Chapter 8

Energy r&d policy in Canada[1]

Yves Gingras and Robert Dalpé

Introduction

Canada is a country richly endowed in natural resources. Energy has always been important to it's economy. Canada is a net exporter of energy resources with research and development undertaken quite early in order to localise and exploit natural resources such as coal, gas and oil. For instance, a Canadian public laboratory in mineral and energy was already performing r&d on coal and oil at the beginning of this century[2], and the largest and most innovative Canadian program in energy r&d, the development of a nuclear energy system, CANDU, can be traced back to 1942.[3] However, it was only after the 1973 oil crisis that the Canadian government recognised that energy resources were not unlimited and that a systematic energy r&d program could contribute to a more efficient exploitation of existing energy sources as well as to the development of alternative ones.

Before the oil crisis of October 1973, few countries had an energy r&d policy. Most did not even have an energy policy. Energy research and development was, of course, going on in industry as well as in governmental laboratories but there were little more than self-conscious attempts to take stock of and to coordinate overall activities. Governments usually think through institutions and the energy crisis prompted, around the world, the creation of organisations that could handle energy r&d policy matters. In 1974, the U.S. government created an Energy Research and Development Administration, with a mandate to define and coordinate the national efforts in this domain.[4] During the same year, Great Britain created new organisations such as the Energy Technology Support Unit and the Advisory Council on Energy Conservation.[5] In Canada, an Interdepartmental Panel on Energy r&d (PERD) was formed in January 1974 to coordinate activities at the federal level. At the end of 1974, the International Energy Agency (IEA) was created as an autonomous body within OECD to facilitate international collaboration among member countries in the management of perceived energy shortages. Among the many Committees created to monitor the energy situation was one specially devoted to energy r&d.[6] Other countries reacted more slowly to the energy crisis. In Australia, for example, a National Energy Research, Development and Demonstration Council was created only in 1978.[7]

When these institutions were created, there was little accurate information on the level of investment in energy r&d, which is an essential tool for the definition

and implementation of any s&t policy. In 1975, IEA published a first compilation of energy r&d statistics designed to compare levels of activities in the member countries. This new concern about energy r&d was not matched by available data, which up until then had been collected and classified under different categories such as minings, commodities and science. There was a rush to identify and classify energy r&d. An early example in Canada, for federal government departments and agencies was produced in 1976.[8] Also, at that time the new Office of Energy Research and Development, within the Department of Energy, Mines and Resources produced its own inventory of energy r&d supported by the government, institution building and statistics gathering.[9] Before then, little comprehensive information existed on the state of energy r&d in Canada. Institution building and statistics gathering were thus the first steps toward a rational political intervention in energy r&d.

If the 1970s were the years of policy development, the beginning of the 1980s, following the second oil crisis were the 'golden years' of energy r&d policy in Canada. As we will see later, this period was characterised by a large increase of investments in energy r&d and, more broadly, a nationalist and interventionist energy policy, called the National Energy Program (NEP). Established in 1980, it had Canadianisation and self-sufficiency as important goals.

The interest for energy diminished in the mid 1980s with the decrease of oil prices. Energy was no longer a priority, and the NEP was abandoned in 1985 by the newly elected Conservative party. This deregulation process occurred in many other sectors. Government investment in energy r&d suffered from severe cutbacks. For example, the NRC's Energy Division, which was opened in 1975 with the mandate to develop programmes in renewable energy, was closed in 1985.[10]

In the late 1980s, the Canadian energy situation was characterised by a low increase of energy demand caused by stagnation of economic activity. Oil prices were relatively low, though unsteady. Coupled with a growing concern about the environmental consequences of petroleum usage, nuclear reactor accidents and large hydro-electric dams, these factors led both levels of government – federal and provincial – to revise downward their energy demand forecasts. In that respect, environmental protection has become a new and important variable for recent energy r&d policy.[11]

After briefly reviewing patterns of energy production and consumption in Canada, we will discuss in turn the role played in energy r&d by federal and provincial governments and by industry. (In 1989, the federal government accounted for forty-six per cent of the total investment in energy r&d, while provincial governments and industry each contributed twenty-seven per cent).

Energy production and consumption

The pattern of energy production and consumption has changed greatly during the past few decades in Canada. On the production side, the average annual growth rate from 1970 to 1990 was close to four per cent (see Table 8.1).

The increase of production was higher for natural gas, electricity – particularly for nuclear since 1968 – and coal, than for crude oil. On the consumption side, the most important trend is the low increase during the 1980s. Whereas the annual rate of increase was close tofive per cent for the 1970s – when increase in demand was higher than increase in production – it was only one per cent during the 1980s. Furthermore, 1981, 1982 and 1983 saw a decrease in energy consumption

Table 8.1
Production, exportation, importation and availability of energy in Canada (petajoules)

	prod	exp	imp	avail
1970				
Coal	319	108	472	637
Crude oil	2,777	1,346	1,147	2,573
Natural gas	1,986	739	10	1,232
Gas plant	128	82	—	44
Primary elect	510	18	10	502
Total	5,721	2,293	1,640	4,989
1975				
Coal	570	321	427	592
Crude oil	3,175	1,410	1,655	3,424
Natural gas	2,562	898	9	1,620
Gas plant	221	133	—	66
Primary elect	694	37	13	669
Total	7,220	2,799	2,103	6,370
1980				
Coal	891	448	467	928
Crude oil	3,444	460	1,241	4,196
Natural gas	2,600	840	—	1,784
Gas plant	316	211	—	86
Primary elect	1,032	109	11	933
Steam	20	—	—	20
Total	8,303	2,068	1,720	7,950
1985				
Coal	1,487	802	137	1,432
Crude oil	2,516	1,090	577	3,033
Natural gas	3,297	992	302	2,181
Gas plant	317	161	—	172
Primary elect	1,290	156	44	1,122
Steam	24	—	—	24
Total	9,931	3,202	1,060	7,940
1990				
Coal	1,669	943	409	1,077
Crude oil	3,735	1,462	1,198	1,077
Natural gas	4,262	1,537	24	2,676
Gas plant	405	180	4	217
Primary elect	1,306	66	64	1,304
Steam	16	—	—	16
Total	11,392	4,188	1,699	8,754

Source: Statistics Canada, Cat. 57–003 and 57–207.

due to energy conservation measures and the economic recession. The other important trend was a decrease in crude oil consumption in the 1980s, leading to a rising share for natural gas and electricity.

