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ENVIRONMENTAL SCIENCE AND TECHNOLOGIES TO SUPPORT CANADIAN INDUSTRIES: EARLY OPTIONS VOLUME 3 - SCANNING REPORT

REVIEW DRAFT

ENVIRONMENTAL SCIENCE AND TECHNOLOGIES TO SUPPORT CANADIAN INDUSTRIES: EARLY OPTIONS VOLUME 3 - SCANNING REPORT

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1. THE STORY OF A NEW TECHNOLOGY

In 1970, the United States passed the Clean Air Act, also called the "Muskie Act". This called for reductions in three major automotive pollutants -- carbon monoxide, hydrocarbons, and nitrogen oxide -- to 10% of their 1970 levels. The technology for achieving such reductions was entirely unknown at the time the targets were set. despite this fact, the Japanese government adopted the legislation in its entirety.

Both the United States and Japan established committees of experts to select critical technologies for achieving the target. (In the American case it was the Academy of Science.)

In Japan, the key issue was identified as reduction of lead content in gasoline. This was achieved by 1975, and made the development of technologies to comply with the targets directly much easier.

Initially, Japanese manufacturers were strongly motivated by the presence of the U.S. standards. When the U.S. government began to slip the implementation dates, they began to lose interest.

Only domestic political pressures kept them going, coupled with a break in the ranks of the manufacturers themselves as to whether the critical technologies could be produced.

The research laboratories produced a whole range of technological solutions, and the dissemination of information on these critical technologies was the key factor in pushing ahead the work of converting the industry to meet the higher standards. In particular, scientific research on the fuel combustion process proved engineering estimates of reduced fuel economy through pollution control to be entirely wrong. Indeed, the effect of emission control research was to foster basic design changes which dramtically improved engine efficiency.

The overall result of a critical technologies selection process was that Japan met all of the Muskie Act targets years before the United States did, and improved their market share substantially in the process.[1]

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[1] This story is based on Hajime Nishimura and Masayoshi Sadakata, "Emission Control Technology" in H. Nishimura, ed., How To Conquer Air Pollution: A Japanese Experience (Amsterdam: Elsevier, 1989), pp. 115-122.

2. PURPOSE AND SCOPE OF THIS SCANNING REPORT

This report reviews the available literature and indicates the results of interviews conducted in search of strategic information and ideas on "critical" environmental science and technologies. That is, those which are likely to be most important in the future to help protect Canada's industrial sectors under challenge, to meet or exceed new environmental standards, to enter new or expanding domestic and international markets, or to meet the Federal government's own procurement needs.

The report focusses mainly, but not exclusively, on scanning for "early options" which would not require legislative or policy change, but which could test new approaches for the longer term, using existing resources.

Specifically, the report seeks:

- to determine the extent to which available literature and contacts with industry associations and Federal departments and agencies can identify some actual projects for pursuit in the next two to three years, while more in-depth studies are taking place;

- to help assess from the literature and contacts what may be the most appropriate selection process for critical science and technologies in the future.

The development of insights about each of these topics involves consideration of six key types of information:

- environmental science and technology monographs and reports;

- reports on the state of current developments in public and private sector technology centres working on environmental projects.

- environmental and industrial policy and strategy reports;

- reports on key "drivers" of technological change as a whole, including those most obviously linked to environmental impacts;

- publications and interview results which assemble the views of industries, industry associations and environmental groups regarding priorities for technology development;

- reports and interview results which convey the views of Federal departments and agencies most directly concerned with environmental science and technologies in day-to-day operations.

3. ENVIRONMENTAL SCIENCE AND TECHNOLOGY

3.1 The Nature of the Literature

There is at present no literature specifically devoted to the topic of critical environmental science and technology in precisely these terms.[2] However, many of those engaged in research and development oriented to the creation of marketable environmental products or services have at least miniature versions of critical technologies in mind. It is reasonable to assume that those working in laboratories on new products or processes envisage their widespread use and the attainment of fundamental improvements in the environment as a result.

The problem faced by policy-makers is partly how to choose amongst the competing claims about the critical nature of given developments. This may appear simple in relation to the scale of a given product or process.

The establishment of the size of the potential market, based on the current state of affairs, is a relatively straight-forward process. However, it is difficult to predict when what appeared to be a minor technology in fact, turns out to have major potential, and vice versa.

At the opposite end of the spectrum of competing claims for the importance of given developments is the number of gaps in literature and potentially in research and development itself. The theme of environmental protec-tion is beginning to come into the literature on process technology, particularly in the trade publications, but it is still very much a secondary issue. An exception is water purification and sewage treatment, obvious reasons.

There is a fairly small "intermediate" literature in between the very specific claims for individual products and discoveries, and the broad calls for "more environmental technologies".

In what follows, we will begin with the literature which seeks to identify key or critical technologies for the whole array of environmental industries and then proceed to those more sharply focussed on a given subset, such as wastewater treatment, energy conservation, and hazardous waste.

In each case, the Canadian literature will usually be presented first, followed by the international literature.

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[2] The U.S. National Bureau of Standards in Washington has developed a listing of "Emerging Technologies Critical to U.S. Industry". As well, Congress now requires the Department of Defense, as part of its budget submission each year, to submit a "critical technologies plan". This is typically a 200-page document, with 22 critical technologies in the 1988 version. See Manufacturing Engineering, Vol. 102, No. 6 (June, 1989), pp. 70-72.

At the conclusion of the section are some assessments of how best to track the future developments in environ-mental science and technologies, and what their implications for the selection of early options may be.

3.2 Comprehensive Canadian Reports on Environmental Technologies

The Task Force on Environmental Protection Technologies was commissioned by the Minister of State for Science and Technology in 1981. Its report groups technologies for further action under three headings:

- "economic opportunities", including equipment and instrumentation, industrial process development to reduce environmental impact, recycling of wastes, services, and training in Canada and abroad;
- "best commercial opportunities", comprising automated control systems, environmental services, monitoring equipment, remote data gathering, and waste control and disposal techniques for temperate and cold climates;
- "technology gaps", which range from limiting the effects of acid deposition, to personal monitoring of exposure to hazardous substances in the work place, disposal of toxic substances, noise control, and elimination of odours.[3]

In addition, the report notes that "[i]n the long run, optimal environmental management will be achieved through improved harvesting, extraction, processing and manufac-turing technologies, which avoid the problems of exis-ting technologies."[4]

The categories for sorting technologies employed by this Task Force, along with their substantive findings, should be studied carefully. It is the only exercise which parallels the current effort to choose critical techno-logies in scope and intent, although it appears to have had far fewer resources to deploy.

The Task Force limited itself to recommending broad cate-gories of innovations to be pursued. Most have not been overtaken by events.

The issue is: how much more precise than this report is it possible to get? The answer is: much more specific, although at the risk of controversy over the technologies selected.

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[3] Report to the Minister of State for Science and Technology (Ottawa: Minister of Supply and Services, 1984), pp. 23-24. The "best commercial opportunities" were those considered to have the largest immediate financial return.

[4] Ibid.

More recently, Woods Gordon have produced the most comprehensive and up-to-date Canadian study of the environmental protection industry.[5] Although restricted to Ontario, many of the findings relevant to critical technologies probably apply to other provinces as well.

The bulk of the report is descriptive, seeking to assess the status of the industry and to measure its role in the Ontario economy. However, there are implicit views on critical technologies in relation to the major areas of market opportunity for the future, and in the results from interviews of the users of environmental technologies.

The major areas of future opportunity identified in the field of air pollution control are:

- pollution control equipment for the paper and metals industries;
- continuous warning devices on underground storage tanks;
- portable gas detection and monitoring equipment;
- energy-efficient air quality monitors;
- air control equipment -- dust collectors and fans --for the woodworking industry;
- cartridge collectors and baghouses, including new and improved fabrics;
- scrubbers, especially relating to winter operation;
- consulting and process evaluation functions leading toward process improvements, rather than end-of-pipe changes, especially where these lead to reuse of sludge waste.

In relation to water pollution control and water treatment, the following are singled out for future attention:

- chemical or advanced treatments for industrial water, including ion exchange, electrodialysis and reverse osmosis;
- technologies for the replacement or rehabilitation of existing sewage treatment facilities;
- technologies for groundwater clean-up;
- instruments for monitoring and analysis of low levels of contaminants, including on-line analyzers.

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[5] (Toronto: Queen's Printer for Ontario, 1989).

Regarding solid and hazardous waste, industry people feel there are opportunities in relation to:

- o equipment for photochemical oxidation of organic contaminants as an alternative to incineration;
- o biochemical means of toxic waste destruction;
- o specialized equipment to process waste materials for recycling purposes;
- o biodegradable packaging;
- o removal of heavy metal from soil;
- o equipment for monitoring lead levels around petroleum retail sites.

As well as talking to suppliers and purchasers about areas of market growth, the consultants asked about areas of concern on the part of each group.

The pulp and paper industry informants were concerned that simple adoption of American technology for extended aeration and sludge treatment would not work well in Canadian conditions.

For example, in Northern Ontario, biological activity involved in extended aeration works for as little as six weeks per year. Moreover, this industry is concerned about the capacity of available technology to remove all toxic material, e.g., chlorinated hydrocarbons, from effluent.

The petroleum refining companies find it necessary to design all their own water treatment facilities, sulphur plants and soil clean-up projects. They have to import much of their instrumentation and analytical equipment at present.

The chemical industry finds pollution control to be a difficult task because most manufacturing processes still leave trace levels of reactants. Scrubbers may remove them from the air, but produces contaminated water. Biological treatment of water effluent presents the need to dispose of sludge and of "bugs" that remain suspended in run-off.

3.3 References to Environmental Technologies in Larger Canadian Reports

Environment Canada recently published the booklet Backyards to Borders, which covers a variety of specific initiatives by that department.[6]

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[6] Subtitled Federal Environmental Action in Canada's Communities (Ottawa: Minister of Supply and Services, 1988), "Promoting Canada's environmental industries".

A new Chair in Environmental Engineering has been created at McMaster University, as a result of a partnership between the Natural Sciences and Engineering Research Council, McMaster, Texaco Canada, and Environment Canada. The purpose of the chair is to build on Canada's reputation as a world leader in development of "clean technologies". Researchers will focus in wastewater treatment, industrial waste clean-up, and management of toxic chemicals.

The report also highlights Canadian work to develop fuel oil from sewage sludge. Dried sludge is heated to 350 degrees Celsius in an oxygen-free environment. A usable fuel oil is the major by-product. Pilot-scale tests having proved successful, the next stage is a full-scale demonstration at a regular operating sewage treatment plant.

3.4 International Reviews of Environmental Technologies

In 1986, six different Swedish government agencies collaborated to prepare a statement of what are effectively critical science and technologies from a Swedish perspective.

The report, Research for a Better Environment, has four major sections:

- research on environmental problem description and risk assessment;
- research and development aimed at prevention and resolution of environmental problems;
- methods of improved environmental protection and natural resource management;
- responsibility, cooperation and resource requirements for environmental research and development.[7]

Within the overall assessment, the following emerge as key Swedish priorities:

- minimum-environmental-impact cellulose technology, with particular emphasis on reduced emission of chlorinated organic substances;
- minimum-environmental-impact mining methods, with emphasis on reducing/disposing of mine waste;
- methods of neutralizing discharge of nitrogen compounds in municipal sewage effluent;

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[7] Subtitled An investigation of the need for environmental research in Sweden (Stockholm: National Environmental Protection Board, 1986), pp. 68-69.

- development of new manufacturing processes with reduced environmental impact;

- low-environmental-impact road vehicles, traffic technology innovations, and more environmentally-sensitive road construction technology.

The report notes a paradox about development of new environmental technologies. In order to formulate requirements for regulating discharges and emissions, there must be a way of meeting the regulation within reasonable economic limits.

Yet companies are not willing to undertake development and manufacture of new technologies unless the regulations are in place to require their purchase. In the view of these Swedish bodies, this situation leads to a need for State support for prototype and demonstration installations.

It is clear that as well as Sweden, Finland is making a strong push to develop and to market clean technologies.

Environmental High-Technology from Finland is intended to showcase a variety of Finnish developments.[8] It covers the following fields: food processing; pulp and paper; chemical production; building construction; metals production; electricity and heat generation; waste treatment; process automation for waste treatment; and a few smaller items.

The approach of the publication could well be emulated by Industry, Science and Technology Canada in presenting Canadian products and services. It briefly describes each problem to which new technologies are addressed.

Next it outlines the conventional solution and the clean technology alternative. Finally, the book indicates the comparative economics of the two solutions and gives a "summary and outlook" on the technology and when it will be available. A comprehensive listing of Finnish contacts is also provided, along with fairly extensive photos and diagrams. At the end, there are summaries in French, Swedish, German, Russian and Spanish.

Since the document is intended to market all of the technologies, it does not even attempt to say which are more critical than others.

Of especial interest to Canadian firms as potential competitive products are those for the pulp and paper, basic metals production and waste treatment. There is nothing of a startling nature in the book, although all the technologies appear to have distinct niches to fill.

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[8] Prepared by Mexpert Consulting Engineers Limited, subtitled Handbook of Low-Waste Technology (Helsinki: Ministry of the Environment, 1986). See pp. 8, 15, and 127.

At the back there is a useful status report on each innovation by industrial branch, showing developer, whether production is at pilot-plant or full-scale stage, applications, volume of emissions, and materials balance.

The report concludes with is a brief history of the development of clean technologies in Europe, beginning in 1976 with work by the United Nations Economic Commission for Europe.

In 1984, the European Community prepared a review of the previous decade of environmental cooperation among the members entitled Ten Years of [European] Community Policy on the Environment.[9] While it is cast in fairly general terms overall, the report does make it clear what the consensus of Community members on the critical technologies are:

- o techniques for regulation of heavy metals, including lead, mercury, cadmium, nickel, chrome, and arsenic;
- o methods of controlling the impacts of chemical products;
- o clean technologies generally, with emphasis on chemicals production, metal coatings, food processing, pulp and paper, textiles, and tanning.

Of particular interest is the major conference on clean technologies which the Community held in 1980, at The Hague, of which the proceedings have been published.

In March of 1985, the U.S. Council on Environmental Quality presented a Report on Long-Term Environmental Research and Development setting out priorities for long-term environmental research.[10]

Most of the priorities were quite predictable, and did not relate directly to the selection of critical technologies for the environmental industries.[11]

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[9] (Strasbourg: Commission of the European Community, 1984), pp. 58-60. [Translation]

[10] Executive Office of the President, (Washington: U.S. Government Printing Office, 1985), pp. 6-11 and IV-12 to IV-13.

[11] They included: monitoring environmental systems; molecular epidemiology and exposure estimation relating to toxic chemicals and their effects on human health; geohydrological processes occurring in hazardous waste sites; genetic diversity and susceptibility to toxic chemicals; toxicity of mixtures of chemicals;
anticipating the environmental impact of emerging technologies such as genetic engineering and the production of micro-electronic chips.

In addition, the report called for work on: fresh water, ocean, and atmospheric cycles; intermedia transfer of pollutants, e.g., from air to water; assimilative capacity of different types of waste; global biogeochemical cycles; impact of global pollutants on ecological processes; fundamentals of ecosystem structures and processes; and quantitative risk assessment.

The most interesting comments in the report were those concerning the need to mitigate the impacts on the environment of current pollution control technologies.

