A DECADE OF ACHIEVEMENT

Environment and Energy Research & Development

Canada

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"In no area is the link between our economic activity and environmental disruption more evident or more troubling than in the area of energy policy. Canada is committed to applying the principles of sustainable development to our energy future."

The Right Honourable Brian Mulroney, Prime Minister of Canada, at the World Conference on the Changing Atmosphere, Toronto, June 27, 1988.

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FEDERAL PANEL ON ENERGY RESEARCH AND DEVELOPMENT (PERD)

The Panel's objectives are to provide, in conjunction with efforts in the private sector and by the provinces, the technical base for:

- maintaining oil self-sufficiency;
- developing a diversified energy economy; and
- making Canada less reliant on non-renewable energy sources.

The Federal Energy R&D Programme is an interdepartmental programme whose overall objective is to provide the science and technology for a diversified, economically and environmentally sustainable energy economy. The Panel is responsible for reviewing and coordinating the programme and monitoring its products. It operates through a system of interdepartmental committees that incorporate private-sector recommendations, and the Office of Energy Research and Development of Energy, Mines and Resources Canada, which acts as the Secretariat to the Panel.

PERD resources are designed to augment the existing budgets of government departments in order to accelerate and coordinate their response to federal energy policy objectives. These departments contract out about 70 per cent of PERD funds to the private sector and to universities. In August 1988, Cabinet approved three years plus one planning year (1989–1993) of funding for federal energy R&D, with PERD's annual budget set at about $89 million.

INTRODUCTION

In Canada today, environment and energy are being accepted as two complementary parts of the vital whole known as sustainable development. For too long, they were treated as mutually exclusive – as if meeting urgent energy needs automatically meant destruction of our already fragile environment. As Prime Minister Mulroney makes clear in the passage that provides the epigraph for the report you are about to read, Canada is now firmly committed to meeting its future energy requirements without compromising its environment.

We need only look at the world economy to know that, ultimately, prosperity and a decent standard of life depend on secure, reasonably priced energy. At the same time, however, there is greater awareness that life itself hinges on a healthy environment now and in the future.

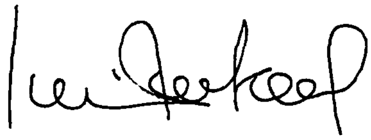
Canada was an early and strong supporter of the World Commission on Environment and Development, which, in its 1987 report to the United Nations, first articulated the concept of sustainable development. Sustainable development – which treats resources on the basis of their future, as well as their present value – is the key to development and exploitation of energy in the future.

The philosophy of sustainable development is a logical extension of Canadian experience during the past ten years, a period in which a healthy environment has become a primary consideration in evaluating energy policies and programmes.

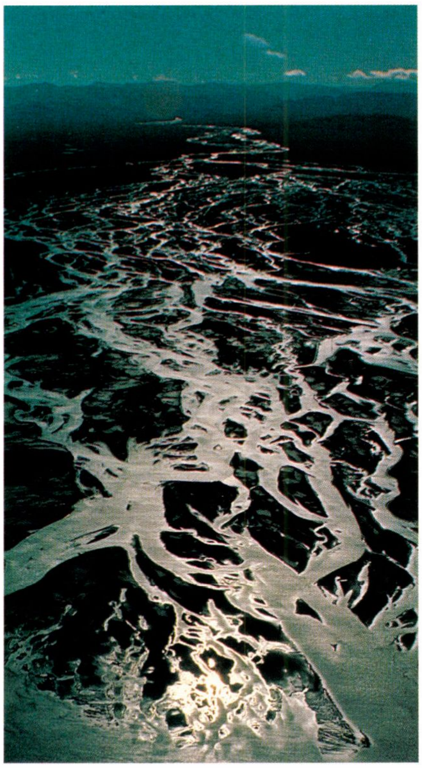
Research and development is crucial if we are to make the most efficient use of our energy supplies and, at the same time, anticipate and prevent environmental problems. That is why, for the past decade, Environment Canada and Energy, Mines and Resources Canada have been exploring the link between the environment and energy, and have co-operated on this vital issue with other federal departments and agencies, with universities and the private sector, through the Panel on Energy Research and Development (PERD), the focus of this report.