The Canadian energy industry remained a net exporter of energy during the last two decades. However, during the 1970s, when demand growth was higher than production growth, it's foreign sales decreased. For instance, in 1980 Canada was a net importer of crude oil. Exports increased during the 1980s. One-third of natural gas production was exported. Electricity exports increased up to 1987, but remained at a relatively low level, and declined after that year.

Table 8.2 presents data on energy production in Canada in 1990. This table reveals the high level of production in natural gas and crude oil. Also important is the regional distribution of energy production. Natural gas and crude oil are available only in Western provinces, where Alberta is the largest producer. Ontario and Québec produce almost exclusively electricity, from nuclear power plants and hydro-electricity respectively. As far as production is concerned, regional interest for energy r&d differs accordingly.

Table 8.3 presents provincial consumption of energy in 1990. Here also regional patterns are evident.

Eastern provinces rely almost exclusively on petroleum products and Québec shows greater consumption of electricity. Ontario and British Columbia use petroleum products, natural gas and electricity, while the Prairie provinces rely on petroleum products and natural gas. Energy r&d needs will then also differ according to consumption patterns.

The federal role in energy r&d

The Federal Panel on Energy r&d

In the mid 1970s, the federal government created institutions with a mandate to coordinate the federal energy r&d policy. In January 1974, a Task Force on Energy r&d was established, chaired by the Deputy Minister of Energy Mines and

Table 8.2
Production of Primary Energy, 1990 (petajoules)

	Coal	Crude oil	Natural gas	Gas plant	Primary electricity	Steam	Total
New Foundland	—	—	—	—	1254.0	—	124.0
P.E.I.	—	—	—	—	—	—	—
Nova Scotia	97.3	—	—	—	4.3	—	101.6
New Brunswick	14.8	—	—	—	31.9	—	46.7
Québec	—	—	—	—	482.4	—	482.4
Ontario	—	9.5	17.0	—	359.7	16.0	402.2
Manitoba	—	28.5	—	—	71.4	—	100.1
Saskatchewan	141.1	479.9	262.4	2.6	15.2	—	901.1
Alberta	667.23	057.83	546.9	390.5	7.4	—	7,669.7
British Columbia	748.9	83.8	427.9	11.7	206.3	—	1,478.7
Yukon, N.-W.T.	—	75.4	7.4	—	2.4	—	85.2
Canada	1,669.33	734.8	4,261.6	404.9	1,306.0	16.0	11,392.6

Source: Statistics Canada, Cat. 57–003.

Table 8.3
End Use of Major Fuel Types, 1990 (petajoules)

	Coal	*Oil products and LPG's**	*Natural Gas*	*Electricity*	*Steam*	*Total*
Newfoundland	4.2	121.1	—	37.9	—	163.2
		(3%)	(74%)		(23%)	
P.E.I.	0.2	19.9	—	2.7	—	22.8
		(1%)	(87%)		(12%)	
Nova Scotia	64.1	174.0	—	34.9	—	273.0
		(23%)	(64%)		(13%)	
New Brunswick	14.3	191.9	—	47.7	1.4	255.3
		(6%)	(75%)		(19%)	(1%)
Québec	26.8	722.1	211.7	567.6	0.1	1528.3
		(2%)	(47%)	(14%)	(37%)	
Ontario	579.4	1 104.3	817.0	515.9	19.1	3035.7
		(19%)	(36%)	(27%)	(17%)	(1%)
Manitoba	7.1	102.2	86.9	63.1	0.2	259.5
		(3%)	(39%)	(33%)	(24%)	
Saskatchewan	115.5	136.6	189.9	49.2	—	491.2
		(24%)	(28%)	(39%)	(10%)	
Alberta	397.5	541.8	1 075.3	152.5	0.2	2167.3
		(18%)	(25%)	(50%)	(7%)	
British Columbia	8.1	379.0	290.7	206.6	—	884.4
		(1%)	(43%)	(33%)	(23%)	
Yukon and N.W.T.	—	24.0	3.1	3.8	—	30.9
			(78%)	(10%)	(12%)	
Canada	1 217.3	3 516.6	2 676.5	1 681.8	21.0	9 113.2
		(13%)	(39%)	(29%)	(18%)	

*Liquid Petroleum Gas Product
Source: Statistics Canada, Cat. 57–003.

Resources, and composed of Deputy Ministers or senior officers from seventeen departments and governmental agencies having responsibilities or interest in energy matters. It's objectives were to review federal energy r&d activities, define a coordinated programme and advise the government on the allocation of funds.[12] Tabled a year later, the report of the Task Force led to the creation of a coordination structure composed of an Interdepartmental Panel on Energy Research and Development (hereafter referred to as the Panel), assisted by an Office of Energy Research and Development (OERD) which played the role of secretariat to the Panel. Bringing together senior representatives of s&t branches of all the federal government ministries and central agencies involved in energy r&d, the Panel acts as a central policy and planning committee responsible for coordinating the programme of federal energy r&d and for recommending allocation of resources within the different sectors of energy.[13] The coordination activity also includes collaboration with provinces and with foreign countries through the international programmes administered by the IEA.

The government provides the Panel with it's own annual budget, which is distributed according to priorities set up in relation to the energy policy defined by the federal government. The ministries and agencies involved are in charge of implementing those aspects of energy r&d which relate to their domain. Though the most important federal institutions in matters of energy r&d are Energy, Mines and Resources and Atomic Energy of Canada Ltd. The Panel also includes other departments affected by energy resources such as Transport, Public

Works, Agriculture, Environment, Fisheries & Oceans, Indian & Northern Affairs, Health & Welfare and National Defence.

Because of the many departments involved in energy, Canada rejected the option of a central agency like the American ERDA, and adopted a cooperative structure designed to ensure coordination of efforts between the activities of the departments. This seemed to be an appropriate choice because, in addition to being divided between many departments, energy r&d is also divided between different provinces, which have control of their natural resources. An interdepartmental panel could define joint projects with provincial authorities and avoid unnecessary duplication.

