostic and control systems, thermo-chemical systems, process integration technology, heat exchangers and alternative refrigerants such as ammonia and hydrocarbons.

Other Cross-Cutting Technologies. Separation, drying and de-watering are important especially from an energy/environment perspective and projects are supported by several federal departments in specific niches. Ongoing energy R&D projects in this area focus on membrane separation, oxygen separation from air, freeze crystallization and drying of grains.

Renewable Energy **($5 million FY 1998-99)**

Canada has abundant renewable energy resources: hydropower, solar energy, wind energy, and biomass. The government considers the future of renewable energy promising because of the many environmental benefits they offer and because of the technological improvements that have made renewables more cost-competitive. Energy from renewable sources accounted for approximately 18% of Canada's total primary energy supply in 1995. Of this, hydroelectricity represented about 62% and bioenergy (derived principally from agricultural and forest wastes, and, to a lesser extent, from municipal solid wastes) represented nearly 37%. The renewable energy program has five main components: hydroelectricity, solar energy, wind, bioenergy, and hydrogen production from renewable sources.

Hydroelectricity

Hydroelectricity is the predominant renewable energy source in Canada. PERD focuses mainly on small-scale hydroelectricity, defined as installations of less than 20 megawatts (MW). In Canada, the total installed capacity of small-scale hydroelectricity is 1500MW. Research focuses on: reducing equipment complexity, increasing efficiency, advanced materials, and standardization of equipment. Some research is also devoted to the sustainable use of existing large hydroelectric equipment and facilities. R&D in this area focuses on increasing the knowledge base with regard to the risks from dam instability, and the assessment and mitigation of environmental impacts of existing large hydro installations.

Solar Energy

R&D efforts included in this program focus on the development of both photovoltaic and active solar systems. Photovoltaic research aims to develop technologies intended primarily for deployment in remote Canadian communities. Active solar technologies, those that directly convert solar radiation into thermal energy that can then be used to heat a fluid (e.g., water or air), are being developed for broader use in water heating, pool heating, and commercial/industrial ventilation and air heating. A third type of solar energy, passive solar energy, is developed under various buildings technologies in the energy efficiency program.

Wind Energy

R&D efforts currently focus on the integration of wind energy technologies with traditional fossil-fired power plants in hybrid installations, primarily for deployment in northern Canada. PERD funds research projects aimed at improving the reliability of wind technologies in harsh environments and, more generally, at reducing the cost of wind generating equipment.

Bioenergy

PERD bioenergy activities address a variety of issues including feedstock supply (e.g., biomass or municipal solid waste), the development of bioenergy collection and delivery systems, and the development of conversion facilities. Biomass currently meets about 6% of primary energy demand in Canada, most of which is produced and used within the forest sector. PERD projects are also focusing on Canada's large amounts of agricultural waste, such as straw and chaff, which might be used in the production of biomass energy.

PERD addresses the whole biomass chain (from supply to conversion), placing its emphasis on biomass conversion. This work seeks to optimize biomass combustion processes to ensure higher efficiency and reduced emissions, through, for instance, the development of expert systems and monitoring devices. The program also strives to

improve significantly the conversion of biomass to liquid fuels, resulting in lower production costs.

Hydrogen Production from Renewable Resources

Research on Hydrogen Production from renewables focuses on more efficient and less capital-intensive electrolysis methods, storage and transport of hydrogen, and related health and safety concerns. It also includes work on small, integrated power supply systems using hydrogen to generate electricity for off-grid applications.

Transportation ($8 million FY 1998-99)

The PERD Transportation program aims to improve the energy efficiency and reduce the environmental impact of Canada's transportation systems. The transportation sector is responsible for about 30% of the country's CO_2 emissions and pollution from transportation is a major contributor to acid rain, smog and poor urban air quality in many urban areas. The Transportation R&D program focuses mainly on land and marine transportation with a smaller component on air transportation. The program is divided into the following four research areas: fuels technology development, efficiency, infrastructure, and health impacts.

Fuels Technology

The Fuels Technology program focuses on the development of alternative transportation fuels technologies (natural gas, propane, alcohols, biofuels, electricity and hydrogen) and ways to improve their market penetration. Some project areas include hybrid vehicle component development, gaseous fuel technologies, systems integration, control technologies, and advanced materials. This program also funds research on advanced energy storage systems like batteries and energy storage flywheels (electro-mechanical batteries), and on-board storage of gaseous fuels. Lastly the program looks at emissions control technologies.

Transportation Efficiency

The transportation efficiency program segments the transportation sector by mode and carries out research projects in three areas: land, marine, and air transportation efficiency. Because the land transportation sector is so large, the efficiency component of the program concentrates on specific options that will provide the largest payback. These include efforts to improve the efficiency and reduce the emissions of diesel engines; the design of lightweight urban transit buses , and the development of intelligent transportation systems for more efficient use of the existing infrastructure.