Research is helping us learn how energy production affects the environment and how pollution can be reduced and environmental damage minimized. Through the panel Environment Canada assists other departments and the private sector to develop new environmentally sustainable energy options, better methods of controlling water and air pollution, new waste management techniques, and a clearer understanding of terrestrial and offshore climatic systems. Panel funds are also used to stimulate research into specific questions related to energy, environmentally positive energy options, and the development of better energy regulations. These measures support the commitment of the Government of Canada to sustainable development in energy, as in all areas of Canadian life.

I trust that you will find in these pages a clear understanding of what is being accomplished by research and development projects that hold the promise of plentiful energy supplies in an environmentally sustainable world.



Lucien Bouchard
Minister of the Environment



The Mackenzie delta – delicate ecosystem.

Heavy oil pump jacks in Alberta.

Oil sand tailing pond and the Syncrude plant.

THE WESTERN PETROLEUM BASIN

Canada is blessed with a great variety of energy resources. Across the country large rivers have been developed for hydro-electric power, and in the West and the East we have considerable reserves of natural gas, oil and coal. Forests provide wood for fuel, and there is abundant sunlight for solar power. All these energy sources are being tapped, and the result is abundant, low-priced energy for domestic and industrial use. Canada's major accessible oil and gas reserves are found in the Western Basin, which extends from the northeast corner of British Columbia to the southwest corner of Manitoba. Under PERD, Environment Canada has developed research programmes on all aspects of the environmental impact of exploring, operating and extracting these reserves. Concerns here are focussed on drilling wastes, gas plant wastes, gas flares, and upgrader wastes. All this research is designed to improve management of the conventional oil and gas industry, as well as to enhance the government's ability to regulate and protect the environment.

One of our largest energy resources – the oil sands and heavy oil reserves of Alberta and Saskatchewan – has hardly been tapped. Only a few plants are extracting oil from these reserves, because of the expense and technical difficulties of oil recovery and the severe climatic conditions under which the work must be conducted. There are two distinct approaches to oil sand extraction. Where the oil sands are near the surface, open-pit mining techniques can be used. The in situ technique currently used on deeper oil sands and heavy oils consists of injecting steam into the ground, heating the oil to make it flow better, and then separating the oil from the water after it is pumped to the surface. However, both methods have significant environmental impacts.

Oil sands extraction at the Syncrude and Suncor sites uses the Clark Hot Water Process. This process produces tailing ponds containing enormous volumes of contaminated water (the Syncrude tailing pond, for example, covers 22 square kilometres), and piles of sandy tailings that are difficult to revegetate under semi-Arctic conditions. The same extraction process has been chosen for the recently approved OSLO oil sands project.

Oil sands extraction generates large quantities of contaminated water containing chemical and oil residue that, if not removed, will damage the delicate northern ecology, the Athabasca river system and local groundwater reserves. Because the industry uses some of the high-sulphur oil for the extraction process, there is also a certain amount of air pollution. This is worse in winter, when calm air conditions give rise to inversion layers that keep the polluted air near the ground. The PERD programme has been used to study many of these issues. Research has concentrated particularly on defining the distribution of the worst pollutants (especially phenols) in oil deposits and reducing the environmental damage they can cause, and on finding ways to improve the water treatment process.

LAND TREATMENT DISPOSAL OF OILFIELD WASTES

Large amounts of oily wastes, generated during the production of heavy oil in western Canada, must be disposed of in an environmentally sound and economically feasible manner. For example, over 100 000 cubic metres of such waste oil and sludge are produced annually in Alberta alone. Research at the University of Calgary's Kananaskis Centre for Environmental Research is focussing on this issue. The research is jointly funded by Environment Canada and the Canadian Petroleum Association.

Particular attention is being paid to the rate of oil degradation and the potential environmental effects, as well as to our ability to return waste treatment sites to full agricultural production. Other concerns include the amount of groundwater contamination. Results provide a scientific base for the establishment of industrial guidelines for the land treatment of oilfield wastes. These research activities are coordinated by Rick Scroggins of Environment Canada.

