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Research and Development for New Energy Technologies in the Private Sector

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Research and Development for New Energy Technologies in the Private Sector

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Summary

The rising cost of energy and the growing concern over climate change and global warming have led to research and development (R&D) for new technologies aimed, among other things, at reducing the environmental impact of energy production and consumption.

For example, some scientists involved in energy R&D are interested in photovoltaic cells, which convert sunlight to electricity. Others are looking into biomass, which is plant matter such as trees, grasses, agricultural crops, waste or other biological material. This can be used as a solid fuel, or converted into liquid or gaseous forms, for the production of electric power, heat, chemicals or fuels.

In 2003, Canadian industries devoted a total of $649 million[1] to overall R&D in energy, a broad area that includes R&D in fossil fuels, nuclear technologies, energy conservation, as well as alternative energy sources. R&D in energy represented about 5% of all industrial R&D in Canada.

However, the search for alternative energy has taken on a new life during the past decade. Canadian industries have been dedicating more and more of their R&D dollars into the development of cleaner, more renewable energy practices.

Between 1993 and 2003, the only form of energy R&D on which spending actually increased was R&D in alternative sources of energy. In 2003, this type of spending reached $204 million, accounting for 31% of total R&D spending on energy, double the proportion of only 15% in 1993. The manufacturing sector accounted for most of this increase.

In contrast, R&D spending in fossil fuel technologies was almost identical in 1993 and 2003. In 2003, it accounted for 33% of total energy R&D, a proportion unchanged from a decade earlier.

Alternative energy R&D conducted by Canadian industry in 2003 was heavily concentrated in developing alternative fuels and energy storage technologies. Over 40% of the $204 million was spent on R&D in storage of energy technologies, such as hydrogen cells for use in cars, or on alternative fuels, such as ethanol and biodiesel fuels.

R&D spending on fossil fuels actually fell during the late 1990s, but rebounded between 2001 and 2003 with the surge in crude oil prices. Some of this recent growth might be attributed to the increased economical feasibility of mining the oil sands in Alberta.

This study examines R&D efforts made by Canadian industry from 1993 to 2003 in five different types of energy R&D. It excludes spending by others, such as government and universities.

1. All dollar values are expressed in 1997 constant dollars, unless otherwise specified.

Definitions

Alternative energy R&D: Comprises all internal R&D spending self-reported as renewable resources R&D or other cross-cutting techniques or R&D. From 1993 to 2003, more categories of renewable energy R&D became available for the respondents of the Energy R&D Expenditures by Area of Technology Survey to describe their enterprise's R&D activities.

In 2003, the renewable resources categories were solar energy, biomass energy, wind energy, hydro and other renewable resources. R&D in cross-cutting techniques included: energy system analysis, R&D on environment and climate change, energy storage (fuels, batteries) and alternative transportation fuels. In 2003, carbon capturing technologies appeared as on the questionnaire under "Fossil Fuel R&D," but was regrouped in the "Alternative Energy R&D" category for the purpose of this paper, as it seeks cleaner energy usage through technological advances.

Energy conservation R&D: Comprises all internal R&D spending self-reported as energy conservation R&D. The sub-categories were: conservation in residential and commercial buildings, transportation, industrial processes and other conservation.

All **dollar** values are expressed in 1997 constant dollars, unless otherwise specified.

The importance of energy R&D

Concerns over the world's energy consumption seem to have intensified over the last decade. Global warming, increasing worldwide energy consumption, geopolitical tensions together with the rising prices of fossil fuels appear to be the leading issues.

The 1990s were the warmest decade of the millennium. Greenhouse gas emissions are widely accepted as the primary cause of global climate change, and in the industrialized world, these have been on the rise. Canada's greenhouse gas emissions are almost entirely related to energy production and use, coming mainly from electricity and heat generation, energy consumption by vehicles and fossil fuel production industries.[2] Canada, a geographically large country with a dispersed population, is the world's second largest per capita energy consumer, just behind the United States and consuming three times as much per capita compared with Italy, the lowest per capita consumption of the G-8 countries.[3] A recent study showed that in 2003, Canada emitted 23% more greenhouse gases per capita than in 1990,[4] representing a per-capita level that was lower than only two other countries in the world.

In order to begin addressing the problem of Canada's energy consumption and related emissions, it is useful to look at the R&D efforts that are being made in developing energy alternatives. This is because the development of new, cleaner energy technologies is one way that our society can continue using energy while reducing its environmental impact.