In contrast to the Australian National Energy Research, Development and Demonstration Council which regroups members of government, universities and industry, the Panel is strictly a governmental structure. The lack of representation from industry at the level of definition and shaping of policy was noted by the IEA in it's 1978 Report, and it was suggested that industry should be associated in some way.[14] Though not officially present on the Panel, industries as well as provincial governments, are nonetheless consulted through 'formal and informal routes by scientists, r&d managers, Panel members and officers of OERD'.[15]

Though the report of the Task Force served as a starting point for the definition of a national programme of energy r&d, there was another important document produced at the time on the subject by the Science Council of Canada. Created in 1966 as an advisory body on science policy, the Council produced many documents on sectorial aspects of s&t policy. In the context of one of it's policy projects, the Science Council established a committee on national resources in September 1971 to study those aspects of science policy connected with the production, distribution, conservation and end use of energy resources. The committee, composed of five members from governments departments and agencies, five from industry and two from universities, issued its report on *Canada's Energy Opportunities* in March 1975, suggesting an expansion of energy r&d activities in the sectors of conservation, conversion and more efficient use of energy.[16] Four years later, the Committee published another report recommending eleven demonstration programmes, ranging from oil and gas production in ice-congested water to nuclear, bioenergy and solar energy.[17]

Though energy r&d had obvious links with science policy and thus with the federal government's Ministry of State for Science and Technology (MOSST), the official responsibility for developing an energy r&d policy lay with Energy, Mines and Resources.

With rich and diversified energy sources, Canada has frequently taken stock of it's energy situation and produced at least nine studies related to energy policy between 1944 and 1985, but energy r&d was not an important preoccupation before 1973.[18] In the summer of that year, the federal government published *An Energy Policy for Canada: Phase 1* which, as one commentator put it, 'can be read as the last document of the sixties'.[19] The document still took for granted the necessity of high level energy consumption and thus recommended more efforts on the development of nuclear energy and research on synthetic oil.[20] However, the report became obsolete a few months later with the oil crisis, so that the definition of an energy r&d policy adequate to the new situation would only come with the report of the Task Force in 1975. According to this document, a composite goal for a national energy r&d program should be 'to develop the scientific and technical capability to achieve self-reliance in energy with minimal environmental, social or economic costs and maximum industrial or quality of life advantages'.[21] For the next decade, this objective of self-sufficiency was at the core of the National Energy Policy (NEP).[22]

The NEP was the most important energy policy statement of the 1980s. It's main objectives were self-sufficiency and Canadianisation of the oil industry.[23] Canadianisation of the petroleum industry was achieved through the Petroleum Incentive Programme, which offered grants to stimulate oil and gas exploration in relation to the degree of Canadian ownership, and through Petro-Canada's strategy to acquire foreign-owned competitors.[24] These actions meshed well with the Foreign Investment Review Agency (FIRA), an institution created in 1974 by the same Liberal government charged to oversee foreign investments in Canada. Other NEP priorities were frontier and oil sands development, conservation and oil substitution. An important federal objective was to establish a national price for petroleum products, despite the fact that energy was a provincial jurisdiction. This particularly affected Alberta, the main oil producer, which objected to this aspect of the NEP, but was well received by the central provinces, who were consumers and thus paid less than the international price for their oil. Energy r&d funding increased dramatically under NEP, as the programme nevertheless established alternative fuels, energy efficiency and new energies as priorities for r&d.

The election of the Conservative Party in November 1984 marked a shift in federal r&d policy. Canadianisation was no more a priority, the NEP was abandoned, and competitiveness and environment were the new goals.[25] Concerning energy r&d, *Energy Options*, published in 1988, stated that a 'commitment to research, development and management of technology is critical to enhancing Canada's energy choices and environmental quality into the 21st century'.[26] The mandate of the PERD was adapted to reflect this new trend and it's objective is now 'to provide the s&t for a diversified, economically and environmentally sustainable energy economy'.[27]

Federal Energy r&d Expenditures

In its survey of the state of energy r&d at the federal level, the 1975 report of the Task Force showed that research on nuclear energy was by far the main activity in energy r&d and that it amounted for more than three quarters of the total expenditures over the years 1972–1975.

The expenditures on nuclear energy were dedicated to the development of the state-of-the-art CANDU nuclear power plant. The Atomic Energy Commission of Canada Ltd., a Crown Corporation was responsible for the development of the CANDU nuclear power plant. The OPEC oil embargo of 1974 led the Canadian Government to a broadening of energy r&d expenditures. This was precipitated by a recognition that r&d could help lead to increased security of supply. The Program of Energy Research and Development was established in 1975 and mandated to focus on energy conservation and on the identification of alternative energy supplies that would increase security of supply. The provinces also established programs aimed at the increased security of supply.

With the advent of these federal and provincial intiatives, energy r&d expenditures were applied to a variety of energy sources (e.g. conservation, coal, renewable energy and fossil fuels). By 1987, r&d expenditures devoted to nuclear (fission and fusion) energy represented 43% of total federal and provincial energy r&d expenditures (Table 8.6).[28] It should be noted that AECL's budget greatly decreased in 1987 and 1988. AECL activities concern application of nuclear technology in energy and in other sectors, such as the biomedical industry. (see Chapter Four). In the energy sector, AECL has developed the CANDU technology and was also involved in smaller projects such as the Tokamak and the SLOWPOKE.[29]

Starting with the fiscal year 1975–1976, the Interdepartmental Panel on Energy r&d would distribute additional funds according to the objectives of diversification and self-sufficiency which were at the core of the federal energy policy. It should be noted that the Panel has the formal responsibility for coordinating and

Table 8.4
Energy r&d Expenditures in Canada (millions, current dollars)

	Federal (% administered by PERD)*	*Provinces*	*Sub total federal provinces*	*Industry***	*Total*
1974	105,3 (0,0)	35,6	140,9	n.d.	—
1975	109,4 (1.0)	34,9	144,3	n.d.	—
1976	111,3 (9,0)	41,6	152,9	n.d.	—
1977	127,1 (16,4)	69,4	196,7	113	309,7
1978	150,4 (22,3)	92,2	242,6	161,1	403,7
1979	157,1 (23,7)	101,1	258,2	186,6	444,8
1980	204,6 (19,2)	103	307,6	259,7	567,3
1981	251,0 (31,0)	107	358,0	402,6	760,6
1982	345,1 (35,6)	67,1	412,2	404	816,2
1983	403,1 (40,3)	85,3	488,4	347	835.4
1984	407,5 (41,8)	110,5	518	363	881
1985	396,8 (28.8)	95,9	492,7	414	906,7
1986	352,4 (27,0)	115,1	467,5	411	878,5
1987	409,6 (21,7)	86,0	495,6	386,4	882,0
1988	404,8 (22,0)	90,3	495,1	437,9	933,0
1989	417,8 (21,6)	73,9	491,7	433,1	924,8

*PERD: Panel on Energy Research and Development
**To eliminate double counting, the amount for industry includes only self—funded activities. The large, provincially-owned electric utilities are included under industry.
Sources: EMR, Office of Energy Research and Development; Government of Canada, Statistics Canada, Science Technology and Capital Stock Division, *Industrial Research and Development Statistics* (Catalogue 88–202), 1981 to 1988.

implementing the Program on Energy r&d which continues to be the Federal Government's cornerstone of investment in energy r&d in all areas except nuclear (CANDU) fission. The Panel establishes the strategic direction for the Program and allocates resources to energy r&d activities on the basis of established priorities and strategic directions.