WATER TREATMENT AT LINDBERGH

A major research effort is under way to find an economical and reliable way to recycle or discharge the water used in the in situ heavy oil extraction process. The contaminated water produced by this process contains excessive amounts of certain chemicals that eventually render the water unusable. If sustained re-use is to be achieved, the water must be either diluted or treated. At the moment, no demonstrated technology exists for removing the chemicals; however, Abbas Zaidi of the Wastewater Technology Centre in Burlington, Ontario, has worked with the Alberta Oil Sands Technology Research Authority (AOSTRA) and several oil companies to evaluate removal processes such as vapour compression evaporation and electrodialysis. Pilot tests are being conducted by the Dearborn Chemical Co. Ltd. at the Amoco Canada site in Lindbergh, Alberta, and at Environment Canada's Wastewater Technology Centre.

The costs of this work, like most of the research funded by PERD, are shared: the major players are AOSTRA (50 per cent) and Environment Canada (26 per cent), with the oil companies in question (Amoco Canada, Murphy Oil, Pan Canadian and Westmin Resources) sharing the remaining 24 per cent.

Terri Bulman, Environment Canada, studies oily sludge waste disposal.

Crew de-icing vessel during stormy conditions.

Beaufort Sea oil exploration.

SAFE DESIGN OF OFFSHORE OIL AND GAS FACILITIES

The design and safety of offshore oil and gas operations in Canadian waters are a matter of concern to industry, government, and the public. Not only did the Ocean Ranger sink in a storm with the loss of 84 lives, but the rig Rowan Gorilla capsized recently while under tow off Canada's east coast. In the latter incident the entire crew was saved, thanks in large part to design and safety regulations implemented by the Government of Canada and administered through the Canada Oil and Gas Lands Administration (COGLA).

Two of the more critical factors in planning safe offshore exploration are the engineering design of the platforms and attendant vessels, and an appreciation of the enormous power of offshore storms. Under PERD, Environment Canada is conducting research that will lead to the development of improved safety standards and the ability to better predict the intensity, track and timing of offshore storms.

The safe design of offshore facilities requires an in-depth knowledge of the various forces that can affect them. We must consider not only the enormous waves generated in winter storms but also the wind, sea ice, icebergs, the effect of ice build-up on the rigs and vessels, water pressure at great depths, and undersea currents that can affect pipelines and other submerged equipment. Designers must also deal with the complex issue of the interaction among these forces.

Research in this field, directed toward a better understanding of the natural physical forces at work, is managed by Environment Canada's Atmospheric Environment Service at Downsview, Ontario, and the National Water Research Institute located at the Canada Centre for Inland Waters in Burlington, Ontario. Research is undertaken in cooperation with a wide range of private companies, such as Seaconsult Ltd. of St. John's, Newfoundland, and MacLaren Plansearch Ltd. of Halifax, Nova Scotia.

WIND AND WAVE HINDCASTING IN THE BEAUFORT SEA

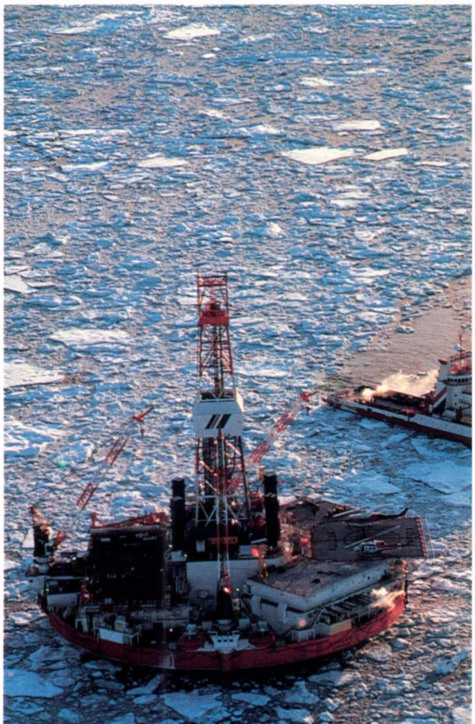
In the absence of ice, waves are the dominant load on offshore structures. Wind-driven currents and storm surges may also be important considerations, especially in the Beaufort Sea. For these reasons, an accurate climatology of wind and waves is critical for many engineering designs.

Over the past year, such "hindcast" wind field information bases for large wave-generating storms have been produced for 20 Beaufort Sea summer storms and 14 winter storms. These wind fields are used in a cooperative programme with Fisheries and Oceans, as input data for wave, current, surge and ice motion models for the area.