Marine efficiency projects aim to improve fuel efficiency and reduce emissions in shipping. Project areas include the development of better methodologies for vessel routing development of technologies to improve the efficiency of intermodal links

between the marine/land interface at ports, and development of the capability to predict environmental information to improve fleet efficiency.

Areas of research in the PERD aviation efficiency program include improved air traffic sequencing and monitoring, flight data monitoring and analysis, aircraft wake vortex prediction, airport weather prediction, satellite-based navigation and air traffic management.

Infrastructure

The Infrastructure program focuses on the development of standards and technologies required for efficient, cost effective fuelling infrastructure for alternative fuels.

Health

The Health program focuses on the assessment of health risks associated with the use of reformulated and alternative transportation fuels, and the assessment of the toxicity and other health risks associated with particulates from combustion-related emissions.

Hydrocarbons **($12 million FY 1998-99)**

The objective of the Hydrocarbons program is to ensure that Canada's hydrocarbon resources are developed, upgraded and transported in a safe, economic, and environmentally acceptable manner for long-term benefit to all Canadians. The task is divided into three research areas: coal, oil sands and heavy oil, and oil and gas.

Coal

The Coal program focuses on the characterization of coal properties for control of environmental contaminants, and on health-related issues. However, since its budget has been cut significantly over the past few years, remaining coal research activities have been subsumed into other programs.

Oil Sands and Heavy Oil

The R&D supported by the Oil Sands and Heavy Oil program is coordinated through the Canadian Oil Sands Network for Research and Development (CONRAD) and covers upgrading, tailings, froth treatment, produced water, and emissions. Research seeks to add value to the domestic resource base by enabling the production of heavy oil-based transportation fuels in a manner that is both economic and environmentally acceptable. A major portion of this research is conducted at the National Centre for Upgrading Technology (NCUT) at the CANMET Western Research Centre in Devon, Alberta.

Oil and Gas

The Oil and Gas program focuses on sustainable development opportunities and government responsibilities (operational, safety, and environmental regulation and standards) related to frontier oil and gas development, and environmental issues concerning conventional oil and gas. Research on health and safety issues, such as pipeline integrity, pressure vessel reliability, and offshore personnel evacuation technologies is also carried out as part of the program.

Nuclear Energy

Fission ($93 million, FY 1998-99)

Most nuclear fission research in Canada is carried out by Atomic Energy of Canada Limited (AECL), a company wholly owned by the Canadian government. AECL is a leading vendor of nuclear equipment, selling CANDU power reactors, MAPLE research reactors and the MACSTOR advanced spent fuel storage system. AECL engages in a wide range of R&D activities and provides nuclear engineering products and services to customers worldwide.[xxii] AECL's R&D program has several focus areas including research on nuclear fuel and fuel cycles, use of plutonium derived from weapons in CANDU reactors, safety technologies, hydrogen behavior in reactor containments, improved production of heavy water, and information systems. AECL also funds research in many supporting health, environmental and physical sciences.

Fusion ($13 million, FY 1998-99)

Publicly funded nuclear fusion research in Canada was effectively terminated in 1997, when the Canadian government cancelled the National Fusion Program (NFP). The Centre Canadien de Fusion Magnétique (CCFM) had been created originally in 1987 as the operating entity for the TdeV (Tokamak de Varennes) fusion experiment and associated activities in the context of the NFP. CCFM was a joint venture involving the federal government, Hydro-Québec, AECL, and the Institut National de la Recherche Scientifique (INRS). Since the withdrawal of federal government support, Hydro-Québec and INRS have decided to continue their joint venture, with changes to the mandate to incorporate future partnerships and technology transfer. As of 1997, the CCFM was funded at a level of $9 million annually, 50% of which consisted of phase-out funding from the federal government. The government's financial commitment of CCFM was to continue at that level through fiscal 1999.[xxiii]

Canada also contributes to the International Thermonuclear Experimental (ITER) program through ITER Canada, a non-profit corporation that coordinates and finances the country's technical contributions. ITER Canada has an annual budget of approximately $4 million consisting of cash and in-kind contributions from corporations, industry associations, and municipal governments constituting its membership. [xxiv]

Energy and Climate Change **($5 million FY 1998-99)**

The energy and climate change R&D program is divided into the following four areas: greenhouse gas cycles and storage, capture of greenhouse gases and their disposal climate change prediction and detection, and impact of climate change on the Canadian energy sector.

Greenhouse Gas Cycles and Storage

This program concentrates on the development of methodologies and tools for the measurement and assessment of anthropogenic GHG emissions on natural greenhouse gas cycles. Research focuses on carbon dioxide and methane in particular, given their association with the energy sector and their major role in climate change.