The placement of waste sludges in either landfills or in liquid form on soil may result in soil and groundwater contamination. As well, the report calls for additional work on decontamination of groundwater, dechlorination techniques, and waste recycling and reuse, among others.

The main problem with the report is that there is scarcely a topic on which it does not call for more research in the future. If truly intended as advice to the President, it would leave him almost entirely at a loss to allocated resources.

3.5 Environmental Technologies and Industrial Processes: "Clean Technologies"

One of the key problems in approaching the literature on environmental science and technologies is the fragmen-tation of the topic according to the particular disciplines, problem areas, and even pieces of equipment involved.

While this fragmentation is by no means unique to the environmental field, it is perhaps most difficult to accept in that the related nature of phenomena is at the core of the endeavour.

Strategy of Pollution Control, a textbook by two University of Wisconsin professors is both integrative and easy to understand.[12] It seeks to present "principles applicable to all areas of environmental pollution control." It was specifically developed for a multi-disciplinary course.

After showing the very large magnitudes of resources required to sustain even a city of a million people, per day, and the tons of pollutants it produces, the authors go on to point out why there cannot be a "zero emissions" society or city. "We must face the cold hard fact that our activity has a net damaging effect on the environ-ment, regardless of our good intentions."[13] They go on to indicate that it is not possible to deal with air, water, or land pollution by itself.

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[12] P. Mac Berthouex and Dale F. Rudd, (New York: John Wiley and Sons, 1977).

[13] Ibid., p. 4.

The authors believe that the core of the pollution problem can be revealed first by assessing the flow of materials, through a "materials balance" of inputs and outputs, and then by tracing the energy flow. Together, these show the entirety of the pollution situation.

The essence of successful pollution control strategy is "... the transformation of pollutants into other materials by chemical reaction." The use of chemistry seeks to achieve one or more of three objectives: to change the potential effluent into a material too valuable to let escape, changing waste into a secondary source of raw material; failing this, to change the material so that it can be released into the environment without damage.

Failing this, one would seek to alter the dangerous material so that it can be separated from the bulk of more innocuous material to be released.[14]
The chemical-processing industries have an "arsenal of heavy duty chemical reactions that are particularly useful in the design and development of environmental protection systems."[15]

An example from the book is the replacement of the original process for making sodium carbonate, which created a tremendous amount of pollution. It was replaced with the "Solvay process", which now provides two-thirds of all sodium carbonate required in the United States, with dramatically less pollution, and at less cost.

As well as chemical processing, there is also the potential to use living organisms to process waste, as when waste sulfite liquor from paper-making is converted into alcohol by microorganisms.

In addition, effective strategies for pollution control need to take into account the rules for separation of materials, namely that materials can be separated from one another only if they differ in some chemical or physical way.

The greatest efficiency of operations for pollution prevention and control can be achieved if they are integrated into a complete system. That is why "clean technologies" are preferable to "end-of-pipe" technologies and are likely to supplant them over time.

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[14] This viewpoint is reenforced by recent articles such as that in the "News Focus" section of Chemical & Engineering News which quotes George Muhlbach head of environmental programs at Ciba-Geigy as saying that the future will see much more specific changes in the manufacturing process itself and less end-of-pipe treatments. "Most of the waste reduction will be done with additional in-process changes and by changing the chemical used... We have specific programs for our research and development people to address the whole process from the point of view of reducing the waste stream." Vol. 67, No. 31 (July 31, 1989), p. 14.

[15] Ibid., p. 16.

For example, a given non-integrated system in Germany cost $433,000 a year to operate; this was reduced to $79,000 through integration of new and existing facilities, materials flow and separation, and integration of energy sources and demands.[16]

Finally, the authors note that because action on pollution affects various interests in different ways, there is a major political element to successful anti-pollution strategies.

Because Strategy of Pollution Control is a textbook and is now somewhat out of date, it is not very valuable as a source of current critical technologies. However, it is an essential guide to the remainder of the literature, making sense of many more detailed and involved studies, and guiding one to the critical industries for under-pinning innovation.

The only aspect of environmental technologies about which the book does not have much to say, except by implication, is on reduction and reuse.

Covering somewhat the same ground as the above book, but with an even more practical bent is a book published by the Pollution Probe Foundation entitled Profit from Pollution Prevention.[17] This addresses the potential for both preventive and remedial technologies.

The following topics are covered:

- waste management strategy;
- pollution prevention opportunities in specific industries;[18]
- waste exchange;
- waste recovery technologies;
- waste treatment and disposal technologies.

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[16] Ibid., p. 17.

[17] Monica E. Campbell and William M. Glenn, Profit from Pollution Prevention: A guide to industrial waste reduction and recycling (Toronto: Pollution Probe Foundation, 1982).

[18] These include: dry-cleaning, electroplating, fly ash, sulphur, other solid wastes, food processing, oil, paints and coatings, photography, plastics, printing, pulp and paper, solvents, tanning, and textiles.

The book contains an inventory of "clean technologies" in actual use in Canada, the United States and Western Europe.[19] Since the main intended audience is owners/ managers of industrial plants in operation, the book deliberately avoids technologies requiring more work and testing before they can be used.

The most important section of the book from the point of view of how to select critical technologies is that on "waste management strategy". The authors contrast "conventional pollution abatement" and "waste recovery technologies". The latter attempts to achieve closed-loop systems in which process wastes are recovered and reused repeatedly on the premises.

The waste management strategy proposed employs four steps:

- o reduction, through a waste audit, product reformulation, substitution of another product, more efficient equipment, process redesign, process control, and waste concentration (for example, of oil in oily water);
- o waste recovery, through recycling, reuse for other purposes, inter-industry exchange, and the combination of specific wastestreams in a way that allows one to neutralize another;
- o waste treatment, after the first two steps have been exhausted;
- o waste disposal, for the small residue left.

Just one example given in the book is a vegetable-washing system that reduces water use by 80% and pays for itself in six days.[20]

We will return to the findings of the Profit from Pollution Prevention book again as part of the discussion of policy to foster environmental industries.

Not long after the Ontario Waste Management Corporation was established, a consortium of firms under the leadership of the Ontario Research Foundation undertook a Waste Reduction Opportunities Study, focussing on reduction, reuse, and recycling.[21]

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[19] A similar inventory from and American perspective, but in textbook format is P. Aarne Vesilind and J. Jeffrey Peirce, Environmental Pollution and Control, Second Edition (Ann Arbor, Michigan: Ann Arbor Science Publishers, 1983).

[20] More examples of how cleaner technologies are transforming industry, with an emphasis on Western Europe, are to be found in Essam El-Hinnawi and Manzur H. Hashmi, The State of the Environment (London: Butterworths, 1987). This book was prepared for the United Nations Environment Programme, and so is more general in approach. See especially p. 119.

[21] (Toronto: Ontario Research Foundation, 1983).

A major emphasis of the report is on industrial waste reduction. As the authors note, unlike most industrial decisions, "the cost of doing nothing is not zero. Yet few industrial waste reduction approaches have positive economic benefits when considered in isolation."

The report suggests that the following are among the most promising for research and development:

- o recovery of zinc from galvanizer's acid wastes;
- o use of sludge from paint wash solvent as a low-grade paint product;
- o recovery of base metals from treated electroplating sludges;
- o reuse and recycling of oily mill scales and sludges;
- o recovery technology for sulphuric pickling acids contaminated with metals other than iron;
- o alternatives to cyanide heat treating;
- o foundry sand reclamation technology;
- o recovery technologies for steel plant chromium contaminated waste water.[22]

These items amount to an illustration of the work yet to be done in pursuing the agenda set by the two major works described immediately above.

In October of 1985, the United Nations Environment Programme, and the West German Ministry for Research and Technology co-sponsored an "International Symposium on Clean Technologies". While the emphasis of this conference was on process technologies which could be applied in developing countries, there was also an opportunity for the West Germans to showcase what they had achieved.

The definition of "clean technologies" for purposes of this report included:

- o reduction of pollution generated by conventional industrial processes;
- o improvement of process efficiency, and energy conservation;
- o optimization of the use of raw materials, promoting more efficient use of natural resources.[23]

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[22] Ibid., pp. 8-29 and 8-30.

[23] Final Proceedings, Volume II: Clean Technology Practices in the Federal Republic of Germany (Nairobi: United Nations Environment Programme, 1986), pp. 5 - 7.

The latter presented recent developments in the following fields:

- o clean-technology applications in the pulp and paper industry, including wastewater-free paper production and low-pollutant bleaching of pulp;
- o a low-pollution tanning process;
- o lower-pollution cement kilns;
- o low-waste processes of metal finishing and coating;
- o low-emission technologies in the food industry;
- o pollution prevention and reduction in the textile industries, including dry cleaning and textile printing;
- o environmental management practices for metallurgy, including regeneration of used foundry sand.[24]

The question arises: if clean technologies are so obviously superior, why are they not being adopted much more rapidly, including in West Germany itself?
A major review of the attempt to implement clean technologies in OECD countries found the following obstacles to their adoption:

- o a market restricted to the establishment and modernization of plants, i.e., they cannot be readily adopted by plants which have already adopted earlier technologies, and do not need major retrofitting for other reasons;
- o limited availability of clean technologies themselves;
- o higher front-end costs, even if eventual operating costs are lower;
- o higher technological, economic, operational and political risks associated with adopting a relative untried technology;
- o lack of support from manufacturers of clean- technology machinery and equipment;
- o regulations which may implicitly encourage add-on treatment systems;

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[24] Ibid., p. 3.

- poor dissemination of technical information.[25]

Let us turn now to one of the major literatures on more specific environmental technologies, that on water and wastewater pollution prevention and treatment.

3.6 Studies of Environmental Technologies Relating to Water

As part of a larger study on water demand management, David Brooks and Roger Peters put forward twelve specific ideas for technical R&D in relation to water conservation and treatment:[26]

- demonstration of available water-efficient equipment such as faucets, for use in the residential, commercial, and institutional sectors;
- research to improve the efficiency of washing machines and dishwashers;
- development of standard methods of measuring water efficiency;
- residential-scale products to prevent overwatering of lawns and gardens;
- more water-tolerant varieties of irrigated crops and demonstration of new products for managing water use for irrigation;
- research on large-scale membrane separation and integrated waste treatment equipment;
- demonstration of recirculating cooling water used in industries or commercial establishments;
- research to redesign machine-tools and equipment that use water for washing/cooling;
- improved control systems to help plant and building managers to use water more efficiently;
- low-cost methods to repair leaks and infiltration in water and sewage systems;
- process design research in industries where water-efficient processes have not been developed;

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[25] Organization for Economic Cooperation and Development, The Promotion and Diffusion of Clean technologies in Industry (Paris: OECD, 1987).

[26] Water: The Potential for Demand Management in Canada (Ottawa: Science Council of Canada, 1989).

- o demonstrations of techniques used to improve water efficiency in irrigated agriculture in the United States, such as computer-controlled distribution.[27]

As in the case of the Task Force on Environmental Protection Technologies described above, Brooks and Peters do not make it clear in detail how they arrived at their proposals. However, the analysis which leads to them in general terms is quite well laid out.

The authors demonstrate the necessity to look at the need for innovation as part of a whole system of interrelated economic, social, and environmental factors.

Indeed, a vital service performed by the report is the provision of key dimensions of the problem, including the water-use rates of different sectors, and the regulatory and market forces which are likely to determine the rate of technological innovation.

It can be seen from their report that industrial water use is the largest, and probably most critical area for innovation by far.

From other sources, it would appear that municipal water systems are receiving more attention from a technology development perspective, although many of the elements are certainly transferable. In the field of "clean technology", industrial water use and reduction would appear to be a very good place to start.

Prepared about the same time as the Brooks nad Peters report was The Canadian Water Resources Equipment Industry: Opportunities for Research and Manufacturing.[28]

If similar ones existed for all of the environmental technologies, the work of the Sector Initiative would be rather easy. The author is associated with one of the most dynamic environmental industry firms in Canada, Zenon Environmental Incorporated of Burlington, Ontario.

Bruce Fenton provides the overall numbers on the size and scope of the environmental industry in Canada, as well as describing the competitive and technological challenges facing the water resources equipment industry in particular.

The report identifies six critical technologies and assesses Canada's competitive position in each case.

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[27] (Ottawa: Minister of Supply and Services, 1988), p. 47.

[28] Bruce A. Fenton, (Ottawa: Minister of Supply and Services, 1988).

The technologies are:

- o adsorption, in which Canada lags seriously behind the United States and Europe;
- o advanced separations technology, which is dominated by foreign subsidiaries carrying out little technology development activity in Canada;
- o biological processes, in which the equipment is generic and can be readily supplied by Canadian firms, but which are characterized by little R&D effort at present;
- o instrumentation, computer control, and plant automation, in which Canadian firms are competing well;
- o destruction or treatment of removed solids, in which the Canadian industry holds "a reasonably strong position";
- o treatment chemicals, resins and polymers, in which Canadian companies hold strong positions in relation to commodity chemicals, such as chlorine, and have a few specialty chemical firms doing innovative work.

The issue posed by the Fenton report is whether the critical technologies strategy of the future should concentrate on areas of strength or of comparative weakness.

In addition, it is important to be able to "package" information on other sectors the way that Fenton does, since reports covering all environmental technologies at once are likely to lose the main messages for specific subsectors of the industry.

Denny Parker, a leading American expert on wastewater technology has been prompted to write on the priority needs for research in this field because of the "... unanswered questions that continue to plague our practice".

In "Wastewater Technology Innovation for the Year 2000", he lists ten areas as a "personal agenda":[29]

- o sedimentation design and operation;
- o odour control in wastewater treatment;
- o control of organisms that produce foam in activated sludge systems, such as Nocardia;

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[29] Denny S. Parker, Journal of Environmental Engineering, Vol. 114, No. 3 (June, 1988).

- o reliable and low-cost small wastewater treatment facilities;
- o digester foam reduction or elimination;
- o reliable, low-maintenance digester mixing designs;
- o disinfection criteria for public health protection and shellfish production;
- o improved trickling filter processes, based on fundamental understanding of how they work;
- o attached growth system research;
- o more accurate modelling of receiving water capacities to assimilate wastes in order to avoid unnecessary advanced waste treatment systems.

These items include a mix of both critical science and critical technologies.

Parker's article is also interesting for what it says about the market for wastewater technology in the United States. According to a report prepared for Congress in 1986, there is a need for $34 billion in treatment facilities and an additional $57 billion in sewers and storm drainage systems to the year 2005.

Parker estimates the potential savings from innovative and alternative wastewater technologies at $14 billion over this period.

Another measure of critical technologies for wastewater treatment, although a retrospective one, is provided in Parker's review in the form of a list of innovations which have most frequently been funded by grants from the Environmental Protection Agency.

These include:

- o the interchannel clarifier;
- o ultraviolet disinfection;
- o land treatment;
- o oxidation ditches;
- o countercurrent aeration;
- o sequencing batch reactors.

The above list is those which have been funded twenty times or more.

In October of 1979, Canadian and German experts gathered in Burlington for the "First Canada/Germany Wastewater Treatment Technology Exchange Workshop", resulting in a report entitled Water Pollution Control Technologies for the 1980s.[30]

A key paper presented at the workshop was "Status of Biological Waste Treatment in Canada", by K.L. Murphy. It is noteworthy in that it attempts to sum up what has been learned about a particular major environmental technology over a long period of time. A 1978 survey of Canadian sewage treatment facilities found that 213 of 1028 were of the activated sludge type, but that these plants treated sewage from over half of the population served.