A major initiative was undertaken to produce extreme wind and wave hindcasts for the Grand Banks, Scotian Shelf and Georges Bank. This joint project is part of a larger plan to completely describe the wind and wave regimes (both normal and extreme) for east- and west-coast waters, in accordance with the recommendations of the Royal Commission on the Ocean Ranger Marine Disaster. Many other agencies are involved in this plan, including the oil and gas industry and the federal departments of Fisheries and Oceans, National Defence, Transport Canada, and Energy, Mines and Resources Canada.

These projects contribute to safer, more economical and environmentally sound offshore energy development.

Determining the processes that generate waves and their powerful forces requires considerable ingenuity and resources. The really important information on the worst conditions is difficult to collect. Under the direction of Dr. Mark Donelan, Scientists at Environment Canada's National Water Research Institute utilize an off-shore tower to make remote recordings of physical information and transmit the data to their laboratory on shore. The study on "Deep Water Wave Breaking and Wave-Turbulence Interaction" is yielding results that improve our understanding of how winds generate waves and ocean currents. With this better understanding we can improve the engineering design of offshore structures, accurately calculate the mixing of pollutants spilled in oceans, and extend our knowledge about the interchange of energy, heat and gaseous pollutants between the atmosphere and oceans.



ICING ON OFFSHORE STRUCTURES

Under extreme conditions, ice build-up from freezing spray can cause a vessel to capsize and, in combination with more powerful wind and wave forces, can compromise the stability of offshore floating platforms. It can immobilize safety equipment, interfere with communications, and create dangerous working conditions. It is therefore important to quantify the icing hazard for vessels and offshore structures operating in Canadian waters. Research is difficult, since data must be collected in the most trying weather conditions. Under the direction of Ross Brown of the Atmospheric Environment Service (Canadian Climate Centre) in Downsview, this subject has been investigated in the laboratory, at sea, and by the development of detailed computer models. A drill rig icing model is run as part of a cooperative project with the Norwegian Hydrotechnical Laboratory. The work includes continuous monitoring of icing on drill rigs, supply ships, and fishing vessels, and the results are used in the design of new offshore structures and vessels.

Ross Brown manages the drill rig icing model studies at Environment Canada.

Wave breaking, Cape St. George, Newfoundland.

Gannet breeding colony on the shoreline.

SAFE OPERATIONS IN OFFSHORE OIL AND GAS DEVELOPMENTS

Just as the design of offshore equipment is important, the safe management of operations is of concern to all Canadians. The responsibility for safety is in the hands of the oil industry, but plans are overseen by the Canada Oil and Gas Lands Administration (COGLA) and the regional offshore petroleum management boards, such as the Canada-Newfoundland Offshore Petroleum Board. COGLA relies heavily on the scientists of Environment Canada and Fisheries and Oceans to provide detailed information on, and understanding of, the harsh physical conditions (currents, winds, ice, and waves) under which the exploration and exploitation of our offshore petroleum resources must take place.

Additional research is under way to examine the impact of oil exploration and development on the environment. This has included studies on drilling muds (the debris left after a well is drilled), the monitoring of oil from aircraft, and the efficiency of chemical oil-dispersants used when a spill occurs. Results of these studies have been used by COGLA in the development of regulations for offshore discharges from oil and gas facilities. Particular attention has been paid to studies on the impact of spills on marine life and the shoreline. For example, the potential for the tainting of commercial species of fish and shellfish by spills of oil and gas condensates is being assessed. Canadian Wildlife Service biologists have undertaken research to determine the extent and significance of sea bird oiling, including the long-term damage that small quantities of oil might have on the birds, both directly and indirectly, and the particularly damaging effect of oil in the harsh environmental conditions of the Arctic, where stress from the intense cold can reduce the birds' residence to pollutants.