2. See *Human Activity and the Environment: Annual Statistics 2004*, Statistics Canada Catalogue no. 16-201-XIE, October 2004, http://www.statcan.ca/english/freepub/16-201-XIE/0000416-201-XIE.pdf (accessed October 3, 2006).
3. See Marinka Ménard, "Canada, a Big Energy Consumer: A Regional Perspective. 2005," *Analysis in Brief*, Statistics Canada Catalogue no. 11-621-MIE2005023, March 2005, http://www.statcan.ca/english/research/11-621-MIE/11-621-MIE2005023.htm (accessed October 3, 2006).
4. See Tarek Harchaoui, "Greenhouse Gas Emissions in the Canadian Economy, 1981-2000," *Insights on the Canadian economy*, Statistics Canada Catalogue no. 11-624-MIE2003001, May 2003, http://www.statcan.ca/english/research/11-624-MIE/11-624-MIE2003001.pdf (accessed October 3, 2006).

Alternative energy: The only type of energy R&D posting an increase

Research and development performed by Canadian industry accounted for about 56% of all R&D spending in Canada in 2003. The rest was performed by universities, governments and private non-profit organizations.

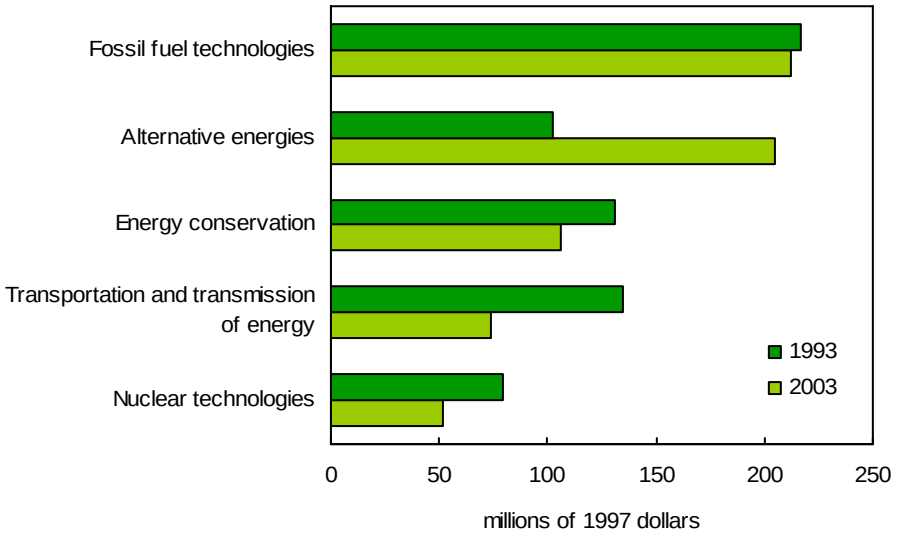
In 2003, Canadian industries dedicated a total of $649 million to overall research and development into energy. This represented about 5% of all industrial R&D in Canada.

Energy R&D is a broad area that, for the purpose of this paper, includes five different fields of R&D: fossil fuels, nuclear technologies, energy transportation and transmission, energy conservation, and alternative energy sources.

Between 1993 and 2003, the only form of energy R&D on which spending actually increased was R&D in alternative sources of energy. In 2003, this spending hit $204 million, which accounted for 31% of total R&D spending on energy, more than double the proportion of only 15% in 1993.

In contrast, R&D spending into fossil fuel technologies was almost identical in 1993 and 2003. In 2003, it accounted for 33% of total energy R&D, unchanged from a decade earlier. Industries spent $213 million on fossil fuel R&D in 2003, down marginally from $217 million a decade earlier.

Chart 1 Only alternative energy R&D posted spending increase



Source: Statistics Canada, Science, Innovation and Electronic Information Division.

Similarly, R&D spending on the transportation and transmission of energy was cut nearly in half during the 10-year period. In 1993, this area accounted for 20% of all spending on energy R&D. By 2003, the share had slipped to 11%.

Similarly, in 1993, R&D on nuclear technologies accounted for 12% of all energy R&D spending. By 2003, this proportion had fallen to only 8%.

Prior to 1996, Canadian industries were spending more on R&D in energy conservation than for alternative energy sources. This situation changed completely from 2000 on.

In 1993, R&D spending on energy conservation represented 20% of all R&D spending into energy. Ten years later, this proportion had declined to 16%, which was only half the share devoted to alternative energy. Between 2000 and 2003 alone, spending on energy conservation R&D fell from $132 million to $106 million.