Murphy notes that despite the importance of the process, its heavy use, and sixty years of development work, two major problems persisted with it. These were the tendency of such systems to discharge biological solids in the effluent periodically, and the need to dispose of waste sludge at the end of treatment, a costly affair.

Various approaches to resolving these problems through technological improvements had not been very successful at the time of Murphy's review of the scene.

In 1988, the United Nations Economic Commission for Europe, in which Canada is quite active, issued a report Two Decades of Cooperation on Water on the cumulative recommendations of the Commission to its members regarding water and wastewater treatment.[31]

The vast majority of the recommendations are pitched at a very general level or are very obvious, e.g., "consideration should be given to potential health hazards especially when sewers laid in the same trench as water supply pipes are leaking."[32]

However, some of the recommendations for further research amount to the selection of critical science and technology topics for the environmental industries:

- performance of small-scale sewage treatment facilities;
- reduction or decrease of water abstraction/ consumption;
- application of water recycling and effluent re-use systems within production processes;

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[30] (Ottawa: Minister of Supply and Services, 1979), pp. 14-18.

[31] (New York: United Nations, 1988).

[32] Ibid., p. 56.

- o replacing water by other materials, and the introduction of dry processes;
- o alternatives to water for transportation, cleansing, and transferring heat in industrial processes.

Earnest F. Gloyna has wriiten a major paper on "North American Needs in Waste Management in the Next Decade".[33] While the title of this paper suggests a wide ambit, in fact all of its technological emphasis is on wastewater treatment.

Gloyna notes that "[f]ew new municipal or industrial wastewater treatment technologies have been developed over the last 20 years; rather there have been many adaptations."

He proposes a specific focus on the properties of sludge from sewage treatment, leading to: removal of water, stabilization, inactivation of organisms and viruses, thermal processes, reclamation, and disposal.

As critical new technologies he puts forward:

- o phototrophs, or organisms which transform chemicals and accumulate hydrophobic compounds;
- o fungi to degrade hydrocarbons;
- o genetic engineering to develop stronger organisms forming the basis of new treatment processes.

The authors of another article, "Innovations in the Proper Management of Hazard" begin with material that covers much the same ground as Strategy of Pollution Control and Profit from Pollution Prevention.[34]

However, they conclude by focussing on three innovative technologies:

- o supercritical fluids, created by high temperature and pressure, which change the properties of the original substances and may permit new approaches to separation;
- o computer-assisted process control, leading to more fully automated water and wastewater treatment plants;

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[33] S.E. Jasper, ed., New Directions and Research in Waste Treatment and Residuals Management (Vancouver: University of British Columbia, 1986). See pp. 9 and 12.

[34] Stacy L. Daniels and Felix T.R. McElroy, in E.A. Glysson, et.al., eds., Innovation in the Water and Wastewater Fields (Boston: Butterworth, 1985), pp. 255-256.

- o use of biotechnology or bioacclimation to secure more effective organisms to break down wastes.

Since 1972, the United States Environmental Protection Agency has been assisting local authorities to construct wastewater treatment and conveyance facilities. A special Innovative and Alternative Wastewater Treatment Technology Program was established in 1977 to promote technological innovation in the field. "Innovative and Alternative Wastewater Treatment Technology Experience in the United States" is a report on the results to date, based on 2,700 projects, and $4.4 billion of investment.[35]

The following types of alternative technologies were most popular:

- o land treatment of wastewaters;
- o sludge treatment;
- o non-conventional collection systems;
- o on-site treatment;
- o energy recovery from sludge;
- o aquifer recharge, nonpotable reuse or containment ponds.

A major result of the program has been transfer of new technologies, such as pressure sewers, to the United States. Only community mound systems have not worked well among the alternative technologies.

Among the innovative technologies, the majority of projects funded were in aeration/mixing, lagoons, sludge technologies, and disinfection.

Major successes were achieved with both sequencing batch reactors -- with new electronic and mechanical controls -- and ultraviolet disinfection. Both have now come into widespread use.

Performance problems have been encountered with draft tube aeration systems, rapid infiltration projects; and in a few other cases.

The specific technologies mentioned will not mean a great deal to the layman, but what is especially helpful about the article is the fact that a whole array of attempts at innovation over a period of years are considered systematically. As a note to Canadians for comparison, it is unlikely that anything approaching the funding provided by EPA for demonstration projects has been offered in Canada to date.

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[35] By Peter E. Shanaghan, in Proceedings: 11th International Symposium on Wastewater Treatment (Ottawa: Minister of Supply and Services, 1988).

What's New in Wastewater Technology? was produced by Environment Canada for a series of technology transfer seminars.[36] It consists of monographs or articles on very specific developments, with a limited attempt to place them into context, or to rank them in order of priority.

The volume contains valuable pieces on such topics as conversion of sludge to oil, operational audits of improved process controls for sewage treatment plants, and anaerobic treatment of cheese whey. In an introduction, Bruce Jank, Director of the Wastewater Technology Centre in Burlington does summarize the results and relate them to the evolution of wastewater treatment technology as a whole. He notes in particular that "... it may be possible to reduce projected infrastructure upgrading costs of $1.3 billion by $1 billion if design deficiencies are cor-rected and a computer control system installed, rather than expanding the capacity of the plant."[37] By anyone's measure, if these figures are borne out, Canadians have in their hands a very definite critical technology, with large potential for the developed world's existing sewage treatment plants.

3.7 Energy Conservation Technologies

Another aspect of environmental technology is the conservation of energy. This has both direct and indirect beneficial impacts on the environment.

Conservation results in lower emissions of sulphur dioxide, nitrogen oxide and other waste by-products harmful to the environment. As well, it extends the time horizon for existing sources of fuel and makes new mega-projects for development of energy sources less necessary.

In 1982, the Minister of State for Science and Technology commissioned a report entitled Energy Conservation Technologies and their Implementation.[38] This explicitly seeks to identify the "most promising technological opportunities". Moreover, the report seeks to suggest the best mechanisms for undertaking the development of the opportunities, and of transferring the new technologies to end users.[39]

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[36] Environment Canada and the Canadian Water and Wastewater Association, (Ottawa: Minister of Supply and Services, 1988).

[37] Ibid., p. 2.

[38] Subtitled Report to the Minister of State for Science and Technology by the Task Force on Energy Conservation Technologies (Ottawa: Minister of Supply and Services, 1982).

[39] Ibid., p. 10.

As in the case of the Brooks and Peters report on water, each assessment of an area of opportunity is placed into a wider economic and technological context. The report takes each sector in turn, identifies energy use patterns and dimensions, and indicates the major technologies which have most promise.

In the case of buildings, they suggest technologies to increase air tightness, and lighting as being most critical. In the buildings sector as a whole Canadian technology is well-developed.

The transportation sector holds out less opportunity for Canada, because of the dominance of a few large multi-national firms which take the major decisions. However, opportunities are identified in relation to small specialty aircraft, urban transit systems, and some rail systems.

Industrial energy conservation technologies proved to have a number of significant Canadian opportunities, including energy cascading, industrial cogeneration, heat pumps, and reverse osmosis.

The importance of this report is that it represents a benchmark against which the substantial learning which took place in the field of energy conservation technology development from 1976 to the present can be measured.
Of the opportunities identified as critical by the Task Force, which have been taken up and pursued? Which remain open, and which have been closed off by the decline in world oil prices or by various failures to perform as promised?

3.8 Hazardous Waste Management

Perhaps the most complete model for how to select criti-cal technologies in the field of environmental industries is presented in a report on treatment and handling of ha-zardous wastes prepared by Robert D. Shelton.

The report, Hazardous Materials Management Markets: Turning Problems into Profits, begins with a review of the basic technological options relating to hazardous waste, then addresses remedial work on hazardous waste sites, and concludes with a review of technological opportunities and risk management.[40]

Two formats used in the report are especially relevant to the wider task of selecting critical technologies. One ranks the major management technologies available according to: applicability; effectiveness; confidence in the technology; capital cost; capital to operation and maintenance cost ratio; and projected level of use.

Critical technologies could be identified using this type of assessment by searching out those technologies which have high effectiveness and substantial confidence, but suffer from high capital costs or other problems. Via the Sector Initiative, the latter may be resolved using R&D, field testing, or other means.

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[40] Report No. 752 (Menlo Park, California: SRI International, 1987).

The Shelton report also takes the assessment of technologies one step down to consider the actual companies, processes, and stages which they have reached.

Each process is then considered from the perspective of environmental performance, and the performance in relation to requirements of user-firms or agencies, including costs, and applicability to various typical situations.

Shelton's report shows how data from a variety of sources can be pulled together into an overall picture of the prospects for a given technology of environmental protection or enhancement. However, the underlying work was done by others. Notably, the specific assessments are the product of the U.S. Office of Technology Assessment.

3.9 Chlorofluorocarbons

While the problems of dealing with toxic chemical wastes of various kinds are now decades old in the science and technology literature, chlorofluorocarbons are a comparatively recent concern. A recent article in Challenges magazine produced by the Ontario Ministry of Industry, Trade and Technology contains an excellent summary of the problems and opportunities in seeking to implement or go beyond the 1987 Montreal Protocol, which calls for production of these ozone-destroying chemicals to be reduced by half by 1999. The article notes the cumulative effects of the chemical, which would continue to destroy ozone well into the next century, even if all production ceased immediately.[41]

There are major difficulties to be surmounted in developing and putting replacement chemicals into use. One is cost to the consumer, and the other is regulatory acceptance. While, for example, Du Pont has spent about $100 million developing CFC alternatives, it has not yet received the kind of long-term approvals it wants to continue and to justify the investment. Regulatory bodies are reluctant to approve the replacements as more than "bridging" chemicals, according to an Ontario Ministry of the Environment official.

In the meantime, both Du Pont and governments are trying to reduce the impact of CFCs on the ozone by recovery and recycling the chemicals in use as refrigerants. Even here, there are some important regulatory hurdles to be overcome before a full-scale recycling industry can come into being.

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[41] Lydia Dotto, "Producers Say They're Moving Quickly to Create Safe Substitutes for CFCs", Vol. 2, No. 2 (Spring, 1989), pp. 14-15.

3.10 Canadian Sources For Tracking Development in Environmental Technologies

The foregoing review of the literature covers some of the major concepts and developments. However, "the literature" is obviously growing on a daily basis. It will be important for ISTC to develop a capacity to monitor developments in Canada and abroad, now that it has made a firm and active commitment to the environmental industries.

This section provides some key starting points for monitoring Canadian innovation in the environmental technologies.

Most obvious among the potential aids to monitoring is Environmental Science and Engineering, a bi-monthly trade publication. This covers Canada's municipal and industrial environmental control systems, energy management, drinking water treatment and distribution, air pollution monitoring and control, solid and hazardous waste treatment and disposal, and occupational health and safety.

It claims a readership of "consulting engineers, industrial plant managers, municipal engineers and officials, key provincial and Federal environmental officials, water and wastewater treatment plant operators, contractors, equipment manufacturers, representatives, distributors and academics".[42]

The magazine contains an "R&D News" section with paragraph-long notes on such items as "Decay of Chlorine in Diluted Municipal Effluents" and "Biological Leachate Treatment."

While there are a few articles and notes on broader issues and on chemicals, energy management, and other topics, the bulk of the magazine appears to be focussed on water pollution control and water treatment. This focus is also reflected in the range of advertisers.

Whatever its limitations, Environmental Science and Engineering is clearly a mark of the maturing nature of the environmental industries, and a valuable tool for communicating with key elements of these industries.

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[42] Vol. 2, No. 4 (August, 1989), p. 3.

Each year, the Research and Technology Branch of the Ontario Ministry of the Environment sponsors a Technology Transfer Conference in Toronto, and then publishes the papers presented there[43]. There are typically five "sessions": air quality research, water quality research, liquid and solid waste research, "analytical methods", and environmental economics. Findings relating to technological developments may appear in any session, but are most heavily concentrated in the one on "analytical methods".

A review of the contents of conference papers over a four-year period from 1986-89 reveals none on the topic of selecting critical technologies. Careful analysis of all of the papers together might reveal the areas in which innovation is occurring, as opposed to simple elaboration of the existing information base and received technologies. Overall, the papers confirm the tendency of the different subdisciplines to be fragmented and to avoid cross-references or attempts to situate their work in a larger context of progress toward environmental improvement.

The same unit of the Ontario Ministry also publishes an Inventory of Research and Development Projects.[44] As in the case of the Technology Transfer Conferences, there is a tendency for projects to have a narrow focus on either examination of pollutants on the environment or the performance of specific "end-of-pipe" technologies. Only in the case of the Waste Management Branch (at least in the case of the 1989 projects) is there an important focus on "clean technology" approaches. Some examples are: "Recovery and Reuse of Phenol in Plastic Making Processes", "Demonstration of Proprietary Ultrafilter and Zero Discharge Rinsing on Recovery of Metal Finishing Wastes", and "Evaluation of Zero Discharge Technology for Tannery Operations".[45]

Another approach to tracking new developments in Canada is by examining subject areas of personal research by Canadian experts in the field.

There are at least two comprehensive reference works on the people who work on environmental problems in Canada. One is Canadian Sources of Environmental Information, which gives names, addresses, phone numbers, and recent areas of work of environmental experts across Canada.[46]

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[43] Ontario Ministry of the Environment Technology Transfer Conference Proceedings (Toronto: Environment Ontario, 1986, 1987, 1988, 1989).

[44] (Toronto: Research and Technology Branch, Environmental Ontario, 1989).

[45] Ibid., p. 150.

[46] Environment Canada Departmental Library, (Ottawa: Minister of Supply and Services, 1986).

The other is Environmental Assessment in Canada: Directory of University Teaching and Research, 1985-1986.[47] It provides for each university in Canada: location, address, phone number, teaching in environmental fields, individual research and work, and "program activities" such as specialized research centres.[48]
In addition, there is a Directory of Scientists in Canada With Research Interests in Global Environment Monitoring and Modelling.

3.11 International Journals in Environmental Science and Technology

Environmental Pollution is a journal that focusses on very specific case studies of pollution and pollution control. Typical topics are "The Impact of Methoxychlor Treatment of the Saskatchewan River System on Artificial Substrate Populations of Aquatic Insects", and "An Explanation for the Apparent Losses of Metals in a Long-Term Field Experiment with Sewage Sludge".

A similar journal, with a focus on air pollution and related matters is Atmospheric Environment: An International Journal. Typical articles concern "Identification of pollution sources of anomolously enriched elements", and "A study of sources of acid precipitation in Ontario, Canada".[49]

The Journal of Environmental Economics and Management
contains such articles as "Measuring Welfare Effects of Product Contamination with Consumer Uncertainty".

Some broader topics in environmental science and technology are covered in Environmental Management and in Environmental Conservation, a journal published in Switzerland. Topics in a typical issue of the former include "Global Sustainability: Toward Measurement", "The Organization of Integrated Environmental Research in the Netherlands", and "Market and Non-market Values of the Georgia Landscape". The latter addresses such issues as "Sustainable Development: Theoretical Construct or Attainable Goal?".