Comparing Tables 8.5 and 8.6, we see that the major part of these funds go to research on nuclear fission coordinated by AECL which receives its budget directly from Parliament.

The most important federal energy r&d performers are AECL, the Panel and the Ministry of Energy, Mines and Resources, where the Mineral and Energy Technology Sector get slightly more than half of Panel funds. For university research, the main source of funds is the Natural Sciences and Engineering Research Council (NSERC).

Concerning Panel funds, on the basis of Table 8.5, we can distinguish three periods in the evolution of the federal energy r&d budget allocation. The first period covers the years 1975–1980, during which the Panel concentrated more than half of it's resources on renewable energy and conservation, followed by oil sands and heavy oil which received seventeen per cent of the $142 million distributed by the Panel over this six year period. These three domains translated into r&d measures the objectives of conservation and enhanced production of petroleum put forward by the government in *An Energy Strategy For Canada* published in 1976.[30] During this period, energy r&d accounted, on average, for fifteen point eight per cent of the total r&d budget of the federal government.

In addition to doubling the budget of the Panel in 1977–1978, the federal government also gave additional funds to NSERC with the stated requirement that these new resources be used to support university research in areas of national importance of which energy was one. Accordingly, NSERC created, in 1977–1978, a Strategic Grants programme focused on environmental toxicology, oceans and energy.[31] From $2.3 million, the budget gradually rose to $32.3 million in 1984–1985 and the number of eligible sectors rose to eight, energy always remaining the most important sector in terms of allocated funds (fifty-four per

Table 8.5
Allocation of panel on energy r&d resources for the 1975–1990 period (millions, current dollars)

	Energy efficiency	*Oil sands, heavy oil, coal*	*Fusion*	*Renewable energy*	*Alternative fuels*	*Conventional energy**	*Coord-ination*	*Total*
1975–76	0,114	0,410	0,0	0,0	0,429	0,0	0,020	0,973
1976–77	1,977	3,017	1,909	1,150	0,938	1,716	0,160	10,867
1977–78	4,957	4,017	1,090	4,915	2,179	2,680	1,025	20,863
1978–79	8,408	5,417	1,450	10,236	2,959	3,860	1,238	33,568
1979–80	7,902	5,417	0,310	15,427	3,054	3,830	1,388	37,328
1980–81	7,607	6,136	0,310	15,574	3,750	4,722	1,238	39,337
1981–82	15,290	8,479	2,884	21,355	14,936	10,008	4,996	77,948
1982–83	26,850	12,421	5,200	28,500	34,418	12,691	3,054	123,134
1983–84	32,290	16,747	10,329	36,141	35,526	29,302	2,234	162,569
1984–85	33,785	20,575	7,767	39,680	35,003	29,584	1,790	168,184
1985–86	18,100	20,132	9,492	20,067	22,102	22,612	1,751	114,256
1986–87	16,374	22,740	8,935	10,149	17,991	22,082	1,291	99,562
1987–88	15,316	21,404	8,374	8,281	15,136	19,195	1,108	88,814
1988–89	15,828	21,332	8,374	9,001	14,219	19,143	1,180	89,077
1989–90**	15,854	11,189	8,374	11,397	22,635	18,463	2,186	90,098

*Includes oil, natural gas and electricity.
**Changing definitions of categories moved oil sands and heavy oil in "alternative fuels.
Source: Energy, Mines and Resources Canada, Office of Energy Research and Development.

cent in 1979, when three sectors were eligible and twenty-nine per cent in 1983, when eight sectors were eligible). With this programme, the federal government's energy r&d policy was thus extended to cover basic research in order to develop scientific expertise in energy areas of potential importance in the long term. (Of course, one should recognise that considerable activity in energy-related research was already well-established in Canada's university research community). It also assured the continued training of scientists in a sector of national importance. In order to secure a certain relevance to industrial needs, however, fifty per cent of the members of the evaluation committees for strategic grants on energy were drawn from industry – the highest proportion of all the strategic grants committees.[32] Analysis of strategic grants awarded in bioenergy and solar energy revealed that it contributed to an intensification of research in these fields.

The second period runs from 1981 to 1984, and follows the implementation of the National Energy Program of 1980. While still concentrating on renewable energy and conservation, the Panel gave new priority to research on new liquid fuels for transportation – such as natural gas, alcohol, gasification and liquefaction of biomass and coal – which was the main consumer of petroleum.[33] During this period, the budget of the Panel grew rapidly from $39 million in 1980 to $78 million in 1981 and $170 million in 1984. This raised the part of energy r&d in the total r&d budget of the federal government to an average of twenty per cent for this period, with a peak at twenty-two per cent in 1983. All sectors were beefed up and nuclear fusion r&d came of age during this period, so to speak, with the construction of a Tokamak reactor at Varennes near Montreal, a joint project of the federal government and Hydro-Québec. This project originated from a group of researchers from Québec which, after years of negotiation, convinced the Panel and NSERC to define a national fusion programme and to fund a magnetic confinement apparatus to gain knowledge on fusion in anticipation of when commercial fusion reactors will appear.[34] Research on inertial confinement is also going on in NRC laboratories on a smaller scale. Later on, a fusion

Table 8.6
Energy r&d Expenditures by Federal and Provincial Governments (millions, 1989 Canadian $)