UNDERSTANDING OCEAN STORMS

Under a programme partly funded by PERD, the Canadian Atlantic Storms Programme (CASP) was established to improve understanding of ocean storms. This project measured oceanic and atmospheric conditions over the Scotian Shelf and the entire Atlantic Canada region during 16 east-coast winter storms in 1985-86. The project was conducted in conjunction with a major American project called GALE, which also monitored storms along the Atlantic seaboard. CASP, a joint venture of Fisheries and Oceans and Environment Canada, involved scientists from the National Research Council of Canada, National Defence, and the United States. Environment Canada's efforts were directed by Ron Stewart and George Isaacs of the Atmospheric Environment Service. Weather station operational staff and representatives from McGill University were involved as well, and many residents of the Maritimes recorded specific data throughout the period of the study. The total cost of the CASP/GALE field project amounted to $22.5 million; of this, $4.5 million was provided by the Canadian government. The balance was covered by the United States Navy and other American scientific agencies.

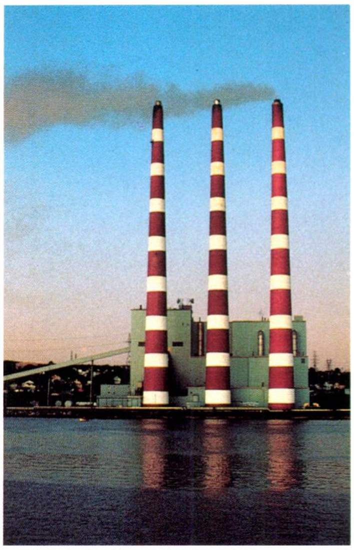
The programme captured an unprecedented amount of data over two months, using an extensive array of current-, wind-, and wave-measuring instruments, land-based meteorological instruments, aircraft overflights and coastal radar observations of waves. The comprehensive set of data obtained is unique, and has helped us to understand and predict storms in the region, to design equipment that will survive in that environment, and to establish procedures that will protect both people and the environment.

REMOTE-SENSING MONITOR FOR SPILLS

Oil spills are inevitable. Their effective management requires immediate warning of their occurrence as well as continuous monitoring. Since 1984, Environment Canada, with the help of funds provided by PERD, and in cooperation with the oil industry, has been evaluating remote-sensing instrumentation for tracking the presence of oil on water. The objective has been to develop a monitoring and warning system to detect and track both deliberate and accidental oil discharges offshore. This system, mounted on oil rigs or production platforms, allows for early spill detection. The Infrared Oil Film Monitor, manufactured by Wright and Wright Inc. in the United States, is the system that has been chosen. It is now undergoing modifications to improve its sensitivity under very rough sea conditions.

Aircraft-mounted instruments measure atmospheric conditions during CASP.

Roger Percy and Sue Day of Environment Canada at oil spill monitoring.



Coal-fired generating station in Nova Scotia.

COAL

Our society is dependent on electricity: it runs our factories, homes, hospitals, and airports. Hydro-electric dams and nuclear power plants meet a large percentage of our requirements, but as we use up feasible hydro sites and as the cost of nuclear power plants increases, we are turning more to coal-fired plants. However, like dams and nuclear power plants, coal-fired plants and coal mining have an environmental impact.

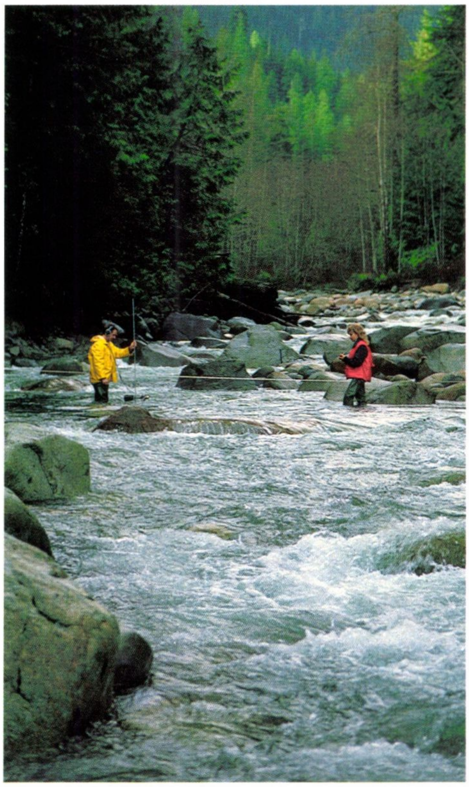
Environment Canada, with funding from PERD, has focussed its attention on the main environmental effects of coal-fired power plants. The most serious pollutants from these plants are the acidic flue gases which, after emission into the atmosphere, return to the earth dissolved in rain (acid rain). Measures to remove the acidic compounds from coal-fired power plant flue gases often produce large quantities of solid waste by-products that are themselves sources of environmental concern. Disposal sites containing these by-products may release irritating dust, contaminate water supplies, or be physically and chemically unstable and therefore unsuitable for further use. In addition, the wastes and activities associated with coal mining, processing, drying, storing and transportation can have an adverse impact on water, air, and land.