Water Science and Technology is published in Oxford by Pergamon Press and is the journal of the International Association on Water Pollution Research and Control.

Some of the same ground is covered by the journal Water Research, published by Pergamon as well.

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[47] Federal Environmental Assessment Review Office, Environment Canada, (Ottawa: Minister of Supply and Services, 1986).

[48] The University of Manitoba is currently undertaking a more complete survey of expertise in this field for that province, to be used as a pilot for a Canada-wide study.

[49] Vol. 23, No. 7 (1989).

3.12 Assessment of Environmental Science and Technology Literature

Consideration of a large sampling of the recent environmental science and technology literature does not yield a clear set of early options.

Overall, the direction of the future appears to be clean technologies, rather than ever more refinement of end-of-pipe methods. However, the latter will still need to be held in readiness for Eastern Europe and the Third World, where large amounts of old plant need to be retrofitted with controls of any kind.

Wastewater technology is a clear Canadian strength. The advantage of this technology is that it addresses the needs of many different users, from industries such as pulp and paper, steel, and chemicals, to municipalities.

Beyond these conclusions, we are left to ask: why is there not a clearer set of priorities for action emerging from the literature?

The system for producing this literature tends to be fragmented, and focussed along the paths of particular disciplines. Perhaps one in a hundred books or articles contains a sense of priorities. Often these are couched in fairly general terms. There is a tendency to push forward all new developments as options.

Part of the resistance to priority-setting lies in the organization of scientific envdeavour. It tends not to be multi-disciplinery, which could lead to a clearer sense of societal priorities through the interaction of physical, ecological, economic, social and political perspectives.

There also does not appear to be very much migration of concepts across different areas of activity, although this is changing rapidly, for example, as computerized controls move from other industrial processes to environmental machinery and equipment.

Because so much of environmental science and technology has been driven by non-market forces in the past, it is possible that the rate of technological change has been slower than it might otherwise have been.[50]

However, the pace of discoveries in environmental science has appeared very rapid indeed to those who must cope with the results of such findings as the depletion of the ozone layer and global warming.

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[50] See Arlon R. Tussing, "Environmental Policy Issues: Market Failure in the Third Phase of Economic Activity", in G. Bruce Doern, ed., The Environmental Imperative: Market Approaches to the Greening of Canada (Toronto: C.D. Howe Institute, 1990), pp. 59-60.

There is another factor in the apparent unwillingness to choose which is perhaps more profound: the risks associated with environmental choices. It may be difficult to rank different options for investment in science and technology precisely because it is very hard to say in moral or intellectual terms that saving life here has a higher value than saving it there. Given a choice between investing in reduced cancer and reduced respiratory disease, what does one do?

In addition, there is a fundamental difference between the way in which those who tend to be producers of environmental science, i.e., scientists, deal with uncertainty, and the way those who make effective decisions about its use do, e.g., politicians, corporate executives. Scientists tend to seek necessary and sufficient evidence to stand up to scrutiny by their peers in formulating an argument. Policy or management decision-makers seek only "enough to go with" based on the confines of their decision situation at the time.[51]

The very volume and jargon of the environmental science and technology literature would appear to be a major problem for managers. There are relatively few engaged in synthesis and communication to lay people of the results.

There are some, but still not many tools for organizing the data in ways that managers can readily use, e.g., expert systems. The substantial environmental risks and uncertainty are thus compounded by communication gaps between producers and consumers of knowledge.

One rather obvious early option would be to advance the science and technology work associated with the assessment of environmental risks, and the presentation and interpretation of environmental science and technology findings and results.

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[51] For a discussion of these issues, see T.F. Schrecker, Political Economy of Environmental Hazards. Law Reform Commission of Canada Study Paper (Ottawa: Minister of Supply and Services, 1984) and C.F. Smart, and W.T. Stanbury, eds. Studies on Crisis Management (Ottawa: Institute for Research on Public Policy, 1978).

4. CURRENT DEVELOPMENTS IN FEDERAL TECHNOLOGY CENTRES

4.1 The Nature of the Literature

There are a few centres of excellence in environmental technologies in Canada, notably in Ottawa, Burlington, and Waterloo. Most are Federal establishments.

The bulk of the literature which they produce is best addressed from a substantive point of view, that is, as part of the environmental science and technology literature. However, it is also important to consider what these organizations or organizational units say about their work as a whole, in annual reports, information brochures, house organs, etc. Implicitly, they have chosen critical technologies in the course of their work. A map of these may help to identify oppor-tunities which have already been taken to a certain stage of development.

4.2 River Road Environmental Technology Centre

The River Road Environmental Technology Centre is one of two technology centres operated by Environment Canada. The other is the Wastewater Technology Centre in Burlington.

A central function of the River Road Centre is to develop and apply air pollution measurement technology in Canada.
It coordinates the operation of the National Air Pollution Surveillance Network. As well, it develops technologies for measuring industrial emissions.

To date, these have included:

- measurement of lead, arsenic and mercury from non-ferrous smelters;
- measurement of lead from manufacturing plants, e.g., for making batteries;
- measurement of mercury from plants making caustic soda;
- measurement of particulates from industrial plants like steel mills;
- measurement of dioxin from incinerators and other combustion sources.

The Centre is also involved in a National Incinerator Testing and Evaluation Program, and in measuring automotive emissions.

Finally, it is very much engaged in oil spill and chemical clean-up, and in responses to environmental emergencies.

The following environmental technologies have been developed as a consequence of work by the Centre, especially in the last connection:

- a small-scale oil skimmer;
- an oil-spill tracking buoy;
- a mobile unit using reverse osmosis to remove undesirable chemicals from wastewater;
- a towable container for oil recovered in spill clean-up;
- a light-weight oil spill boom for use in sheltered waters;
- an air deployable igniter for oil spilled in the Arctic.

4.3 Wastewater Technology Centre

The work of this Centre in Burlington is perhaps the best known of any technology centre focussed on the needs of the environmental industries. It has been involved in the following developments:

- high-rate anaerobic technology for pretreatment of wastes which have high organic strength, e.g., dairy wastes;
- automated process control and on-line instrumen-tation for municipal and industrial sewage treatment plants;
- land application of sludge.

4.4 National Water Research Institute

This Environment Canada centre conducts a national program of research and development in the aquatic sciences. While it is not a "technology centre" as such, it does have significant technological spin-offs.[52]

Current long-term research priorities of the Institute include:

- toxic chemicals in the Great Lakes and St. Lawrence River;
- exchange of toxic contaminants between air, water, sediments, and living things;

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[52] See National Water Research Institute, Reflections, 1987-88 (Burlington: NWRI, 1988).

- o ground-water contamination;
- o pesticide contamination in rivers;
- o acid rain;
- o lake rehabilitation;
- o development of methodologies for aquatic monitoring, ecotoxicology, and risk prediction.

The most promising aspects of the Institute's work from the standpoint of environmental technologies is the last of these project streams.

For example, the Institute has devised an approach called Quantitative Structure-Activity Relationships (QSAR).

This starts by specifying environmentally undesirable chemical properties and behaviour and then works back to identify chemicals likely to show those characteristics.
Some early results are being applied to the analysis of toxic chemicals in the Niagara River.

A key element of the Institute's work is water quality sampling.

The Institute has developed a fast method of screening water samples and selecting those containing toxic substances. As well, it has developed new methods of detecting chlorophenols and dioxins in pulp and paper mill effluents which are more cost effective. Finally, it has begun to apply a robotic system which can process up to 300 water samples per hour.

On another front, the Institute has produced an expert system called RAISON, in cooperation with computer specialists from the University of Guelph.

This helps to answer basic questions about acid rain impact and to assess the response of aquatic ecosystems to it over large geographic areas. Its primary purposes are to make sense of large amounts of data collected across the country, and to predict water quality resulting from different acid rain control measures.
There has already been demand for this expert system from Malysia and the United Nations Environment Programme, as well as the private sector.

Working with the U.S. Office of Naval Research, the Institute has also bee developing methods of using satellite sensors to infer wind speed and direction from ocean waves. Data from the satellite sensing will in turn be used to assess weather patterns and to forecast the distribution of wind-borne pollutants.

One of the success stories of the Institute's past efforts has been the use of ultra violet light to disinfect sewage effluents. Trojan Technologies Incorporated adapted the results to produce a large-scale disinfection system, which was tested with help from the Institute. The firm has begun to win major contracts for the new technology.

On another front, the Institute has assembled a simple set of tests for assessing the safety of community water supplies, which can be applied in remote communities by local residents.

4.5 Assessment of Developments in Technology Centres

The efforts of Canadian technology centres are clearly focussed on a fairly narrow range of the spectrum of environmental science and technology. The chief area of concentration is water, whether water monitoring, sewage treatment or marine emergencies. The overall impression is that progress on monitoring and measurement science and technology has been more rapid than that on treatment and prevention.

As well, considerably less Canadian work appears to be underway on air pollution control technology , major aspects of soil pollution remediation, recycling, recovery of materials, and clean manufacturing technologies not involving wastewater treatment. This implicit decision to establish water as the most critical area for Canadian work may or may not be wise from a longer-term point of view. However, it has obvious implications for the choice of early options: if we are going to build on a Canadian strength, it will be in the field of wastewater technology.

5. ENVIRONMENTAL/INDUSTRIAL POLICY AND STRATEGY

5.1 The Nature of the Literature

The volume of literature documenting the broad nature of the "environmental problem" has grown tremendously in recent years. The purpose of such literature is obviously not to help identify critical technologies or early opportunities for the environmental industries, except in the most general sense. Such works serve to give added legitimacy to those engaged in entrepreneurial pursuits in the cause of the environment.

The literature on industrial policy and strategy has been languishing in Canada for a number of years. However, with renewed interest in the United States and the evident example of Japan, this trend may turn around. The environmental technologies are very likely to form part of the turnaround, if the early evidence is a valid indication.

5.2 Reports Directly on the Topic of Industrial Strategy to Enhance the Environment

In the past four years, an increasing amount of attention has been devoted to the ways in which environmental policies can relate to industrial policies.
The Science Council of Canada has developed one of the most concise and complete statements of strategy for developing environmental technologies in its November, 1988 report Environmental Peacekeepers.[53]

This asserts that "[a]the present, Canadian public policy dealing with the environment concentrates on encouraging industries to install 'remedial' technologies to mitigate the harm done by ... production equipment." The Science Council believes that "[r]emedial technologies often simply change one environmental problem into another." As examples, the report notes that incinerators to destroy rubbish also emit dioxins, and acid gas scrubbers create large volumes of sludge.[54]

The Council holds that "[r]emedial technologies are best promoted by environment departments, whereas preventive technologies are best promoted by industry departments concerned about industrial competitiveness." It is not necessary to go this far, or to let environment departments "off the hook" in promoting pollution prevention.

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[53] Subtitiled Science, Technology and Sustainable development in Canada. (Ottawa: Minister of Supply and Services, 1988.

[54] Ibid., p. 14.

It is true, however, that environment departments are more likely to find remedial technologies "sufficient unto the day", while industry departments need to search further for solutions which make economic as well as environmental sense.

The report moves on from the premises outlined above to make a series of recommendations about what Industry, Science and Technology Canada should be doing in the environmental technologies field. Specifically, the report proposes a project like the Environmental Industries Sector Initiative now underway in the department.

Our Common Future, the Report of the World Commission on Environment and Development is the source of much of the current interest and commitment to the concept of sustainable development. As one would expect from an essentially political, coalition-building document, what it says about technology development is rather general. Nevertheless the Commission had a clear view of what the critical technologies were from its perspective.

Specifically, it chose:

- information technology, as a way of improving the productivity, energy and resource efficiency and organizational structure of industry;
- new materials as contributors to energy and resource conservation;
- biotechnology as a source of cleaner, more efficient alternatives to wasteful processes and polluting products;
- space technology as a means of weather forecasting and determining environmental conditions through remote sensing;
- the chemical and energy industries as drivers of change in Third World agriculture.

The Commission warns that these new technologies will not be unequivocally beneficial for the environment. There are important risks, even in carrying our research and development, for example in genetic engineering.[55]
While their discussion of the levers to be used in achieving strategies for sustainable development in industry emphasize environmental goals, regulations, incentives, and standards, they also note the potential for new technologies to assist.

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[55] World Commission on Environmental and Development, Our Common Future (Oxford: Oxford University Press, 1987), pp. 217-219.

Small businesses find it especially difficult to meet environmental regulations and product controls.

> "New technologies, especially micro-electronics, already allow small industries inexpensive means to control an entire production process. Energy-saving biological systems may be well suited to the needs of small and medium-sized industries for pollution control or waste treatment facilities."[56]

In December of 1985, the Economic Council of Canada sponsored a colloquium on the relationship between the economy and the environment. The resulting report was called Managing the Legacy[57]

James W. MacNeill took the opportunity at this colloquium to lay out the contrast between "react-and-cure" strategies and "anticipate-and-prevent" strategies. He quoted results from OECD work as well to the effect that investment in environmental technologies were shown to have a positive economic effect.[58]

5.3 Reports and Books on Broader Aspects of Industrial Strategy

In Competing in the New Global Economy[59], the Premier's Council of Ontario has formulated a classic industrial strategy in order to:

- encourage all industries to move to competitive higher value-added per employee activities;
- focus industrial assistance efforts on businesses and industries in "internationally traded sectors;
- emphasize the growth of major indigenous Ontario companies of world scale in these sectors;
- create an entrepreneurial risk-taking culture;
- build a strong science and technology infrastructure;

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[56] Ibid., p. 223.

[57] Subtitled Proceedings of a Colloquium on the Environment, (Ottawa: Minister of Supply and Services, 1986).

[58] Ibid., p. 8.

[59] Premier's Council, (Toronto: Queen's Printer for Ontario, 1988).

- o improve education, training and labour adjustment infrastructure;
- o follow a consensus approach.

The environmental industries are not specifically mentioned by the strategy, although they would appear to fit many of the above criteria, at least in potential for the future.

By contrast with the Ontario report just cited, the Science Council of Canada has singled out the environmental technologies as one of two major programs for government spending in the future. The Council proposes in Not a Long Shot: Canadian Industrial Science and Technology Policy that Federal effort take the form of demonstrations of technology.[60]

Legacies: Twenty-Sixth Annual Review of the Economic Council of Canada asserts that "[t]o the extent that the current generation degrades the environment, it is consuming capital and reducing the heritage of future generations."[61] The report goes on to note that "[t]he social costsarising from environmentally harmful activities are largely absent from the national accounts system."

In "Wastewater Technology Innovation for the Year 2000", Denny Parker makes a strong plea for the "entire research cycle" to be addressed by public policies. He notes that

> "[e]very researcher has a different agenda. With this situation, it is easy for an outside observer to misperceive the researcher as having too narrow a view or perhaps speaking to only his or her own interests. Consensus statements from a knowledgeable group of experts carry much greater weight."

He calls for research partnerships to work on such topics as secondary clarifier research to foster cooperation among different players in the wastewater technology community.[62]

5.4 Responding to the New World Situation of the 1990s

Events in the latter half of 1989 and the first months of 1990 have forced Western governments to reconsider their industrial policies and strategies from a number of perspectives, with direct implications for the environmental industries.

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[60] Guy P. Steed, (Ottawa: Minister of Supply and Services, 1989), p. 113.