	Fossil fuels	*Fission/ Nuclear*	*Coal*	*Renewable energy*	*Supporting* technologies*	*Conservation*	*Fusion*
1978	83.3	213.7	37.1	51.3	5.6	31.3	7.9
1979	82.0	192.8	29.2	57.1	13.4	31.2	7.3
1980	61.6	187.5	23.6	59.3	10.5	40.9	9.9
1981	71.7	173.8	30.1	92.1	9.8	59.9	10.3
1982	105.0	216.6	44.6	76.9	14.9	69.8	9.5
1983	160.6	213.4	49.2	84.4	24.3	87.8	15.3
1984	271.7	202.7	44.0	66.1	19.7	88.2	10.0
1985	158.8	219.3	36.1	39.0	10.5	92.3	12.9
1986	204.3	208.5	56.4	22.7	9.5	37.4	12.7
1987	156.9	173.9	30.7	19.4	8.1	37.7	19.8
1988	144.5	149.8	36.2	17.7	6.3	40.0	18.5
1989**	144.0	149.4	36.3	17.6	6.2	39.7	18.4

*Analysis of energy system and others.
**Estimated
Source: International Energy Agency 1991 *Energy Policies and Programmes of IEA Countries – 1990 Review* Paris OECD

fuels technology group was established jointly by Ontario Hydro, and the Ontaria and the federal governments. Both the Varennes group and the Toronto are also involved in international collaboration and participates in feasibility studies for the ITER project, an international project for a magnetic confinement fusion reactor.

The third period, from 1985 to 1990, began with the election of the Conservatives in November 1984 and was characterised by major cutbacks in energy r&d and the abandonment, in 1985, of the National Energy Policy followed by a stable distribution of energy r&d investments. A major objective of the new government was to diminish the budget deficit and reorient the energy r&d activities. The government's deficit reduction program resulted in the significant reduction to Program of Energy R&D's (PERD) budget. As well, the National Research Council's portion of PERD funds was eliminated and reallocated to other departments. This had a major impact on the r&d subject areas that were the responsibility of the NRC (e.g. conservation, hydrogen, renewable energy and fusion). These activities were subsequently sustained at minimum viable levels from the PERD Program budgets of EMR and AECL. Between 1985 and 1987, energy conservation and renewable energy budgets diminished by fifty per cent and seventy-five per cent respectively. The budget of the Panel was reduced by thirty-three per cent in 1985 and by a further sixteen per cent in 1986. It decreased slightly in 1987, where it was stabilised, in current dollars, which indicates, of course, a decrease in real money. The proportion of the federal energy r&d administered by the Panel decreased from forty-one per cent in 1984 to only twenty-seven per cent in 1986 and even lower, at twenty-two per cent, in 1987.

It should be noted that the activities in this area are supportive of the economic development, energy diversity and environmental policies of the government. A significant portion of the activities in this sector are designed to ensure that exploration, production and utilization these resources are carried out in ways that minimize the damage to the environment.

In 1989, some sectors were redefined and oil sands and heavy oil research was moved to the 'alternative fuels' rubric. The increase of that sector is thus more apparent than real and does not constitute a major shift in priorities. In the near future, environmental concerns will likely bring an increase of investment in alternative fuels through the Canadian government's commitment to decreasing carbon dioxide emissions. The Green Plan, an important $6 billion environmental programme, also provides funds for projects devoted to energy research and represents another significant source of funding .

If we compare the distribution of the Panel's funds with the distribution of the total amount of money invested in energy r&d by the federal and provincial governments (Tables 8.5 and 8.6), we can see what the real effect of the Panel has been on energy r&d policy. The Panel has been highly successful in directing r&d to those areas which are of vital importance to Canada (e.g., regulations, health and safety standards, longer term energy supply options, etc.). PERD has increased the size and scope of all energy r&d activities in Canada, the variety of possible approaches, the pool of expertise available to explore the research, the mechanisms by which r&d can be accomplished and the ability to undertake the project.

In order to stimulate r&d in industry and the diffusion of innovation, the federal government instituted, in 1972, a contracting-out policy limiting the amount of r&d conducted within government laboratories.[35] In the case of energy r&d, this policy stimulated contracting out thirty-six per cent of the budget of the Panel in 1976, seventy per cent in 1985 and sixty per cent in 1989. For certain programmes, such as those in renewable energies, projects which are not financed

entirely by the programme are now preferred: financial participation of firms is a requisite. From this perspective, the Mineral and Energy Technology Sector and CANMET of EMR, which, in 1991–92, received more than half of Panel funds, continued to follow the principles of the government's r&d contracting out policy. They gave funds to industry, university and other public laboratories. Whereas CANMET has facilities in coal and petroleum research, the administration of conservation and renewable energy research programmes is done for the most part without intramural r&d facilities and research is contracted out or cost-shared through contributions.[36] This strategy had the advantage of offering great flexibility in energy priorities and the possibility of relatively rapid reorientation. It's weakness, however, was the lack of stability for organisations which had to adjust their r&d projects according to changing priorities. The creation of 'centres of expertise' dealt with this problem: for example, in solar energy, four research centres in universities and one at the Ontario Research Foundation received the mandate to specialise in a sector and to offer services to industry[37] CANMET, the federal public laboratory in oil and coal, spent close to half of it's budget in contracts with industry.[38] CANMET's mandate is to find safer, cleaner and more efficient methods to develop and use Canada's mineral and energy resources. Important projects concern the development of more efficient upgrading technologies for heavy oil. As with other large federal public laboratories, CANMET has an industry-led advisory board, with a mandate to recommend how it can more adequately serve the Canadian industry.[39] Federal r&d institutions have had therefore to adjust themselves to energy priorities, as well as to s&t policy.

Through IEA, Canada participates in international r&d projects. Over the years, it has been involved in nearly fifty projects coordinated by IEA.[40] In 1991–92, for instance, Canadian organisations were active in thirteen projects contributing nearly one million dollars. More than one third of these funds go to two coal research and combustion projects, the rest covered participation in heat pumps, fusion buildings, solar, wind and alcohol research. In addition to these IEA related projects, Canada also participates with Europe, Japan, Russia and the USA in an international project on nuclear fusion, ITER. Of course, though harder to estimate, there are also international activities through the initiatives of researchers that lead to scientific projects with foreign collaborators.

The provincial role in energy r&d

As is shown in Table 8.4, direct provincial spending in energy r&d is less than ten per cent. Seventy per cent of these provincial expenditures are spent by the government of Alberta. It should be noted that these statistics do not take into account provincially-owned electricity, which are important r&d spenders: forty per cent of industry energy r&d spending came from utilities and particularly these state-owned firms. At the provincial level, the distribution of energy r&d investment is even more skewed than at the federal level, for each province depends on a particular source of energy for it's development. Moreover, the fluctuations over the years are more important than at the federal level because the r&d of the provinces depends more critically on specific projects such as the James Bay project in Québec, or the tar sands project in Alberta.