Table 1 R&D private spending, Canada, 1993 to 2003

	Initial survey years				Subsequent survey years			
	1993	1994	1995	1996	2000	2001	2002	2003
	millions of 1997 constant dollars							
All industrial R&D	6,834	7,959	8,219	8,095	11,749	13,376	12,538	12,313
Total energy R&D	664	659	631	651	685	687	698	649
Fossil fuel	217	220	187	198	154	183	215	213
Energy transportation and transmission	135	142	135	121	144	94	80	74
Nuclear technologies (energy)	79	72	53	94	44	56	88	52
Alternative energy	102	95	111	104	211	228	196	204
Energy conservation R&D	131	130	145	134	132	126	119	106

Note: Components might not add up to the total due to rounding.
Source: Statistics Canada, special tabulation, Science, Innovation and Electronic Information Division.

Spending on fossil fuel R&D rose with crude oil prices

Spending on fossil fuel R&D fell during the late 1990s, but rebounded between 2001 and 2003 with the surge in crude oil prices. Some of this recent growth might be attributable to an increased economical feasibility of mining the oil sands in Alberta.

In 2001, the average price of a barrel of crude oil was US$25.98 (current dollars). By 2003, it had increased 20% to US$31.08. During the same period, R&D spending on fossil fuel technologies grew by 16% to $213 million, to reach about the same level as in 1993.

Some of this recent growth in fossil fuel R&D might be attributed to the increased economical feasibility of extracting oil from the oil sands in Alberta. The production of synthetic crude oil and crude bitumen from Alberta's oil sands jumped from 35.4 billion cubic metres in 2000 to 50.1 billion cubic metres in 2003.[5] (One cubic metre is equivalent to about 6.3 barrels.)

Interest in energy R&D may have evolved even more post-2003. Since January 2003, prices of a barrel of crude oil have more than doubled, from current US$31.97 to US$74.93 (as of August 1, 2006).

In addition, during this period, prices for natural gas increased 10.4%, as measured by the Statistics Canada Consumer Price Index, while electricity prices rose 13.8%, both outstripping overall inflation.

The crude oil sector continued to boom after 2003. For enterprises involved in gas and oil extraction, operating profits reached a record high in 2005, as did capital spending on construction.[6]

5. Source: Statistics Canada, CANSIM table 126-0001.
6. See Miles Ryan Rowat, "Boom Times: Canada's Crude Petroleum Industry," *Analysis in Brief,* Statistics Canada Catalogue no. 11-621-MIE2006047, September 2006, http://www.statcan.ca/english/research/11-621-MIE/11-621-MIE2006047.htm (accessed September 5, 2006).

Operating profits were 44% higher in 2005 than they were in 2003. During this period, capital expenditures in the gas and oil extraction industry surged by more than 38%.

Alternative energy R&D: Mainly energy storage and alternative fuels

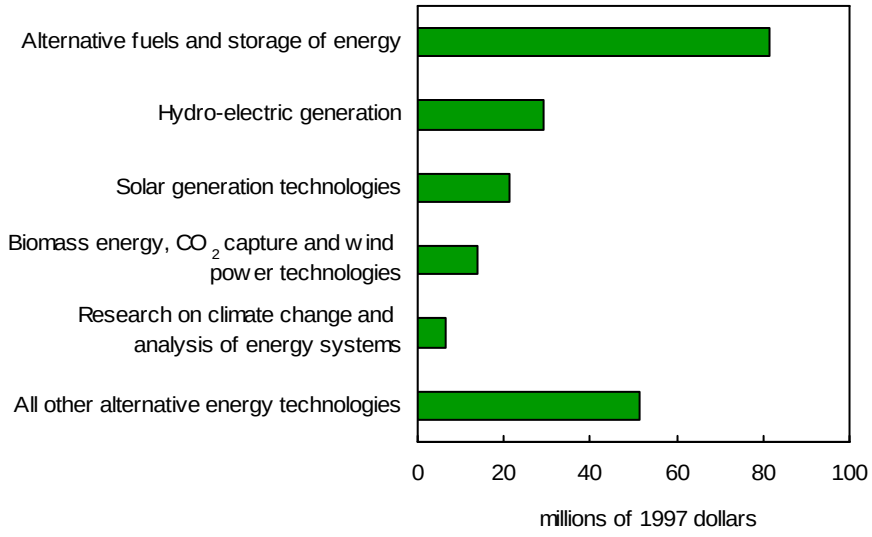
This paper looks at six main forms of alternative energy: alternative fuels and storage; hydroelectric generation; solar generation technologies; biomass, wind power and carbon dioxide (CO_2) capture; research on climate change; and other renewable technologies.[7]

Of these six sub-categories, R&D in alternative energy conducted by Canadian industry in 2003 was heavily concentrated in developing alternative fuels and energy storage technologies.