[61] (Ottawa: Minister of Supply and Services, 1989), p. 58.

[62] Parker, op.cit., pp. 498-499.

Specifically, the end of Communist rule in Eastern Europe has meant that resources previously devoted to the defence of Western Europe can now be put to other uses.

As well, the reduction in East-West tensions has facilitated the stabilization or ending of regional conflicts in the Third World. With peace and greater security, the attentions of those countries can be turned to the environment and development agenda envisaged by the Brundtland report already covered above.

A recent issue of the U.S. publication, Government Executive, has a series of articles on these issues.

In "After the Thaw", Henry Butterfield Ryan notes the pressures for change within the United States Government which have been created by the changes in Eastern Europe, including the role played by Commerce and the Environmental Protection Agency.[63]

In order to facilitate the process of assisting the new regimes, two new non-profit organizations have already been established. These are the Polish-American and the Hungarian-American enterprise funds which have broad authority to make loans and grants, undertake feasibility studies, create technical and management training programs, establish joint venture firms, and invest in existing or new enterprises. Environmental projects will likely be an important aspect of their work.

In "Rethinking Defense", James Kitfield notes that Department of Defense planners have been ordered to submit plans for cuts as deep as $180 billion for the next five-year plan following the 1991 budget. He notes that changes in the world security situation are calling for a basic rethinking of defence procurement in the United States, including the cancellation of many whole weapons acquisition and modernization programs. Particularly hard hit are likely to be the most expensive, most sophisticated high-technology weapons systems, like the B-2 "stealth" bomber, which would have a very limited role, if any, in responding to Third World crises of the future.[64]

There is a domestic Canadian dimension to the shift in U.S. and other NATO resources described above: the Canadian defence industries employ some 49,000 people and are a major source of jobs for highly-qualified people in ship-building, aerospace and electronics. Individual firms, such as MacDonald Dettwiler, Oerlikon Aerospace and Indal Technologies have already been giving thought to how to diversify. The Canadian Centre for Arms Control and Disarmament has assembled a panel of experts to consider defence industry diversification, and the Royal Military College has work underway on this subject.

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[63] Vol. 22, No. 2 (February, 1990), pp. 11-16.

[64] Ibid., pp. 22-28.

The environment is a natural growth market possibility for consideration by the defence industries.

5.5 Assessment of Environmental and Industrial Policy and Strategy Literature

The available literature on environmental policies and on related industrial policies and strategies is adequate to the task of providing broad guidance for initiatives to support environmental science and technologies. However, for specific instruments, it is necessary to consider the precise details of how technological change occurs in this sector.

6. TECHNOLOGICAL CHANGE PROCESSES

6.1 The Nature of the Literature

For a process which is so central to an understanding of the modern world, technological change is in many respects still rather poorly documented and understood.

There are innumerable models of how it is supposed to take place, and some in-depth studies of how it actually occurs. But these do not apply fully to the case of Canada. Fortunately, the process as it relates to environmental science and technologies is considerably less complex than for society as a whole.

The literature falls naturally into three major groups, for purposes of this review:

- studies of how government policies, strategies, and regulations with environmental objectives affect the pace of technological change in industry;
- studies of how technological change processes work within the environmental industries themselves, and between the environmental industries and the "user" or client industries;
- relevant studies of how the processes of technological change as a whole operate across the economy.

6.2 Government Policy and Technological Change

There are a large number of calls in the policy literature for what amounts to a more rapid pace of technological change in industry to adapt to new environmental requirements. Despite this, there is a surprising lack of literature which seeks to trace through the processes of change and what their side effects may be for industry. Unless this work is undertaken, there are two grave dangers:

- that industry, faced with a life-and-death struggle for survival will counterattack against environ-mental regulations;
- that in a rush to do the "environmentally-friendly" thing, the equivalents of the "oat bran" phenomenon will emerge over time and diminish or destroy the credibility of environmental technologies.

The OECD has undertaken one of the few comprehensive studies of the relationship between environmental policies and technological change on a broad basis. The rest of the literature consists mainly of micro-economic assessments of specific instruments in relation to specific industries.

Key findings of the study Environmental Policy and Technical Change are that:

- o environmental regulation hits smaller firms and industries harder than larger ones, leading to speculation that it may contribute to industry concentration;
- o larger firms have easier access to technological know-how and can lead smaller firms into innovation, as is illustrated in Canada in the automotive sector;
- o environmental regulations work most effectively when an industry is in an expansion mode, and is already undertaking modernization projects;
- o collective R&D across industries is especially important in the environmental technologies field;
- o greatest successes in responding to environmental regulation in a way that leads to further growth has been had by firms with an "active" and "combative" strategy.[65]

6.3 Dynamics of Technological Change Within the Environmental Industries, and Between Environmental Industries and Their Clients

In his excellent review of the prospects for innovative wastewater technology in the United States "Wastewater Technology Innovation for the Year 2000", Denny Parker has a number of significant findings about how techno-logical change occurs in this field.[66]

He notes that factors such as the potential for profit, bidding climate, and professional conservatism have influenced the decisions of environmental engineers on the use of innovative technology. More specifically, he flags:

- o unwillingness to assume risks associated with new technology by state and local governmental decision-makers and by consultants;
- o a perception by consulting engineers that there is inadequate time and budget to locate or obtain data necessary to provide workable and reliable systems;
- o readiness of state and local officials to become discouraged by unknowns associated with innovative technologies, including performance and operating and maintenance costs;

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[65] OECD, op.cit., pp. 57-67.

[66] Parker, op.cit., pp. 492-493.

- high levels of competition, low profits, and difficult market conditions facing equipment suppliers;

- Federal programs which encourage innovation at cross purposes with state and local enforcement provisions concerning wastewater treatment and sludge disposal.

In this context, he believes that equipment manufacturers have been responsible for much of the innovation that has taken place in the field of wastewater technology. Over half of the technologies which have received major funding from the U.S. Environmental Protection Agency are proprietary systems promoted by individual equipment manufacturers.

6.4 Overall Processes of Technological Change in Industry and Society

According to "Making Information Flow", the new reality of manufacturing in advanced industrial societies is that "[t]he people ... who move information around - and that includes manufacturing engineers - predominate over the people who handle and produce product... Direct labor rarely comprises more than 10-15% of payroll. People processing information get the rest."[67]

In order to implement computer-integrated manufacturing, the following steps are needed:

- define the product/process flow;

- define the data flow to and from the process;

- determine a more precise classification of delays;

- identify management information needs;

- acquire hardware and software tools;

- educate and train managers and employees;

- develop a lab prototype of the new system;

- implement the system on the shop floor.[68]

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[67] John M. Martin, in Manufacturing Engineering, Vol. 102, No. 5 (May, 1989), p. 75.

[68] Ibid., p. 77.

There are many points of complementarity between implementation of a new manufacturing system and a new environmental control system. Moreover, such approaches as "just-in-time" delivery of parts are generally more environmentally friendly than previous approaches which required large heated warehousing.

At each point in the steps above the environmental needs and relevant technologies can be brought to bear, including perhaps expert systems which assist in developing the least damaging processes. An example of the latter is "Hazardexpert" which predicts the toxicity of different organic chemical structures across eight living systems.[69]

6.5 Identifying the "Drivers" of Key Canadian Industries

There are two levels on which the process of technological change should be considered in relation to environmental factors:

- o change caused by environmental regulations, already discussed above;
- o change which is underway for reasons unrelated to the environmental imperative, but which presents opportunities to "piggy-back" environmental improvements along with others entirely in the interests of the given industry.

The promise of "profit from pollution prevention" is that, rather than being a dead weight, higher environmental quality can be associated with greater competitiveness. As D.G. McFetridge notes in a recent C.D. Howe Institute publication, [t]here is a tension between economists and environmentalists that ought not to exist. The message of both groups is essentially the same: there is no free lunch."[70]

The Department of Industry, Science and Technology itself has produced some of the most useful information for considering how best to link overall processes of technological change with those immediately associated with upgrading environmental performance. This takes the Industry Profiles first prepared in 1985-86 and recently (1988-89) published in a more polished form.

The consultants sorted these profiles into two distinct groups:

- o those for industries which seem to be under substantial pressure from an environmental perspective;

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[69] See Chemical and Engineering News, Vol. 67, No. 31 (July 31, 1989), p. 17.

[70] "The Economic Approach to Environmental Issues", in G. Bruce Doern, ed., The Environmental Imperative: Market Approaches to the Greening of Canada (Toronto: C.D. Howe Institute, 1990), p. 83.

- those for industries which seem to have the greatest capacity to offer solutions to environmental problems, based on the foregoing analysis of where solutions lie.

In the first group are:

- synthetic resins;
- plastics products;
- petrochemicals;
- fertilizer;
- fruit and vegetable processing;
- brewing;
- distilling;
- newsprint;
- fine paper;
- market pulp;
- kraft papers;
- folding cartons and set-up boxes;
- industrial rubber products;
- leather tanning;
- nickel smelting and refining;
- automobiles;
- automotive parts;
- automotive tires and tubes;
- primary iron and steel;
- ferrous foundries;
- soap and cleaning compounds.

Of the above, the industries most under simultaneous world market pressures and environmental pressures appear to be the chemicals industries, the automotive industry, and the pulp and paper industry.

The first two industries are clearly dominated by multi-national companies, and are the subjects of international regulatory regimes and/or integrated Canada/U.S. production arrangements. There is substantial modernization investment underway, but it is driven for the most part by decsions offshore.

The pulp and paper industry appears to be the one which is:

- dominated by 100% Canadian firms;
- under simultaneous pressure from international, e.g., U.S. state recycling laws, and domestic environmental regulations;
- undertaking an extensive modernization program already;
- heavily investing in Canadian R&D, through its organization Paprican;
- already anticipating future environmental regulations, rather than reacting.

On the other side of the spectrum are industries which have fairly limited environmental impact of their own, but which create science and technology solutions to be sold to the resource-processing, manufacturing and service sectors.

These include:

- surveying and mapping services;
- consulting engineering;
- instrumentation;
- defence electronics;
- power generation equipment;
- oil and gas field equipment;
- pulp and paper machinery;
- plastics and rubber machinery;
- construction machinery;

- mining equipment;
- forestry equipment;
- industrial electrical equipment;
- machine tools and tooling;
- metal rolling mill and welding equipment;
- space;
- aerospace;
- ship-building and ship repair;
- buses;
- guided urban mass transit;
- telecommunications equipment;
- computers and office equipment;
- computer services and software.

There are others, but these give a major indication of what might be called the "solution-bearing industries". There are obviously many individual Canadian strengths in the foregoing list, both in terms of individual firms and whole industries.

The most promising consortiums from an environmental science and technologies perspective are those which would tie together stronger, e.g., telecommunications, and weaker, e.g, instrumentation, industries. This is a paradox in its current state, since the technologies and disciplines involved would seem to be very similar. The profile for the latter says:"[t]he largest impediment to growth in the industry ... is the slow rate of diffusion of advanced instrumentation to such potential users as the resource industry..."[71]

One of the major stimulants to a more rapid growth of instrumentation applications is surely going to be the need to monitor and control industrial processes in relation to environmental regulations.

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[71] Department of Industry, Science and Technology, Industry Profile: Instrumentation (Ottawa: ISTC, 1988), p. 6.

Another major "cluster" from the perspective of building on Canadian strengths and achieving environmental solutions at the same time is surely a linkage between consulting engineering, surveying and mapping, computer software and services, and various process technologies.

An example from current Canadian success, which is making a major contribution to the reduction of "greenhouse gases" is urban mass transit, which requires all of the above, plus Canadian excellence in transportation equipment production. Major sales to Third World countries as well as in North American markets suggest what can be achieved when science, technology, services, and manufacturing form parts of an integrated whole.

6.5 Assessment of the Literature on Technological Change

In order to develop a clear picture of the potential for "leverage" for government initiatives relating to the environmental industries, it is essential to understand the main lines of how technological change occurs, both in user and producer industries.

In the simplest terms, the main driver of technological change in the user industries is governmental regulation, requiring a particular standard of effluent, performance, etc. Suppliers of equipment in turn reenforce this process of change by offering new products and services to clients.

The producers of environmental technologies in turn are strongly influenced by the standards which their clients will need to meet. As well, since none of the available technologies provides a perfect solution, there is a continuing drive for at least modest improvements. High-risk technological change on either side is not usually undertaken without government support, and a sense of regulatory certainty.

At least two major areas for combined Canadian effort in achieving early successes with environmental science and technologies are evident: the pulp and paper industry and consulting services followed up by Canadian machinery and equipment in world markets.

7. VIEWS OF INDUSTRIES, INDUSTRY ASSOCIATIONS AND ENVIRONMENTAL GROUPS

7.1 The Nature of the Views of Industries, Industry Associations and Environmental Groups

The development of environmental science and technologies does not take place in a political vacuum, although it may appear at times to be a highly technical matter.

Because scientific and technological resources are scarce, and different technologies affect different interests in different ways, the views of the key "stakeholders" are important.

In order to ascertain the views of key industry associations and environmental groups, key publications were collected from a representative range of these organizations. Brief interviews were conducted by telephone or in person at many of their offices. The aim in all cases was to obtain a measure of interest and activity on environmental issues, including environmental science and technology, without engaging in extensive discussion which might appear to involve them in a formal way or to require a "corporate position" to be developed.
In a few cases, this informal approach resulted in refusal to offer information, but in most cases, organizational representatives were very helpful.
In this section are presented brief reviews of where the different associations stand on environmental issues.

In the vast majority of cases, there was no specific sense of priorities for environmental science and technology evident from our contacts with the associations. Where these have been expressed, they have been accorded full coverage in this section.

There are three broad types of associations considered here:

- national "umbrella" organizations, cutting across many sectors;
- sectoral associations, covering major components of the nation economy, such as agriculture;
- specific industry associations, covering defined groups of firms, such as those engaged in production of machine tools.

The environmental interest groups are considered separately at the end of the section.

7.2 National Umbrella Organizations

Thomas d'Aquino, President of the **Business Council on National Issues** has asserted that "... business leaders ... share [the] conviction that reversing the deteriora-tion of the environment on a global basis is the most important challenge facing Canadians and citizens of the world."[72] While d'Aquino's public statements have tended to remain on a broad plane, he has noted the need for new ways for companies to measure environmental improvements "... which would justify optimum technology and result in higher long-term returns."

Specifically, he notes the need for accounting techniques which assess the potential liabilities to businesses resulting from delays or gaps in investments in environmental measures. He calls for a "satisfactory environmental data base".

D'Aquino also advocates:

- o improved front-end planning to assess the potential risks of new activities;
- o reclamation systems as part of life-cycle management of industrial activities;
- o investing in long-term technology whose environmental benefits exceed current or even planned standards.

He specifically advocates "leap-frogging current norms" and action to improve industrial competitiveness in the marketplace by positioning industries as environmental leaders. "Environmentally-friendly products" are just one opportunity in his view.

In August of 1989, the **Canadian Chamber of Commerce** published the report of its Task Force on the Environment, chaired by Tom McMillan, former Minister of the Environment, and now with Chase Manhattan Bank of Canada. The report is "consistent with the Chamber's overall philosophical thrust" but is not a statement of formal policy as yet. A two-year implementation process has been set in motion by the Chamber.