Oil sands is a vast resource in Alberta, and the province created, in 1974, the Alberta Oil Sands Technology and Research Authority (AOSTRA) to ensure the full exploitation of this resource which accounts for ninety per cent of the total energy r&d budget of the province over the period 1976–1981. AOSTRA, as a crown corporation, now funds research in processes for the recovery and upgrading of oil sands and heavy oils, and also enhanced recovery methods for conventional oils. The most important projects are performed in collaboration with industrial partners and relate to *in situ* oil sands recovery. For instance, one project involves Amoco Canada Petroleum and Petro-Canada in an air-steam injection project at Gregoire Lake. AOSTRA also has programmes which offer funds for university researchers and develop projects in collaboration with the Alberta Research Council. AOSTRA is considered by the federal government as the principal source of funds for research on oil sands. The Alberta Research Council is also involved in energy research in coal and hydrocarbon processing. The Alberta Office of Coal Research and Technology assists the coal industry. Saskatchewan and Manitoba have also devoted r&d spending in similar domains.

By contrast, the province of Ontario depends heavily on nuclear energy with it's 17 reactors generating (in 1986) forty-five per cent of it's electricity – and eighty-six per cent of Canada's total nuclear electricity, which accounts for sixteen per cent of the total production of electricity in the country. This explains the concentration of Ontario's energy r&d on nuclear and supporting technologies (which includes transmission and distribution of electricity). In comparison with other provinces, however, Ontario also makes important efforts in the conservation and renewable energy sectors. Ontario Hydro is the most important provincial energy r&d spender for projects related to it's own electricity system. While it's mandate was, up to the 1980s, to support corporate needs, it now includes the support of 'provincial economic development, especially the electrical needs of Ontario industry'.[41] The role of the Research Division is the development of new technologies which can improve power production and utilisation efficiency. In that respect, it has important activities in the testing of products and services that use electricity. One third of it's r&d is devoted to the efficiency, reliability and safety of nuclear generating units. For instance, projects include methods and tests for the evaluation of equipment. Other important topics are the transmission and utilisation of electricity and fusion.

Québec concentrates it's efforts on hydro-electricity production and transportation. It's main research centre is the Hydro-Québec Research Institute (IREQ) which also studies fusion technology. Since the involvement of Hydro-Québec in hydro-electric megaprojects in the 1970s, the most important challenge has been the development of technologies, such as the 735kv transmission system, to permit the transportation of energy over long distances. More recently, IREQ and Hydro-Québec have had to deal with new technological challenges generated by environmental concerns, such as the installation at Grondines of an underwater line under the St. Lawrence river. IREQ also developed testing equipment used by industry. According to a recent policy statement, hydro-electricity is still the priority and r&d projects concern production and transportation of electricity, and utilisation, since its creation in 1987, in collaboration with the NRC, of the Laboratoires des technologies électrochimiques et des électrotechnologies (LTEE).[42]

In the Atlantic provinces r&d efforts are focused on coal, renewable and energy conservation projects. This great diversity of priorities among the provinces, and the fact that natural resources fall under provincial jurisdiction, calls for a constant collaboration between the federal and provincial governments which often takes the form of joint funding in projects. We have already mentioned the joint fusion projects in Ontario and Québec and there are other similar joint endeavours AOSTRA and the Canada Centre for Mineral and Energy Technology (CANMET) on the treatment of oil sands, *etc.* Some of these projects are part of international endeavours through the IEA.

During the past few years, most provincial governments have been greatly effected by growing environmental concerns: Québec, because of it's Great Whale hydro-electricity project; Ontario, because of it's nuclear projects; and Alberta, because of new norms concerning oil emissions. As a result, provincial governments have shifted their energy policy. For instance in 1990, British Columbia stated energy efficiency and environmental protection as its goals.[43]

This new context has had the effect of delaying megaprojects and upgrading conservation and renewable energy r&d projects. Thus, a new interest has emerged, for example, in small hydro plants. They have less environmental impact and their potential in Canada is evaluated at nearly 8,000 MW, concentrated mainly in Ontario (2,300), British Columbia (1500), Québec (1300) and Newfoundland (1200).[44] Utilities are encouraging private companies to develop this potential and sell them the electricity.

There are few solar energy installations in Canada.[45] In 1991, the total power generated was about 500kW. These installations are used by the Canadian Coast Guard for lighthouses, radio beacons and by railways and telecommunications companies to power remote radio repeater stations. Canadian r&d in this sector is focused on hybrid solar-diesel electric systems to reduce fuel consumption. Ontario Hydro has designed and operates (since 1986) the largest facility, a 10 kW solar diesel plant at Great Trout Lake. According to the Canadian Photovoltaics Industries Association, there are 47 suppliers of photovoltaic equipment and information. Actual projections to the year 2000 do not expect installed solar energy potential to rise substantially. In Canada, the harnessing of wind energy has been more important than solar energy, the National Research Council having been the main actor of r&d in this sector. EMR estimates the installed capacity in the country at about 7.5 MW. Research has concentrated on the vertical axis turbine, the most important of which is a 4MW engine installed at Cap Chat, some 400km north east of Québec city. Of the fifteen installations, three are in Prince Edward Island at the Atlantic Wind Test Site (for a total of 600 kW), six in Alberta (350 kW), two in Ontario (200 kW) and two in Québec (65 kW at Kuujjuaq), with the other two being in the Northwest Territories and on Bell Island.

Though Canada is not the ideal place for geothermal energy, r&d in this sector focuses on energy extraction systems and support for technology and engineering developments. Two projects using underwater energy sources for thermopumps are in operation: one at Carleton University in Ontario, and the other at Springhill, Nova-Scotia.[46] In a related sector, a tidal energy power plant of 20MW was constructed in 1984 at Annapolis in the Bay of Fundy. Overall, one can conclude that provincial and federal governments follow developments in all major alternative energy sources, though they are expected to play a minor and mainly complementary role in the energy matrix of Canada.