Capture of Greenhouse Gases and Their Disposal

This program addresses the development of technologies for the capture of greenhouse gases and their disposal. It approaches the capture of greenhouse gases from two points in the energy cycle: 1) from the greenhouse gas-forming processes (chiefly combustion) prior to the release of the gases, primarily from large stationary sources such as fossil-fired power plants, and; ii) from the atmosphere following their emission. The work in both of these methods is in the early stages and large resources have not yet been devoted to them. A major goal of research efforts in this area is reduction of the high costs associated with greenhouse gas capture. In addition, the program is exploring possibilities for the subsequent sale of captured carbon dioxide, potentially for enhanced oil recovery, which might stimulate private sector investment in this technology area.

The stimulation of natural carbon uptakes, through terrestrial or marine processes, is seen as a more viable means of removing CO_2 directly from the atmosphere. As a step in this direction, the program focuses on the sequestration potential of forests.

Climate Change Prediction and Detection

This program focuses on the collection and analysis of data from the systematic observation of climate patterns and systems in Canada such as snow and ice pack, boreal forests, permafrost, and adjacent oceans. In addition, the program assesses the cooling effects of aerosols and their relationship to greenhouse forcing. The program also supports studies aiming to develop further understanding of historical climate records. Studies are carefully chosen to complement the greater body of climate work organized within Canada and internationally by groups such as the Climate Change Program Board and the Intergovernmental Panel on Climate Change, respectively.

Impact of Climate Change on the Canadian Energy Sector

This program studies the possible impacts of climate change on the Canadian energy sector and identifies appropriate adaptive strategies. An initiative for a comprehensive effort in this regard has been launched as the Canada Country Study. The study will consider many areas of concern, including changes to water availability for hydroelectricity, changes to electricity demand in summer for space cooling and in winter for space heating, and changes to the stability of permafrost which is important for resource exploration over much of Canada's north.

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[i] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997). The data included in this document were collected by a survey conducted by the Office of Energy Research and Development (OERD). OERD advises that the data be treated with caution due to the survey's high level of aggregation designed to protect confidentiality. Moreover, differing definitions of energy R&D may have been used by different survey participants; thus, some participants responses might include expenditures on demonstrations and pilot projects, while other may have omitted these expenditures in their responses.
[ii] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997).
[iii] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997).
[iv] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997).
[v] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997).
[vi] Natural Resources Canada, "Backgrounder on Fuel Cell Technology," http://nrn1.nrcan.gc.ca:80/css/imb/hqlib/fuela.htm, (August 1999).
[vii] Natural Resources Canada, "Backgrounder on Fuel Cell Technology," http://nrn1.nrcan.gc.ca:80/css/imb/hqlib/fuela.htm, (August 1999).
[viii] Technology Partnerships Canada (TPC) is a technology investment fund established to contribute to the achievement of some of Canada's major economic and environmental policy objectives, such as increasing economic growth, creating jobs and wealth, and supporting sustainable development. TPC advances and supports government initiatives by investing strategically in research, development and innovation in order to encourage private sector investment, and so maintain and grow the technology base and technological capabilities of Canadian industry. TPC also encourages the development of small and medium-sized enterprises (SMEs) in all regions of Canada. See Technology Partnerships Canada http://strategis.ic.gc.ca/SSG/tp00167e.html
[ix] Technology Partnerships Canada, "Government of Canada Invests in Innovative Gas Separation Technology for the Industrial Oxygen and Fuel Cell Markets," August 9, 1999, http://strategis.ic.gc.ca/SSG/tp00156e.html; Technology Partnerships Canada, "Government of Canada Invests in Improved Refuelling System for Hydrogen Fuel Cell-Powered Vehicles," February 8, 1999 http://strategis.ic.gc.ca/SSG/tp00139e.html
[x] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997).
[xi] International Energy Agency, *Energy Policies of IEA Countries: Canada 1996 Review* (Paris: IEA, 1996), pp. 109-110.
[xii] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997).
[xiii] Statistics Canada, *Federal Scientific Activities 1998-99*, p. 107.
[xiv] The Ministry of Energy, Mines, and Resources was the predecessor agency to Natural Resources Canada, which was established in 1994.
[xv] Information in this section regarding the Program of Energy Research and Development is from Natural Resources Canada, http://www.nrcan.gc.ca/es/new/perd.htm.

[xvi] Canadian Centre for Mineral and Energy Technology, http://nrn1.nrcan.gc.ca:80/mms/canmet-mtb/valdor/cm_011.htm.
[xvii] CANMET Energy Technology Centre, http://www.nrcan.gc.ca/es/etb/cetc/etcframe.htm.
[xviii] CANMET Western Research Center, http://www.nrcan.gc.ca/es/etb/cwrc/wrcehome.html.
[xix] CANMET Energy Diversification Research Laboratory, http://cedrl.mets.nrcan.gc.ca/.
[xx] International Energy Agency, *The Role of IEA Governments in Energy* (Paris: OECD, 1996), p. 112.
[xxi] Natural Resources Canada, Office of Energy Research and Development, "A Review of Canadian Energy Research and Development Expenditures 1983-1995," (September 1997).
[xxii] Atomic Energy of Canada Limited, http://www.aecl.ca.
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[xxiv] ITER Canada, http://www.itercanada.com/