There are a wide variety of implicit priorities for environmental science and technology in the Task Force report, including sewer and water upgrading, industrial monitoring equipment, hazardous waste destruction methods, and in-plant recovery systems for metals and chemicals. However, these are presented as examples, and do not have the official backing of the Chamber as yet.

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[72] "Environment and Economy: Until Death Do Them Part", Address at a Conference on Sustainable Development (Winnipeg, May 17, 1989), p. 1.

The **Canadian Labour Congress** is almost exclusively concerned with the workplace environment, and particularly with the implementation of "WHMIS" or the Workplace Hazardous Materials Information System at present. Individual member unions have been expressing concern about the impact of environmental regulations on jobs, especially in the forestry sector. This may be one reason why the Congress has avoided more than general statements on the subject so far. Cradle-to-grave management of chemicals is the clear CLC priority.

7.3 Sectoral Associations

The **Canadian Federation of Agriculture** focusses on soil degradation, the use of pesticides, and the confinement of animals as aspects of "sustainable agriculture". They note that the environment is indirectly involved in many issues of concern to farmers.

However, the Federation seems to be chiefly concerned with securing additional Federal funding for work on these issues, rather than in setting specific priorities for environmental science and technologies for its own members to pursue.

The **Canadian Manufacturers' Association** has been quite active on environmental issues over the past five years. It was an active participant in the formulation of the Canadian Environmental Protection Act, continues to inform its members on the implementation of that Act, and has intervened on such matters as Federal Water Policy as well.

One of the interesting things to note about the CMA's position in the latter regard is that it argued against a system of pricing for water to promote conservation and demand management practices. Instead, the Association contended that "... the best way to encourage efficient use of water is through enforcement of effluent regulations, since companies will have to pay the cost of proper treatment of water prior to discharge."[73]

The President of the Association argued further that:

- for some industries, net water use is low, since most was returned to its source;
- criteria for monitoring the quantity and concentration of pollutants were not clearly established;
- there were other sources of pollutants, such as agricultural runoff, which affected water systems.[74]

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[73] Letter from J. Laurent Thibault to Lorette Goulet, September 18, 1986.

[74] While all of these contentions are valid up to a point, they appear to be addressed by the approaches used in the Ontario MISA program, which requires individual plants to

This kind of industry position suggests that the "command-and-control" approach, and the focus on "end-of-pipe" technology are not unique to government agencies. They may pose barriers to the implementation of market mechanisms for promoting environmental clean-up and also to clean technologies.

The **Canadian Construction Association** has completed a major review of the implications of environmental concerns for its members, which was provided to the consultants on a confidential basis. This review concludes that the major area of impact on the industry will be the environmental impact assessment process. Accordingly, it does not set priorities for environmental science and technologies, but focusses on the response to these processes at the Federal and provincial levels.

7.4 Specific Industry and Professional Associations

The **Agricultural Institute of Canada** represents agrologists and others concerned with the scientific and technological aspects of agricultural practice.

Specific areas of concern relating to the environment include: soil conservation, use of pestcides, plant breeders' rights, and promotion of Research and Development.

In 1989, the Institute has given considerable attention to "sustainable agriculture". It defines this as "... design and management procedures which work with natural processes to conserve all resources, minimize waste and environmental damage, while maintaining or improving farm profitability.

The overall approach to sustainable agriculture as described in a recent issue of the publication AgriScience is to reduce or eliminate the use of various technologies, and replace them with mutually reenforcing natural processes.

However, the concept would not appear to rule out such products as a new type of chemical-free herbicide called "BioMal". This uses a naturally-occurring fungus to kill the round-leaved mallow, a common weed in Manitoba and Eastern Saskatchewan.

The **Aerospace Industries Association of Canada** has an range of active committees and represents the defence electronics industries as well as aircraft and parts manufacturers. In the 1989 Annual Report of the Association, the Chairman and President note that defence cutbacks will have "... a serious long range impact on our industry". While the Canadian industry has diversified away from reliance on defence contracts, and relies on them for less than 30% of its business overall, there is a concern about "... the important role that defence programs and research play in the development of new products and new technologies" within this industry.

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monitor quantity and quality of effluents. The low "net use" argument seems to indicate a CMA concern that some firms and industries may be placed at a disadvantage because they are heavy consumers of water. But that is the point of the pricing system.

The Association so far does not seem to have considered the potential of environmental products and services as a potential source of alternatives to the defence market.

The **Air Transport Association of Canada** appeared reluctant to provide information on its activities relating to the environment, if any. Initial contact suggested that there may be a committee established, but the President said that there was not.

The **Association of Canadian Distillers** is in the process of proposing that environmental issues be tackled in a more systematic manner. A key concern of the industry is the fragmentation of government activities, and the lack of information sharing amongst government bodies. The association would like to concentrate efforts on the information-sharing function.

Our informant at the **Association of Universities and Colleges of Canada** noted that the member institutions are responsible for setting their own environmental policies individually. They do have a non-smoking policy within the Association itself, but this is the only area in which a policy position has apparently been developed.

According to the **Automotive Industries Association**, the automotive sector has been looking at the environment much more closely. The Association has been active on the issue of new, higher emission standards, leaded gas, and on the use of CFCs in this industry. They have developed correspondence courses on three environmental topics for their members. They have been seeking government funding for a study of hazardous waste disposal in the automotive sector.

In our interview with the **Brewers' Association of Canada**, it was noted that the Association has been very active in the recycling of packaging in the past.

The Association is currently in the midst of drafting a more comprehensive environmental policy, and expects it to be ready for public release in June of 1990.

The **Canadian Association of Equipment Distributors** has not had a position on the environment in the past, but is in the process of setting up a committee on environmental matters, in conjunction with its U.S. counterpart.

The **Canadian Association of Fish Exporters** considers that their mandate does not include the environment. They referred the consultant to the Fisheries Council of Canada.

The **Canadian Bus Association** is currently considering how to take the issue of the environment in hand, but has not yet developed a corporate position.

According to the Executive Director of the **Canadian Centre for Arms Control and Disarmament**, the environment is going to be the next major issue addressed as a security matter. There is increasing recognition of the relationships between the environment and arms control initiatives, both direct and indirect, e.g., via the diversion of resources from defence to clean-up efforts.

A major new initiative of the Centre's has to do with the conversion or diversification of the Canadian defence industries. It is in the process of establishing a panel of experts on the subject. Environmental opportunities will be a major consideration of the work of this panel.

The **Canadian Chemical Producers' Association** includes environmental concerns in its mission statement, and is very active on environmental matters, in particular through a program called "Responsible Care". This recognizes that responsible management of chemicals must include a combination of self-initiated actions and a degree of government regulation. Responsible management of chemicals follows a series of codes of practice,
including:

- community awareness and emergency response;
- proper transportation of chemicals;
- proper hazardous waste management;
- research and development;
- distribution;
- manufacturing;
- the generation and transmittal of hazard information.

Much of this activity was stimulated by the Bhopal incident in India, and the review conducted by Environment Canada afterwards, focussing on Canadian industry conditions. As well, the industry itself commissioned a Decima poll which revealed a considerable degree of skepticism about the industry in the public mind.

The codes of practice do not mandate specific technological solutions to problems facing the industry: they stress behaviour of managers.

One of the findings of the Environment Canada study of Bhopal's impact was that "[c]ountermeasures technology for Bhopal-type incidents is very limited ... increased efforts are needed to expand the frontiers of this technology and to assess and widen the application of existing technology."[75] Perhaps surprisingly then, the Chemical Producers' Association's Research and Development Committee is focussed on specialty chemicals, rather than on environmental technology issues.

On the other hand, the **Canadian Society for Chemical Engineering** has been active on some key aspects of environmental technologies, in particular process engineering for environmental protection.

In brief, the chemical industry has adopted broad policies leading to certain technological directions, but it has not so far developed a specific view of what environmental technologies it requires. Subgroups of the chemical industry, like the plastics industry, shows a greater interest in environmental technologies, perhaps driven by the evident pressures for recycling and the active plastics machinery and equipment industry.

There are no associations of environmental technology producers specifically directed at the chemicals industry. Instead producers are organized according to the different functions they perform, many of which have the chemicals industry as the largest single client.

The **Canadian Council of Professional Engineers** has become more active on environmental issues over the past year in particular. A workshop held during the CCPE annual meeting in November 1989 addressed the question of a National Model "Code of Ethics" which would relate the practice of engineering to the "social and environmental aspirations and needs of society".

In addition, both recipients of the awards given by the CCPE in 1989 were engineers who have focussed on environmental concerns and projects. One, Dr. Christian Roy of Laval University, is a specialist in vacuum pyrolysis and holds five patent on new mehtids of recovering oil from scrap tires and wood, and treating petroleum-derived organic sludges and residues.

A related body is the **Canadian Academy of Engineering**, which is a learned society for the engineering disciplines and has 100 Fellows considered the leading engineers in the country. It was formed in 1988 "to provide independent and expert advice on matters of national importance pertinent to engineering.

A survey conducted in 1989 among Academy Fellows identified the protection of the environment as the leading problem for engineers last year. Closely related problems also ranked very high.

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[75] Environment Canada, Bhopal Aftermath Review: An Assessment of the Canadian Situation (Ottawa: Minister of Supply and Services, 1986), p. 20.

Here are the most frequently reported urgent engineering problems, in rank order:

- protection of the environment;
- waste management;
- urban infrastructure;
- energy conservation;
- public awareness of the benefits and problems of technology;
- the greenhouse effect;
- the national transportation infrastructure;
- Canadian policy on Research and Development;
- Nuclear energy development;
- Forest deterioration and poor development.

The President of the Academy has asserted that "The public is currently greatly concerned for the environment, but often considers it to be a political or economic problem. It is primarily an engineering problem, which Canada is not too well equipped to handle."

Environmental issues are only a periodic concern of the **Canadian Council of Technicians and Technologists.** They alert their members to new developments in the environment field, but may be more active at the provincial level. One specific initiative is that the Council has begun printing its annual reports on recycled paper.

The **Canadian Export Association** notes that the environmental impact assessment process is not applied to export services. They have been making representations to government that Canada should not get ahead of the rest of the world in setting a new direction on the environmental impact of export activities unilaterally.

The **Canadian Fertilizer Institute** is preparing a position paper for the consumers of fertilizers on sustainable agriculture. The Institute has been involved with environmental issues on the producer side of the business since the 1970s.

Canada is one of the world's largest exporters of fertilizer, and can be expected to be under pressure in the future in relation to the environmental effects of this product and the agricultural practices which it supports.

According to a recent report, the **Canadian Foundry Association** has developed a program for promoting the recycling of foundry sand by its members.

Contact with the **Canadian Gas Association** suggested at first that a task force had been struck on the environment recently. However, this was subsequently denied by the Executive Director.

In the view of the Chief Operating Officer of the **Canadian Home Builders' Association**, the environment is an issue which is here to stay. The Association intends to play a leadership role in this field and has begun discussions at the executive level to this end.

The CHBA has a long-term involvement with energy efficiency in housing through its role in delivering the "R-2000" program. It is currently considering ways to expand this concept into an "environmental house" and is seeking an Environmental Choice designation for the products resulting from the program.

The **Canadian Housing and Renewal Association** has not been specifically involved in environmental issues in the past, except indirectly via efforts to promote housing rehabilitation and neighbourhood improvement. As part of its strategic planning process, the Association is giving consideration to more active involvement in the future.

In the view of the **Canadian Institute of Planners**, land-use planning has a key role to play in promoting sustainable development. The Institute has been very actively involved as lead organization in the "Healthy Communities" project sponsored by Health and Welfare Canada, which has a major environmental aspect. It is promoting new initiatives to exchange information on planning and environmental protection.

The **Canadian Maritime Industries Association** represents the ship-building and ship-repairing industry across Canada. Based on fairly extensive materials provided by the Association on its environmental activities over the past decade or more, it has responded to individual issues on behalf of its members, but has not so far developed comprehensive positions on the environment or environmental technologies.

Specific matters of concern have included:

- impact of new regulations for emissions from internal combustion engines;
- environmental impacts of anti-fouling paints used in drydocks and shipyards;
- prevention of pollution from ships travelling in the Great Lakes.

In several cases, the matters were referred to individual members to respond as they saw fit.

The **Canadian Petroleum Association, the Independent Petroleum Association of Canada, and the Canadian Petroleum Products Institute** are collaborating on task forces to assess the industry's capacity to respond to oil spills in the wake of the Exxon Valdez disaster. Fifteen million dollars has been ear-marked to spend on oil-spill preparedness over the next five years.

Oil-spill clean-up technology, Geographic Information Systems, and monitoring systems could all be affected positively by this concentrated attention on oil spills.

In addition, the **Petroleum Association for the Conservation of the Environment** is continuing its activities in seeking to improve the management and operation of retail service stations from an environmental perspective.

The **Canadian Pulp and Paper Association** is probably the most active and aware of the industry associations considered by the consultants. Major sessions at the Association's annual meetings are being devoted to environmental concerns, including reducing discharge of dioxins and furans, improving the retention of wood fibre, reducing air pollution from waste burning, conserving energy in mill processes, etc. As well, the Association has recently been conducting a major advocacy advertising campaign stressing the strength of its environmental commitment.

On the other hand, individual high-profile industry leaders question the necessity of new environmental standards and stress the high cost of complying with them. An Association spokesperson has estimated that the industry will need to spend about $5 billion by 1994 to meet the Canadian Environmental Protection Act and Fisheries Act regulations.[76] Noranda Forest has contended that spending on environmental projects "'in most cases is beyond what the operation is able to sustain from generated cash flows.'"[77] This firm is calling for "'... an unbiased data base for this issue'".

One of the most active associations on environmental issues, as might be expected, is the **Canadian Water and Wastewater Association.** It is entirely devoted to infrastructure improvement and the diffusion of in formation about water treatment and wastewater technologies. The Association has close links with the Federation of Canadian Municipalities, with which it shares quarters, and with Environment Canada, from which it receives significant funding. Apart from municipal rather than industrial water supply and wastewater treatment, the Association does not appear to have specific priorities for environmental science and technology.

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[76] Adele Weder, "Forecst firms see red over the green wave", Financial Times of Canada, May 7, 1990., p. 9.

[77] Ibid.

The **Federation of Canadian Municipalities** has a long history of involvement in environmental issues through the activities of its members in sewage traetment, solid waste disposal, land-use planning, energy efficiency and other matters. Currently, it is an active participant in the "Healthy Communities" project.

In addition, the Federation was instrumental in founding the Canadian Water and Wastewater Association, described above, which represents these aspects of municipal activities.

The **Food Institute of Canada** is an association representing firms selling and distributing frozen, canned, aseptic, chilled, bottled, and dehydrated food. It was created in 1989 through the merger of frozen and packaged food interest groups. Its major concern is food safety.

The **Industrial Gas Users Association** has not yet developed a position on the environment. However, it would likely become active should there be a proposal for a "carbon tax".

The **Mining Association of Canada** has adopted a comprehensive environmental policy which includes commitments relating to legislative compliance, best management practices, and the following: "foster research directed at expanding scientific knowledge of the impact of the industry's activities on the environment, of environment/economy linkages, and of improved traetment technologies... ".