Over 40% of the $204 million industries spent on alternative energy R&D in 2003 went to R&D in storage of energy technologies, such as hydrogen cells for use in cars or alternative fuels, such as ethanol and biodiesel fuels. It represented over $81 millions.

In contrast, R&D in hydroelectric generation represented only $29 million, or 14% of the 2003 spending in alternative energy R&D. This consisted of R&D in better usage of rivers to produce electricity and was divided between R&D in technologies for small-scale projects such as run-of-river facilities and R&D for large dam projects, which is a relatively more traditional technology.

Chart 2 Alternative fuels and energy storage dominated Canada's alternative energy R&D mix in 2003



Source: Statistics Canada, Science, Innovation and Electronic Information Division.

R&D in solar energy was in third place, at $21 million, or 11% of total alternative energy R&D. Solar energy R&D is mainly driven by the development of better photovoltaic cells to produce electricity. These cells convert rays from the sun into electricity.

7. For detailed information about the various types of alternative energy technologies, see Natural Resources Canada's Canadian Renewable Energy Network website at http://www.canren.gc.

Spending in 2003 was relatively small on R&D for the combined grouping of biomass energy, CO_2 capture and wind power technologies. (These were grouped together for reasons of confidentiality as a consequence of the small number of enterprises involved in the specific fields of this category of alternative energy.) Only $14 million was dedicated to such R&D, representing 7% of total alternative energy R&D spending.

Biomass energy R&D seeks ways to capture the stored energy in waste. Agricultural, forest, municipal and food processing waste, most of which, if left to decay outdoors, become sources of methane emissions. Methane is a greenhouse gas that can be used to generate energy.

CO_2 capture technologies seek to capture emissions of fossil fuel burning processes that would otherwise escape into the atmosphere, or to capture CO_2 already in the atmosphere.

Wind power technologies are mostly aimed at electricity generation from wind turbines. They represent a sizeable portion of total energy production in some European countries. According to the European wind energy association, at the end of 2004, the European Union capacity was just over 34,000 megawatts.[8]

The Canadian Wind Energy Association announced that Canada had become the 12th country in the world to surpass 1,000 megawatts of installed wind energy capacity in June 2006.[9] Its installed capacity amounted to 1,049 megawatts, enough to power more than 315,000 Canadian homes.

Historically, wind power technologies have not represented a large portion of Canadian R&D spending, suggesting that a large part of the technologies used in wind farm electricity generation are the results of other countries' R&D. However, investments in wind farms throughout Canada in recent years and interests from university researchers might have given momentum to this R&D.

Manufacturing sector leads R&D spending on alternative energy

Canada's manufacturing sector accounted for the lion's share of spending on alternative energy R&D in 2003. The sector as a whole spent $151 million on R&D into alternative energy forms that year, which represented three-quarters of all such spending. Between 1994 and 2003, the sector accounted for 98% of the growth in such R&D spending.

For the purposes of this study, three sub-sectors of manufacturing are examined: Electrical and electronic equipment; machinery and transportation equipment; and chemicals, pharmaceuticals, plastics and rubber. Their performance was compared with spending by companies in the utilities sector, including electricity production and distribution, waste management and water distribution.

During the early 1990s, the utilities sector had been the most active participant in such alternative energy R&D. But these sector lost its leading position between 1994 and 2003 when its spending fell from $33.8 million to $25.8 million. This was an average decline of 3.0% a year.

In contrast, the heaviest spenders were firms in electrical and electronic equipment manufacturing, whose outlays on alternative energy R&D reached $67.5 million in 2003. This was an average