Of course, Canadian universities are active in all sectors of energy r&d. If we take their participation in NSERC's energy strategic grant programme as a measure of their activities, we see that among thirty-four participating institutions, only one third are responsible for two-thirds of the projects over the period 1978–1985. Among them, the University of Toronto is the most active and is present in all sectors of energy research, followed by the Universities of British Columbia, Waterloo, Alberta and McMaster. Like Toronto, these institutions cover a wide spectrum of sectors and conduct research in renewable, oil and gas, conservation, storage, coal and nuclear. Others are more concentrated in their specialities as with the University of Calgary which focused more than half of it's projects on petroleum related research, and Québec's Institut national de recherche scientifique-Energy which concentrates on nuclear fusion, while fission research is being concentrated in Ontario, the only province extensively deploying the CANDU reactor. Coal research is undertaken essentially at the Technical University of Nova Scotia, Queen's, and the Universities of Toronto and British Columbia. Research on electricity is found mainly at McMaster, Laval University and Ecole Polytechnique. Renewable energy research is going on in most institutions. Over all, one can say that, except for the largest institutions which cover all fields, expertise in universities tends to correlate with provincial needs in energy.

Energy r&d in industry

A fluctuating commitment to energy r&d is also visible in industry. Whereas the federal government can pursue long term objectives, industry is driven by the market. Through the federal r&d contracting out policy, industry carries on research for the federal government. In addition to these funds obtained for specific r&d projects, industry invests it's own money in energy r&d. Table 8.4 reveals that industry, including utilities, performs close to half of Canadian r&d in energy. As Table 8.7 shows, the major research commitment was on technology related to the production of petroleum.[47]

Though its contribution to energy consumption has fallen from sixty-one per cent in 1973 to thirty-six per cent in 1986, fossil fuels are still a strategic source of energy .The federal government and the province of Alberta invest important amounts of money in this sector – especially after the implementation of the National Energy Policy in 1980. In response to the growing cost of energy, industrial investment in conservation technologies grew steadily between 1977 and 1984 to augment the efficiency of the production processes and of transport vehicles. On the other hand, industry's research on new energy was rather limited

Table 8.7
Energy r&d expenditures by industry (millions, current dollars)

	Fossil fuels	*Nuclear*	*Coal*	*Renewable energy*	*Supporting* technologies*	*Conservation*	*Total*
1977	72.8	6.9	0.7	6.2	21.1	5.3	113
1978	85.8	13.3	4.9	5.5	30.9	20.7	161.1
1979	108.4	–	5.4	5.6	44.5	22.7	186.6
1980	134.7	20.1	3	6.3	51.3	44.3	259.7
1981	255.7	19.9	11.5	18.2	59.2	38.1	402.6
1982	239	33	7	17	61	47	404
1983	179	41	6	16	51	54	347
1984	181	48	9	18	65	50	362
1985	220	45	7	21	69	58	420
1986	159	58	12	51	77	65	422
1987	114	47	11	22	91	65	350
1988	121	33	11	20	175	78	438
1989	114	30	11	19	158	101	433

*Includes transportation and transmission, others.

Source: Statistics Canada. Science Technology and Capital Stock Division. *Industrial Research and Development Statistics*. 1977 to 1988.

and the government invested in this sector specifically to help this young industry finance and commercialise it's products.[48]

In the nuclear domain, industry concentrates it's investment on uranium exploration and production, but the main actor in this sector is the federal government which, through AECL, maintains the technical base for Canada's nuclear reactors. This is probably the sector in which the government will have the most difficult choices to make, as only Ontario is really dependent on this technology. Coal research is another important sector that has been neglected by an industry that does not possess sufficient r&d resources. However, coal is considered a potentially important source of diversification and it's use has been increasing over the last ten years, contributing thirteen per cent to energy consumption in 1990, compared to only five per cent in 1973. Accordingly, the federal and provincial governments have invested in this sector to help in the modernisation of the technology in order to ensure clean burning of coal.

Over the last few years, the pattern of investments in energy r&d by the industrial sector has changed. First, due to the oil price decreases, industrial research on fossil fuels has slowed down drastically since 1985, contributing to a decline in industrial commitment to energy r&d. Secondly, r&d investment is larger in supporting technologies, because of the role of provincial electric utilities. Thirdly, r&d in conservation is increasing.

In 1989, seventy per cent of energy r&d was performed in three industries: electrical power, refined petroleum and crude petroleum (including oil sands/heavy oils).[49] R&D spending in electrical power was performed by provincial electrical utilities. In the petroleum industry, the two most important performers are Petro-Canada, a state-owned firm, and Esso Petroleum.[50] Petro-Canada r&d projects involve extraction of heavy hydrocarbons and their processing.[51] Esso Research Centre is performing research on subjects related to Esso's business.

Conclusion

In addition to helping industrial sectors which cannot by themselves invest sufficiently in energy r&d – like coal and new energy related industries – or to invest in sectors considered as particular to the Canadian situation in terms of natural resources – like tar sands – or in terms of scientific and technical capability – like the vertical axis wind turbine developed by the National Research Council – the role of the federal government energy r&d programme is conceived in terms of achieving longer terms goals, such as energy self-sufficiency and diversification of it's energy source in order to become less dependent on non-renewable energy sources. Recently added to these goals was the question of environmental impact of energy production and consumption.

In 1985, a government document estimated that the distribution of energy r&d investments in the public and private sectors showed a reasonable equilibrium between short and long term objectives. Though this statement was probably true for the private sector, it is doubtful that the government cutbacks in energy r&d implemented that same year, left the public sector with a balanced programme.[52]

Whereas the private sector's investments are legitimately targeted at short term goals, the role of the government should be to provide for longer term options. It is therefore doubtful that further diversification and less dependency on oil will be achieved by reducing budgets in new energy and conservation technologies. In fact, except for the nuclear energy sector, the distribution of the federal government's investments in energy r&d in 1986 had the same structure as that of the private sector, and reflected the government's economic renewal policy with it's emphasis on short term economic benefits. Moreover, given that about sixty per cent of the budget of the Panel on Energy r&d was contracted out to industry, the reductions have had more effects on the private than on the public sector and contributed very little to 'economic renewal'.[53]

Though this general survey of the emergence and development of energy r&d policy in Canada is not intended as an evaluation of the policy itself, or of its benefits[54], one cannot fail to observe that the effective role of the Interdepartmental Panel on Energy r&d was less to drastically reorient the priorities of the mid-1970s in the face of a crisis situation than to open new avenues without disturbing the existing distribution of power among the departments and agencies active in the energy sector. AECL, for instance, was not really affected by the Panel's decisions. Moreover, being less entrenched in the governmental structure than the individual departments, the Panel was more susceptible to seeing it's budgets reduced. And the effect of these restrictions could only be to diminish the degree of coordination among the various projects and to weaken the sectors of energy r&d which were depending on the Panel's budget. In fact, in order to really strengthen the coordination of energy r&d at the federal level, the Panel should be responsible for the effective coordination of all the energy r&d related budget instead of the twenty-two per cent left in 1989.