Because of the recent nature of this policy commitment, it is not yet clear how the priorities of such ancillary agencies as the **Mining Industry Technology Council of Canada** may be affected. The latter is clearly focussed on process-control technologies which may be highly relevant to early options in the environmental science and technologies field.

It is clear that the **Pharmaceutical Manufacturers Association of Canada** works all around the issue of the environment in its concern for health care. However, the Association does not appear to have a formal environmental policy or a set of priorities for environmental science and technologies as such.

7.6 Views of Environmental Groups

Professor Glen Toner of Carleton University has undertaken a preliminary review of trends in Canadian environmental groups which traces their evolution from the 1970s to the present time.[78] He notes that while the environmental non-governmental organizations have changed over time, their policy advocacy role has remained paramount.

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[78] "Whence and Whither: ENGOS, Business and the Environment", 1990, unpublished.

Only three -- Pollution Probe, Ducks Unlimited, and the Rawson Academy of Aquatic Sciences -- have gone beyond the advocacy role to become directly involved in various kinds of active programming. Of these, the most interesting is probably Pollution Probe, which has been active in solid waste management, the promotion of housing renovation, industrial technology diffusion and "green" products promotion.

In this process, which has proven controversial within the community of environmental interest groups, Pollution Probe has effectively set priorities for environmental technologies:

- cloth diapers;
- phosphate-free detergents;
- alternatives to household bleach;
- recycled paper products;
- household composting systems;

and a variety of others.

Overall, however, the environmental groups are more readily understood in terms of what science and technologies they are <u>against</u>. Nuclear power; fossil fuels, and energy megaprojects in particular; genetic engineering; whaling; trapping; use of animals for research purposes; and plastic packaging come to mind readily.

7.7 Assessment of the Views of Industry Associations, and Environmental Groups

Industry associations in Canada have moved a substantial distance in their environmental awareness over the past five years. Many have developed major policy positions on the subject. So far, however, this has not yet translated into a consensus about their environmental technology needs, except in a few cases, such as pulp and paper. Most associations appear to be reacting to government regulations and then seeking the science and technologies which will best assist their members to comply, regardless of origin or industrial spin-offs.

Among the environmental advocacy groups, the degree of sophistication about and the willingness to engage in dialogue about environmental technologies appears to have increased. This means, however, that the view of how environmental should be tackled may be framed in a manner that is essentially regulatory, and even anti-business in some respects.

The environmental groups still have difficulties with the "system" as a whole, but are coming more and more to act as part of a larger consensus-building process on specific actions, rather than carping from the sidelines. In a few cases, they have become active in delivery of specific environmental programs.

ISTC could have a crucial role to play in helping to stimulate an industry consensus about which technologies are most needed.

8. VIEWS OF FEDERAL DEPARTMENTS AND AGENCIES

8.1 The Nature of the Views of Federal Departments and Agencies

Few, if any, Federal departments and agencies have developed coherent corporate positions on the environmental science and technology which they would consider most critical to the achievement of their missions. Nevertheless, many have views which should be taken into account in setting priorities for or choosing among the possibilities.

The following material is based on content analysis of departmental documents and a range of interviews and meetings over the period December, 1989 to May, 1990. As in the case of the industry association contacts, the purpose was to assess the departmental position and relevance without in any way committing or colouring the views received by stressing an ISTC or environmental industries connection. In many cases, the information was collected in the course of work on a related project for Environment Canada on "getting the Federal house in order". However, specific interviews on the topic were conducted with senior officials from Environment Canada in particular.

Departments and agencies can be classified for purposes of this report into three groups:

- o those which control or influence key drivers of the environmental industries, e.g., Environment Canada;
- o those which constitute major operational entities themselves, and could therefore be important markets for environmental technologies;
- o those which have a specific role to play in one sector, region, or industry and could shape the purchasing decisions of clients, or other aspects of specific environmental technologies.

It is important to note that there are no departments or agencies outside of ISTC, including Environment Canada, which have defined positions on the environmental industries. The latter are considered to be instruments for providing what is needed in a few cases, or considered among a host of other industries and groups, or not consciously considered at all.

8.2 Departments and Agencies Which Control Major Drivers

While **Environment Canada** is a very large department, there are a relatively small number of units within it which have a direct role in the selection of critical technologies. The most important are the Industrial Programs Branch and the Technology Development and Technical Services Branch.

The Industrial Programs Branch has units which address the following industrial sectors:

- o mining, mineral and metallurgical processes;
- o urban activities, including solid waste;
- o renewable resources, extraction and processing;
- o chemical industries;
- o transportation systems;
- o oil, gas and energy;
- o waste management.

A major reorientation of the Branch's activities is now underway to enable it to play the roles required of it under the Canadian Environmental Protection Act. Part of the dilemma facing the Branch is that, while it has been freely offering industry advice about appropriate technological solutions in the past, with a strengthened enforcement role, this may become more difficult.

The critical technologies from the perspective of this Branch can be determined by looking at its priority activities. They are:

- o life-cycle management of toxic chemicals;
- o cleaner technologies for the incineration of municipal wastes;
- o remedial measures for underground storage tanks;
- o lowering fuel volatility to reduce ground-level ozone;
- o acid gas control technologies for power plants.

It can be seen that while these are all important from an environmental perspective, about half fall more into the "react-and-cure" category than into "anticipate-and-prevent". A key difficulty facing the Branch is the need to engage in crisis management types of responses.

The Technology Development and Technical Services Branch includes the Program Development Division, the Industrial Incentives Programs Division, and the Technology Transfer and Training Division, as well as responsibility for the River Road Environmental Technology Centre, and the Waste Technology Centre in Burlington.

The following have been identified as critical technologies by this branch, on a preliminary basis:

- o process audits for sewage treatment plants;
- o oil from sewage sludge;
- o sludge dewatering systems;
- o sludge incineration systems;
- o landfill leachate management systems;
- o flow control systems for sewage collection systems.

The **Department of Finance** plays two key roles in relation to environmental industries:

- o establishing specific tax policies or other instruments which favour or inhibit the purchase of environmental technologies by polluting industries, such as the Accelerated Capital Cost Allowance for pollution control machinery and equipment;
- o developing policies which affect all small businesses, or all manufacturers, or all service industries, and therefore have an impact on the environmental industries to the extent that they fall within one or more of these categories.

The Department has naturally taken note of the growing public interest in environmental matters, and has prepared internal position papers on the subject. However, it has no position on substantive priorities for environmental science and technology.

The **Department of Supply and Services** manages the Federal procurement process for larger projects, and for stocked-item supply. The Department has formally included environmental factors in its purchasing considerations, has promoted more "environmentally-friendly" products in its own operations, and is considering ways to offer all departments and agencies an "environmental choice" in their purchasing. Through its Papersave and silver recycling programs, the Department amounts to the largest single force for change in environmental technologies used by the Federal government.

While one might think that Environment Canada would have this role via Part IV of the Canadian Environmental Protection Act, the latter is geared mainly to bring Federal standards and practices into line with those inother jurisdictions. The amount of new science and technology involved could be rather limited.

When Supply and Services enters the picture, the choice of a particular product or service for percompetitive developmental work and subsequent first purchase for

Federal clients can become a powerful tool for promting technological change.

8.3 Departments and Agencies Which Are Major Operating Entities in Their Own Right

The **Department of National Defence** is the largest single corporate entity in Canada, and operates the largest and most diverse array of buildings and facilities. In all, it manages 595,341 hectares of land, 10,123 buildings, 21,471 family dwellings, and 12, 512 other types of facilities in Canada. In Europe, the Department has an additional 3,961 buildings, dwellings and facilities.

The Department has a well-developed awareness of its environmental responsibilities, partly because of the public attention given to such projects as an expanded Tactical Fighter Weapons Centre in Goose Bay, Labrador.

The most visible type of purchase from the private sector to date has probably been environmental impact assessment services. Consultant studies have been completed on seven military bases, and are planned or underway at seven other facilities, including Defence Research Establishments at Valcartier, Suffield and Ottawa.

The major contracts for environmental work to be let in the future will include:

- o environmental restoration upon the closure of facilities, in order to remove or treat asbestos, garbage dumps, underground storage tanks, septic tanks, etc. ... the Cadin-Pinetree and DEW Line sites and military bases to be closed will provide major work of this type for much of the next decade;

- o energy conservation projects ... the Department has set a goal of reducing consumption by 1% a year by utilities and equipment, and is taking steps to this end; as the largest energy user in the Federal government, the Department is obviously a major market for these kinds of technologies;

- o PCB destruction ... the Department has secured mobile incineration equipment for its project in Goose Bay, and is contracting out destruction of "low-level" PCBs on a local basis;

- o underground fuel storage tanks ... the Department is testing and replacing older tanks among the 1,050 which it operates.

Environmental issues which are under consideration for DND attention, depending on availability of resources include:

- o procurement of "environmental choice" products;

- o waste reduction/minimization, including participation in larger recycling programs;

- o environmental training programs for military and civilian DND personnel;
- o reduction of CFCs and Halons in use by DND;
- o indoor air quality;
- o DND role in responding to national environmental emergencies.

All of the above are likely to call for expert assistance from the private sector, and may lead to the purchase of new machinery and equipment for DND use.

Transport Canada is another obvious department for inclusion on the list of major operating organizations with measurable direct environmental impacts. It operates the 129 larger airports across Canada, is responsible for Ports Canada and the Canadian Coast Guard, and regulates/funds the rail system and strategic elements of the motor vehicle transport system. The latter includes administration of the Transportation of Dangerous Goods Act and the Motor Vehicle Safety Act, both of which are key drivers of environmental technologies.

The Airports Group within the Department appears to be in the lead in environmental matters and has developed a comprehensive environmental management plan. The elements of this plan include:

- o a system of Environmental Officers at Headquarters, Regional Offices, and Major Federal Airports;
- o environmental audits of all Major Federal Airports by 1992-93, which will usually be contracted out;
- o monitoring of storm water quality at airports on a more frequent basis, which may also involve private consultants;
- o more extensive monitoring of air quality around airports, together with potential corrective actions including higher aircraft emission standards;
- o installation of emission control equipment on or replacement of non-hazardous solid waste incinerators used to destroy garbage coming off international flights, and replacement of smaller incinerators;
- o improved management of pest-control products used around airports, including training of Transport Canada employees;
- o mitigation of pollution from fire training areas, including clean-up of decommissioned sites, and upgrading of environmental protection at sites in use;

- checking and replacement or repair as necessary of 1,650 underground fuel storage tanks at the airports managed by Transport Canada;
- mitigation of the stormwater pollution caused by gycol deicing fluid, by installing aerated sewage lagoons, or else making a link to a regional sewage treatment plant at eight large airports;
- phase-out and destruction of PCBs in use or in storage at Transport Canada sites;
- restriction of halon use at airports, including limitations on the use of fire extinguishers with halons during training;
- development of site-specific environmental emergency contingency plans;
- clean-up of soil and groundwater contamination andof hazardous sites at airports;
- improved hazardous waste management and disposal.

In addition, the Airports Group is working on two unique environmental problems, the Gloucester Landfill Site Clean-up, and acidic runoff at Halifax Airport.

Some of the environmental technologies which Transport Canada requires are unique to its operations, but most are similar to those needed by National Defence and other Federal departments and agencies, or else by similar authorities in other countries.

Public Works Canada and the **Bureau of Real Property Management, Treasury Board Secretariat** are the major organizations involved in the acquisition, use and disposal of land, buildings and facilities used by all Federal departments and agencies. They have adopted environmental considerations as a formal part of the real property management process.

Key technologies of interest to these agencies are:

- methods of energy conservation in buildings;
- methods of improving indoor air quality;
- alternative incineration technologies;
- solid waste reduction methods;
- best practice boiler technologies for heating buildings.

In some cases, these are being approached within a regulatory framework established by Labour Canada, i.e., WHMIS, and in others by Environment Canada under Part IV of the Canadian Environmental Protection Act.

The **Royal Canadian Mounted Police** and **Correctional Services Canada** are significant because they are large-scale users of domestic-type supplies, of building energy and of vehicles. Like DND and Transport Canada, their needs as major users could drive specific environmental science and technology projects.

However, neither has a set of priorities for technology development at the moment, other than the general principle that operational requirements, e.g., security of personnel, must come first.

8.4 Departments and Agencies With Specific Sectoral Impacts

Agriculture Canada is actively promoting "sustainable agriculture" concepts, although it is not yet clear what this will mean for its major farm subsidy programs. In its own operations, the Department will likely be in the market for improved technologies and for services associated with management of laboratory chemicals.

The **Canada Mortgage and Housing Corporation** has a series of research projects underway which may lead to improved environmental technologies in the residential sector. These include: energy intensity of building materials, hazard lands, radon gas, and housing standards.

Energy, Mines and Resources Canada is involved in environmental science and technologies through its search for low-waste, low-impact mining technologies, its remaining work on energy conservation, and its work on the reduction of pollution caused by the petroleum industry. However, the volume of activity that is relevant to the environmental industries has declined in recent years.

Fisheries and Oceans has found itself in the midst of a major controversy associated with "environmental" monitoring of the Atlantic fish stocks. As well, recent court decisions have indicated that Federal powers under the Fisheries Act appear to give the Federal government a major role in projects across Canada, regardless of jurisdiction. While the Department is likely to continue to be a major purchaser of environmental science, it is not entirely clear how environmental technologies will serve its needs.

Indian Affairs and Northern Development Canada concerns relating to environmental technology tend to be clustered around each of the two major elements of its mandate: the North, and Indian reserves and people.

Because of the ecological fragility of the North, there has been coordinated effort to conduct environmental science there and to develop relevant environmental technologies for several decades.

In particular, the Polar Continental Shelf Project has been in operation since 1958, and involved more than 13,000 scientists from all disciplines.[79]

Specific technologies which have been applied successfully in the North include remote sensing, Geographic Information Systems, wind energy generators, and energy-efficient housing.

The priorities of the department for the future will most likely focus on ways to carry out resource development in a manner that is sensitive to the environment.

Some past work has been done on:

- low-impact oil and gas drilling, storage, and transportation technologies;
- hydro-electric power generation machinery and equipment suitable to the northern river systems, as an alternative to diesel fuel;
- energy conservation technologies for all types of buildings.

These are likely to continue to be priorities.

The Indian Affairs component of the Department's responsibilities has a major environmental concern: the provision of basic water, sewage treatment and solid waste disposal services on reserves. Some $70 million annually will be deveoted to these purposes over the next several years.

The vast majority of the 594 Indian reserves have relatively small populations, settled on scattered sites.

Accordingly, the most needed environmental technologies will likely be small-scale, easy-to-operate and maintain treatment plants and distribution systems, as well as community waste separation and composting systems.
Such technologies would have application to some 3,500 other smaller settlements across Canada.

8.5 Other Federal Departments and Agencies

Most other Federal departments and agencies are likely to have some role in the promotion of environmental science and technologies mainly because they use offices, vehicles, and paper in the course of their operations.
Major organizations include **Employment and Immigration**, the **Canada Post Corporation, Health and Welfare Canada** and **Revenue Canada.**

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[79] Department of Indian Affairs and Northern Development, Looking North: Canada's Arctic Commitment
(Ottawa: Minister of Supply and Services, 1989), p. 33.

Some departments and agencies, such as the **National Research Council, Health and Welfare Canada**, and **Communications Canada** also have important laboratory facilities which will require specialized waste management and disposal technologies and services.