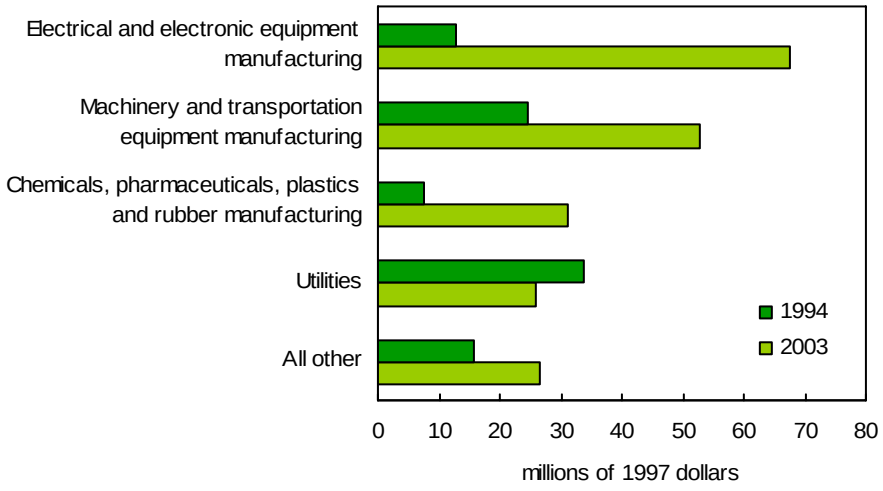
8. See European Wind Energy Association, *European Installed Wind Capacity Map, 2004*, http://www.ewea.org/fileadmin/ewea_documents/documents/graphs_maps_tables/europe_data_05_final.pdf (accessed October 13, 2006).
9. See "Canada's wind installations exceed 1,000 MW milestone," *WindSight*, vol. 19, no. 4, July 2006, Canadian Wind Energy Association, http://www.canwea.ca/images/uploads/File/WindSight/July_2006.pdf (accessed October 13, 2006).

growth rate of 20.2% a year during the previous 10 years. These firms accounted for half of the total increase in spending on alternative energy R&D during this period.

Firms in the chemicals, pharmaceuticals, plastics and rubber manufacturing grouping devoted $31.0 million to R&D, an average annual growth rate of 16.8%.

Companies that make machinery and transportation equipment invested $52.7 million on alternative energy R&D in 2003 from $24.6 million in 1994, an annual average growth rate of 8.8%.

Chart 3 Manufacturing industries responsible for most of growth



Note: This industry classification was only implemented from 1994 onwards, therefore 1994 data is presented instead of the customary 1993 data.
Source: Statistics Canada, Science, Innovation and Electronic Information Division.

More spending, fewer firms active in alternative and conservation energy R&D

Between 2000 and 2003, the number of performers active in alternative and conservation energy R&D fell sharply compared to the period between 1993 and 1996. These activities became concentrated in fewer enterprises.

Of the 287 performers active in energy conservation R&D or alternative energy R&D at some point between 1993 and 1996, only 45 were still active in this endeavour after 2000.

However, these 45 performers accounted for most of the growth in spending for these types of R&D. Their average increase of $3 million per performer a year in extra spending between 2000 and 2003, compared to the period between 1993 and 1996, is in contrast with the pattern of the 242 other firms, some of which may have been absorbed or merged into these larger firms.

A lesser proportion of the growth in alternative energy and conservation R&D spending also took place because of new firms or firms beginning alternative energy and conservation R&D activities for the first time during or after 2000. These 70 firms represented an annual average of $1 million per performer of new alternative energy and conservation R&D spending between 2000 and 2003.

Data sources and methods

Energy R&D spending figures were drawn from the Energy R&D Expenditures by Area of Technology Survey, 1993 to 2003. Data from 1997 to 1999 are not available, because of a temporary interruption to this survey.

As a result of reductions in the science and technology program for the 1992 and 1994 reference years, only the top R&D performers (accounting for 64% of all industrial R&D) were surveyed in those years.

Beginning with 1996, the Research and Development in Canadian Industry Survey estimates R&D expenditures for small firms (those with less than $1 million in R&D) using the Scientific Research and Experimental Development tax credit data.

These methodological changes may account for some of the variation in firm counts for 1992, 1994 and 1996.

This study examines only R&D activities carried out by Canadian industry, thus excluding R&D in others, such as government and universities. R&D performed by Canadian industry represented just over 60% of all R&D spending in Canada in 2000 and 2001, falling to 56% in 2003.

Industry groupings

For the purposes of this paper, the following North American Industrial Classification System industries were grouped into larger categories.

Electrical/Electronic equipment manufacturing
334 Computer and Electronic Product Manufacturing
335 Electrical Equipment, Appliance and Component Manufacturing

Auto parts, machinery, components and avionics manufacturing
333 Machinery Manufacturing
336 Transportation Equipment Manufacturing

Utilities
221 Utilities
562 Administrative and Support, Waste Management and Remediation Services

Chemicals, Pharmaceuticals, Plastics and Rubber Manufacturing
325 Chemical Manufacturing
326 Plastics and Rubber Products Manufacturing