The problem of energy r&d policy is part of the larger problem of the appropriate governmental organisation for horizontal activities which pass through the usual departmental and vertical structures. As the case of the Ministry of State for Science and Technology (MOSST) has shown [55], coordination faces the obstacle of the autonomy of each department which does not want to lose control of a part of it's mandate, be it of broad and horizontal interest as science, technology or energy. From this perspective, the solution adopted for energy r&d policy in Canada – an Interdepartmental Panel with it's own funds – is certainly a more appropriate structure than a MOSST without a portfolio for real coordination of s&t activities at the federal level. In matters of long term planning, however, Canada is ill-equipped since the dismantling, in 1992, of the Science Council, the only independent organisation that existed to think about long term scenarios for research and development. Without a proper institution to plan the future of energy r&d as part of a coherent s&t policy, or for that matter an industrial strategy, energy r&d will continue to be defined only through the energy policy.

Notes

1 Thanks to Jacques Rivard and Elaine Gauthier who assisted us in the different phases of this research. Thanks also to M. Gilles Mercier of the Office of Energy r&d in Ottawa and Jean-Marc Carpentier for providing us with information on energy r&d.

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Chapter 9

Canada in space

Ron Freedman and Jeffrey Crelinsten

Introduction

From the outset, Canada has had a stature in world space research that is far beyond the siz
its technical infrastructure or its gross domestic product ... Canadians have ventured i
space half out of curiosity ... and half from economic practicality.[1]

The story of Canada's involvement in and with space is about the interplay b
tween curiosity and commerce. This is a recurring theme in Canada's pro
space history and had its origins far earlier than most people would imagine.

We can trace Canadians' interest in space over 150 years to the early part of t
19th century. The first magnetic observatory in Canada was established in 183
almost three decades prior to Confederation. Working from a site on t
grounds of the University of Toronto, Sir Edward Sabine used data from statio
in Toronto, Madras, Melbourne and St. Helena to determine that 'magnetic di
turbances occurred world-wide and were related to the number of sunspo
which varied with an eleven year cycle[2].

A number of unique geographic features made Canada's interest in space a
most inevitable. Canada is 'home' to the north magnetic pole, making the cou
try a focal point for map making, for centuries. It is also a locale of the spectacul
aurora borealis ('northern lights'), a scientific phenomenon which has intrigue
humankind throughout the millennia. The aurora results from the interaction
charged particles, arriving from the sun, with the upper atmosphere, the ion
sphere. Finally, the sheer vastness of the country imposed a reliance on space l
early explorers, who depended on the sun and stars to help them position ther
selves and draw maps of the sprawling, often featureless land.

The 1882–83 International Polar Year was the first time that organised scient
ic observations were coordinated on an international basis. The IPY researc
programme included measurements of the meteorological, magnetic and a
roral phenomena in northern Canada. A second IPY was established in 1932, ar
used new scientific equipment, including kites and balloons, to take measur
ments high above Earth's surface. For the first time, radio was used to commu
icate scientific measurements taken at different sites. Long hypothesised l
scientists, the correlation between solar radiation and the ionosphere was der
onstrated during the solar eclipse of 1932, in southern Canada, when radio tec
niques were used to measure the movement of the ionosphere[3].

As with much of technology and science, space and related research
Canada received a boost during and after World War II. Scientific interest in tl

Science and Technology in Canada

Editors:
Paul Dufour
and
John de la Mothe

LONGMAN

The classical structure and strategy of firms that resulted in the separation of marketing and research is no longer successful. There is a merging and integration of technology, marketing, sales and the shop floor within a firm and a new awareness of a firm's responsibility for stewardship of fragile natural resources. Universities and community colleges are increasingly being drawn into a larger and denser network of knowledge institutions that extends deeply into industry, government and society, well beyond national boundaries. Governmental structures, programs and policies are shifting their focus towards activities that are more enabling, diffusion and innovation oriented. Global vision and interaction is becoming commonplace.

This review is a snapshot of the Canadian science and technology system during this vital global transformation. It is a case history for those interested in the interplay of science, technology, innovation, economic restructuring and performance, social and cultural aspirations and rapidly changing trade regimes. It provides an opportunity for the practitioners of science and technology policy to observe the process of re-orientation and renewal.

This review is of more than national interest. The issues herein are being fiercely debated by many other nations of the world. Canada, in its push to foster innovation and more effective deployment of science and technology, has launched new mechanisms, new programs, and new policies that will be of interest to many readers. This book provides insight to the evolving structures of a science and technology system in a country that is undergoing a dramatic transformation. Patterns of public and private investment in science and technology are changing, there are experiments with new institutions, such as networks of centres of excellence that bring together university, industry and government researchers, there are new partnerships between business and education. At a different level is the increasing presence of sub-national entities in science and technology in the restructuring of educational and research structures.

At the time of writing this preface, Canada was drawing to a close an exercise that may well lead to further change. Launched in 1991, a year-long 'Prosperity Initiative' spearheaded by an independent steering committee has functioned in a broadly consultative manner in order to examine means of enhancing Canada's prosperity. A key actor in this examination of competitiveness and learning was a national Task Force on Science and Technology and Related Skills. As Co-Chairman of this Task Force, I was deeply embroiled in debates on how we might better nurture and deploy science and technology for national, and, indeed, global well-being. The recommendations of the Task Force reveal the views of a diverse group – including educators, entrepreneurs, research managers, students – that effective use of the new determinant of growth – knowledge – requires change in three essential areas:

- creating advantage with people
- fostering a climate for innovation
- initiating institutional renovation

Of these, the most profound and far reaching are the proposals for renovation and renewal of institutions that enhance public participation in and support of the policy-making process. There is recognition of a need for a comprehensive and accessible policy research capability grounded in professional interpretation of information and comprehensive data and meaningful international comparisons. All are essential for effective decision-making and well-founded, public dialogue – public dialogue that is a vital force in those nations that profit from their investments in science and technology.

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PD/JdlM
Stowe, Vermont