Environment Canada conducts and supports research and development into better environmental protection standards under the Canadian Environmental Protection Act (CEPA). It also seeks new ways to prevent and control pollution. Together with Energy, Mines and Resources Canada and the utilities, the Department is actively involved in examining processes to reduce the amount of waste or to produce waste that is more stable and less likely to pollute groundwater and surface runoff. Another target of the research is to produce material that is amenable to recycling.

AIR POLLUTION CONTROL

A relatively new approach to reducing air emissions of sulphur dioxide involves injection of a sorbent, such as lime or limestone, into a coal-fired boiler. The sorbent reacts with sulphur dioxide to form solid sulphur-containing by-products that are removed from the flue gas along with ash particles. Although this technology is inexpensive compared with other sulphur dioxide removal technologies, it is relatively inefficient. Research, development and demonstration related to improving the efficiency of sorbent injection technology is being conducted jointly by Ontario Hydro, Saskatchewan Power, Environment Canada, Energy, Mines and Resources Canada, and the Canadian Electrical Association. Recent results indicate that removal of 80 per cent of sulphur dioxide is achievable using sorbent injection, a much higher efficiency rate than that found in past investigations. A promising modification of the system can also remove up to 90 per cent of nitrogen oxides, and thus may help Canada meet its international obligations to control these substances.

Other approaches to removing sulphur dioxide from flue gases include a technology called flue gas desulphurization, which consists of "washing" the flue gases with a sorbent that reacts with sulphur dioxide to form by-products that can then be separated from the washing solution. Another technology, fluidized bed combustion (FBC), consists of burning coal in a bed of limestone; this reacts with sulphur dioxide to form by-products that can be removed with the ash waste. Research on the management of by-products from both these technologies is directed by Geoff Ross of Environment Canada, and is being conducted by private companies such as Dearborn Chemical Co. Ltd. and Canviro Consultants, both of Mississauga, in cooperation with Energy, Mines and Resources Canada, the Canadian Electrical Association, the New Brunswick Electric Power Commission, and Nova Scotia Power Corporation. An example of this work is the field demonstration of environmentally appropriate landfill disposal procedures for FBC solid wastes. This work is being carried out at the Chatham, N.B., FBC power plant, which was financed by Energy, Mines and Resources Canada and is operated by the New Brunswick Electric Power Commission. The work has demonstrated procedures for conditioning and placement of FBC solid wastes in a disposal site so that dust emissions are reduced and the waste occupies a smaller volume, is physically stable, and is resistant to penetration by water.



COAL MINING

Work is in progress to develop a process to remove the pollutants from coal mining and processing wastewater. Such wastewater can contain various pollutants, including low levels of nitrogen compounds from blasting operations. Chemicals of this type can cause significant degradation of natural receiving water, and are difficult and costly to remove with conventional pollution control equipment. Tests are being conducted on a natural process involving the growing of plants in wastewater in order to extract the nitrogen. This research, supervised by Bill Blakeman and Bryan Kelso of Environment Canada, is being performed by two Vancouver companies–Norecol Environmental Consultants and M. Ross Consultants–and by coal companies such as Quinsam Coal Ltd. of Campbell River, British Columbia.

Geoff Ross, Environment Canada (left), Ray Kissel, Dearborn Chemical Co. Ltd.

Monitoring impact of coal mining in B.C.

SUSTAINABLE ENERGY DEVELOPMENT

For the better part of this century, Canada has relied for much of its economic development on its finite fossil fuel resources. In recent years, it has become increasingly obvious that the impact of fossil fuel use on the environment is more serious than originally believed, and that this issue must be addressed. The rate at which chemicals are released from energy-generating operations seems to be in excess of the atmosphere's absorption capacity. These operations could have an enormous impact on the world's environment and economy.