In addition, each of the last three departments is a potential partner for ISTC in developing specific environmental science and technology projects. However, only the National Research Council appears to have addressed this topic consciously, and it has yet to set a final array of priorities.

8.6 Assessment of the Views of Federal Departments and Agencies

By and large, there are no fully-developed views of the priorities for environmental technologies in Federal departments and agencies. However, if ISTC takes on a leadership role, it is likely to find willing participants, particularly in Supply and Services and DND.

As pressures to "get the Federal house in order" from an environmental perspective mount, many departments and agencies will be pushed to purchase what is "on the shelf", provided it meets their operational requirements.

9. CONCLUSIONS

This review of the literature and report of interview results is necessarily partial, since it constitutes only a slice of the very diverse reality affecting environmental science and technology and the environmental industries.

It is based on searches in the Carleton University, Ottawa Public, Industry, Science and Technology, and Environment Canada libraries. The latter in particular has a very large collection of books, reports and periodicals on environmental technologies, of which some 500 reports and articles were consulted.

However, there are substantial literatures as well in languages other than English and French, which are not covered fully by the Environment Canada collection, and were not consulted by the author.

On the other hand, there is a great deal of repetition and duplication in the literature as well. Researchers often circle around the same fundamental themes and technical difficulties. On the whole, the balance of the literature still appears to weigh in favour of examining the effects of environmental problems, rather than in presenting solutions. Engineering solutions are inevitably driven by technologies already in place to a certain extent. However, there is growing attention across the board to clean technology solutions and strategies.

The interviews served to confirm and to probe what had been learned through the literature. Organizations and individuals are doing their best, often in very stressful circumstances. But major opportunities for Canadian industry are being missed or not fully captured, and ISTC can make a difference in this regard. The situation is sufficiently in flux that innovation appears to be possible and hands appear to be extended to potential partners and sources of considered advice and practical information.

BIBLIOGRAPHY*

Bernstein, Gerald W. Infrastructure Innovation and Technology. Business Intelligence Program, Report No. 723. Menlo Park, California: SRI International, 1985

Berthouex, P. Mac, and Rudd, Dale F. Strategy of Pollution Control. New York: John Wiley and Sons, 1977.

Brooks, David B., and Peters, Roger. Water: The Potential for Demand Management in Canada. Ottawa: Science Council of Canada, 1988.

Campbell, Monica E., and Glenn, William M. Profit from Pollution Prevention: A guide to industrial waste reduction and recycling. Toronto: Pollution Probe Foundation, 1982.

Chemical and Engineering News. Vol. 67, No. 31 (July 31, 1989).

Coplan, Lee M. and Shenfeld, Avery B. "The Ontario Environmental Protection Industry and the Impact of Environmental Expenditures on the Ontario Economy", in Proceedings: Technology Transfer Conference, 1988 Toronto: Environment Ontario, 1988, pp. 163-193.

d'Aquino, Thomas. "Environment and Economy: Until Death Do Them Part". Address at a Conference on Sustainable Development. Ottawa: Business Council on National Issues, 1989.

Doern, G. Bruce, ed. The Environmental Imperative: Market Approaches to the Greening of Canada. Toronto: C.D. Howe Institute, 1990.

Economic Council of Canada. Legacies: Twenty-Sixth Annual Review. Ottawa: Minister of Supply and Services, 1989.

_____. Managing the Legacy: Proceedings of a Colloquium on the Environment. Ottawa: Minister of Supply and Services, 1986.

El-Hinnawi, Essam, and Hashmi, Manzur H. The State of the Environment. London: Butterworths, 1987.

Engineering Interface Limited. Healthy Building Manual: Systems, Parameters, Problems & Solutions. Ottawa: Minister of Supply and Services, 1989.

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* Note: The publications below constitute only a sampling from those consulted.

Environment Canada. Backyards to Borders: Federal Environmental Action in Canada's Communities. Ottawa: Minister of Supply and Services, 1988.

_____. Bhopal Aftermath Review: An Assessment of the Canadian Situation. Ottawa: Minister of Supply and Services, 1986.

_____. Proceedings: 11th International Symposium on Wastewater Treatment. Ottawa: Minister of Supply and Services, 1988.

_____. Departmental Library. Canadian Sources of Environmental Information. Ottawa: Minister of Supply and Services, 1986.

_____. Federal Environmental Assessment Review Office. Environmental Assessment in Canada: Directory of University Teaching and Research, 1985-1986. Ottawa: Minister of Supply and Services, 1986.

_____. First Canada/Germany Wastewater Treatment Technology Exchange Workshop. Water Pollution Control Technologies for the 1980s. Ottawa: Minister of Supply and Services, 1979.

_____. National Water Research Institute. Reflections, 1987-88. Burlington: NWRI, 1988.

Environment Canada and the Canadian Water and Wastewater Association. What's New in Wastewater Technology? Ottawa: Minister of Supply and Services, 1988.

European Community, Commission of. Ten Years of Community Policy on the Environment. Strasbourg: Commission of the European Community, 1984.

Fenton, Bruce A. The Canadian Water Resources Equipment Industry: Opportunities for Research and Manufacturing. Ottawa: Science Council of Canada, 1988.

Fielding, Tim, and Orpwood, Graham. Technology and Innovation in Canadian Industry: An Information Kit for Social Studies Teachers. Toronto: Orpwood Associates, 1988. [Prepared for the National Conference on Technology and Innovation]

Glysson, E.A., et.al., eds. Innovation in the Water and Wastewater Fields. Boston: Butterworth, 1985.

Haines, Dr. R.C., "Market Opportunities for Environmental Protection Industries in Europe Post 1992". Birmingham: ECOTEC Research and Consulting Limited, 1990.

Indian and Northern Affairs Canada. Looking North: Canada's Arctic Commitment. Ottawa: Minister of Supply and Services, 1989.

Jasper, S.E., ed. New Directions and Research in Water Treatment and Residuals Management. Vancouver: University of British Columbia, 1986.

Journal of Environmental Economics and Management. Vol. 23, No. 7 (1989).

Martin, John M. "Making Information Flow", Manufacturing Engineering. Vol. 102, No. 5 (May, 1989).

Mexpert Consulting Engineers Limited. Environmental High-Technology from Finland. Helsinki: Ministry of the Environment, 1986.

Nishimura, Hajime and Sadakata, Masayoshi. "Emission Control Technology" in H. Nishimura, ed., How To Conquer Air Pollution: A Japanese Experience Amsterdam: Elsevier, 1989.

Ontario Ministry of the Environment. Research and Technology Branch. Inventory of Research and Development Projects. Toronto: Environment Ontario, 1989.

Ontario Ministry of the Environment. Technology Transfer Conference Proceedings. Toronto: Environment Ontario, 1986, 1987, 1988, 1989.

Ontario Ministry of Industry, Trade and Technology. The Market for Flexible Automation Equipment in Ontario. Toronto: MITT, 1985.

Ontario. Premier's Council. Competing in the New Global Economy. Toronto: Queen's Printer for Ontario, 1988.

Ontario Research Foundation. Waste Reduction Opportunities Study. Toronto: Ontario Research Foundation, 1983.

Organization for Economic Co-operation and Development. Environmental Policy and Technical Change. Paris: OECD, 1985.

_____. The Macro-Economic Impact of Environmental Expenditure. Paris: OECD, 1985.

_____. The Promotion and Diffusion of Clean Technologies in Industry. Paris: OECD, 1987.

Parker, Denny S. "Wastewater Technology Innovation for the Year 2000", Journal of Environmental Engineering. Vol. 114, No. 3 (June, 1988).

Picot, W. Garnett. Canada's Industries: Growth in Jobs over Three Decades, A Review of the Changing Industrial Mix of Employment, 1951 - 1984. Ottawa: Minister of Supply and Services, 1986.

"R&D News", Environmental Science and Engineering. Vol. 2, No. 4 (August, 1989).

Science Council of Canada. Environmental Peacekeepers: Science, Technology, and Sustainable Development in Canada. Ottawa: Minister of Supply and Services, 1988.

Shelton, Robert D. Hazardous Materials Management Markets: Turning Problems into Profits. Report No. 752. Menlo Park, California: SRI International, 1987.

Schrecker, T.F. Political Economy of Environmental Hazards. Law Reform Commission of Canada Study Paper. Ottawa: Minister of Supply and Services, 1984.

Smart, C.F., and Stanbury, W.T. Studies on Crisis Management. Ottawa: Institute for Research on Public Policy, 1978.

Steed, Guy P. Not a Long Shot: Canadian Industrial Science and Technology Policy. Ottawa: Minister of Supply and Services, 1989.

Steed, Guy, and Tiffin, Scott. A National Consultation on Emerging Technology. Science Council of Canada Discussion Paper. Ottawa: Minister of Supply and Services, 1986.

Sweden. National Environmental Protection Board. Research for a Better Environment: An investigation of the need for environmental research in Sweden. Stockholm: National Environmental Protection Board, 1986.

Task Force on Energy Conservation Technologies. Energy Conservation Technologies and their Implementation. Ottawa: Minister of Supply and Services, 1982.

Task Force on Environmental Protection Technologies. Report to the Minister of State for Science and Technology. Ottawa: Minister of Supply and Services, 1984.

United Kingdom, Department of Trade and Industry. Your Business and the Environment. London: DTI, no date.

United Nations Economic Commission for Europe. Two Decades of Cooperation on Water. New York: United Nations, 1988.

United Nations Environment Programme and Ministry for Research and Technology, Federal Republic of Germany. Final Proceedings, Volume II: Clean Technology Practices in the Federal Republic of Germany. Nairobi: United Nations Environment Programme, 1986.

United States. Council on Environmental Quality, Executive Office of the President. Report on Long-Term Research and Development. Washington, D.C.: U.S Government Printing Office, 1985.

United States. National Bureau of Standards. "Emerging Technologies Critical to U.S. Industry", Manufacturing Engineering. Vol. 102, No. 6 (June, 1989), pp. 70 - 72.

Vesilind, P. Aarne, and Peirce, John Jeffrey. Environmental Pollution and Control. Second Edition. Ann Arbor, Michigan: Ann Arbor Science Publishers, 1983.

Woods Gordon. The Environmental Protection Industry in Ontario. Toronto: Ontario Ministry of the Environment, 1989.

World Commission on Environment and Development. Our Common Future. Oxford: University Press, 1987.

ANNEX: LIST OF SOURCES AND CONTACTS

Pulp and Paper Industry

- Michele Gosselin, Chief, Socio-Economic Analysis Division, Environmental Protection Directorate, Environment Canada*
- Eric Hall, expert in pulp and paper technology, Environment Canada
- Bruce Jank, Director, Wastewater Technology Centre, Environment Canada*
- Mackenzie Millar, President, Millar Western, Edmonton
- Arie van Donkelaar, international expert on pulp and paper process technology, Nystrom, Lee, Kobayashi Associates, Vancouver

Defence Industries

- Barney Danson, The Winchester Group, former Minister of National Defence*
- Jim Finan, expert in socio-economic aspects of defence, Department of National Defence and Royal Military College*
- E.T. Jackson, President, Jackson Associates, consultants*
- John Lamb, Executive Director, Canadian Centre for Arms Control and Disarmament*
- Peter Nicholson, Senior Vice-President, Bank of Nova Scotia; member, NABST; member, Board of Directors, Canadian Centre for Arms Control and Disarmament*
- Ernest Regehr, Professor, and specialist in defence industries analysis, University of Waterloo*

Recycling Chlorofluorocarbons

Ben Brasz, President, Refrigerant Reclaim Limited, Weston, Ontario*

Victor Buxton, international expert on CFC replacements, Chief, Chemicals Control Division, Conservation and Protection, Environment Canada

Fred Chen, international expert on CFC recycling, Industrial Programs Branch, Conservation and Protection, Environment Canada*

Sharon Suter, Ontario government expert in CFCs, Waste Management Policy, Waste Management Branch, Ontario Ministry of the Environment*

George Wentlandt, President, Anachemia Limited, Mississauga, Ontario*

Opportunities for Environmental Technologies in the Third World and Eastern Europe

- Jane Barton, External Relations Directorate, Environment Canada*
- Dal Brodhead, Jackson Associates, consultants*
- David Brooks, IDRC manager*
- John Cox, Institute for Research on Public Policy*
- Barney Danson, The Winchester Group, former Minister of National Defence*
- Fern Hurtubise, Director General, External Relations Directorate, Environment Canada*
- E.T. Jackson, President, Jackson Associates, consultants*
- Barbara Lamb, Resource Systems Management International, consultants*
- Jim MacNeill, Institute for Research on Public Policy*

Management of Environmental Risks and Information

- Brian Emmett, Director General, Corporate Policy, Environment Canada*
- Charles Marriott, Director General, Corporate Programs and Services, Environment Canada*
- Dr. Fred Roots, Science Advisor Emeritus, Environment Canada*
- Nola Seymoar, Director General, Special Projects, Environment Canada*
- Michael Simmons, Vice-President, TYDAC Technologies

Sectoral Industry Associations

- Andreas Dolberg, Resource Analyst, Canadian Federation of Agriculture*
- Michael Makin, Director of Government and Public Relations, Canadian Construction Association*

Specific Industry Associations

- Charles Brimley, Executive Director, Canadian Council of Technicians and Technologists*
- L.R. Comeau, Chairman, Canadian Electrical Association
- Sylvia Haines, Executive Director, Canadian Housing and Renewal Association*
- John Hopper, Executive Vice President, Canadian Association of Equipment Distributors*
- Jacques Hudon, Director of Public Affairs, Mining Association of Canada*
- John Kenward, Chief Operating Officer, Canadian Home Builders' Association*
- Jim Knight, Executive Director, Federation of Canadian Municipalities*
- Ken Lewis, President, Aerospace Industries Association
- Gary Nash, Senior Advisor and Director of Regulatory Affairs, Mining Association of Canada*
- Ellen Radix, Information Officer, Canadian Maritime Industries Association*
- David Sherwood, Executive Director, Canadian Institute of Planners*
- Frank Trotter, Executive Director, Canadian Bus Association*
- Dean Wilson, President, Automotive Industries Association of Canada*
- Tim Woods, Association of Canadian Distillers*

Getting the Federal House in Order

- George Cornwall, Director, Management and Emergencies Branch, Environment Canada*
- Len Good, Deputy Minister, Environment Canada*
- Azit Hazra, Chief, Federal Activities, Environment Canada*
- Alain Jolicoeur, Director, Technology Development and Technical Services Branch, Environment Canada*
- Barry Lipset, Director General, Supply Management Branch, Supply and Services Canada

- o Ann MacKenzie, Senior Advisor, Consultation, Environment Canada*
- o Doug Maloney, Corporate Policy and Administration, Public Works Canada
- o Marie-Josee Mercier-Savoie, Director General, Policy Development and Analysis Directorate, Supply and Services Canada*
- o Wayne Richardson, Manager, Technology Transfer and Training Division, Environment Canada*
- o Ken Sinclair, Assistant Deputy Minister, Policy and Coordination Transport Canada
- o Dr. Robert Slater, Assistant Deputy Minister, Corporate Policy Group, Environment Canada*
- o MGen P.E. Woods, Chief Engineering and Maintenance, Department of National Defence*

plus approximately fifty other officials on specific aspects of the subject.

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* Indicates interview or other personal contact