While it is reasonably easy to understand and solve such obvious pollution problems as discharge spewing into a river or black smoke belching out of a smoke stack, many gaseous pollutants are subtle and inconspicuous, and yet potentially more damaging. Three related issues are of great concern to Canadians today: the accumulation of greenhouse gases in the atmosphere, acid rain, and the destruction of the ozone layer in the upper atmosphere. If fish die in a lake because of acid rain, the average person will notice, but there is no way for that person to see the cause. If there is progressive climatic warming as a result of CO_2 build-up in the atmosphere, leading to an increased incidence of Prairie drought, farmers will notice but may not know the cause. One of the important roles of government scientists is to attempt to understand and study the cause of these major global environmental changes, discover solutions to them, and provide advice and information to decision-makers and the general public.

Finding the cause and taking appropriate action is difficult. Understanding climatic change requires very sophisticated instrumentation to measure the flow of carbon dioxide as it circulates throughout the atmosphere and through forests and oceans. It also requires computer models to determine how CO_2 levels affect the climatic system. Only detailed monitoring can tell us whether there really is a build-up of the gas in our atmosphere, and whether it is causing a warming trend (the so-called greenhouse effect). The next step is to estimate the long-term impact.

Another type of invisible air pollution is caused by sulphur and nitrogen oxides. These gases are produced by processes such as the smelting of copper, coal burning for electrical generation, and the use of gasoline in transportation. When dissolved in the atmosphere, they produce acid rain, which can be very damaging to vegetation and wildlife. Its full long-term impact has still not been determined, but our understanding of its effects improves yearly.

Finally, another very complex issue is the destruction of the ozone layer in the upper atmosphere. This layer provides a shield that protects us from cancer-causing solar radiation. People find it difficult to believe that fossil fuel combustion and the use of aerosol household cleaners and foam coffee cups have been responsible for destroying the ozone layer. Such causes and effects are becoming known because of the work of dedicated scientists such as Wayne Evans at Environment Canada.

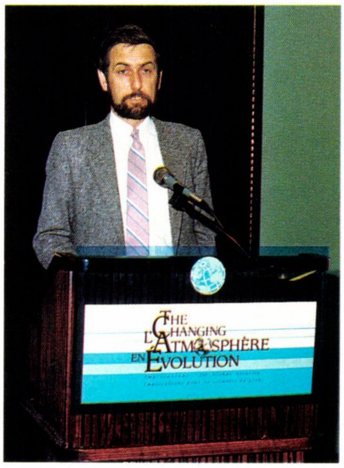
CO_2 COORDINATOR

Environment Canada, with funds from the PERD programme, has appointed a central coordinator, Henry Hengeveld, to the Climate Programme Office of the Atmospheric Environment Service in Downsview, Ontario. His role is to address the carbon dioxide issue, to advise on issues related to the greenhouse effect and climate change based on research in Canada and around the world, and to make all interested Canadians aware of these findings and their implications. This information integration and "packaging" for the use of other scientists and the public is most important in an era of rapidly changing science, vast quantities of information, and increasingly sophisticated technologies.

In June 1988, as part of the global coordination of such efforts, Canada hosted a major international conference in Toronto, funded by Environment Canada and other departments. This conference, entitled "The Changing Atmosphere: Implications for Global Security," was attended by Prime Minister Brian Mulroney and Prime Minister Brundtland of Norway, who had chaired the United Nations' World Commission on Environment and Development. The conference was chaired by Stephen Lewis, who was at that time the Canadian Ambassador to the United Nations.

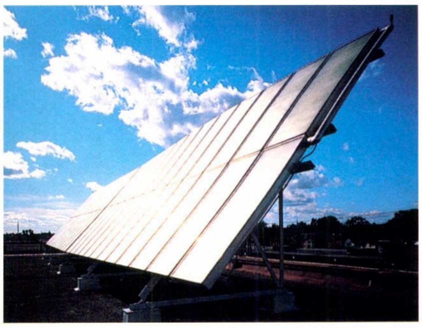
FLUX MEASUREMENT OF GASES

Research funded by PERD is also under way to develop methods to determine more accurately the quantity and type of pollutants in the atmosphere and monitor their movement. Greenhouse gases in the atmosphere are of particular concern. Carbon dioxide, nitrous oxide, methane, and chlorofluorocarbons (CFCs) are known to be increasing. These gases are essentially transparent to incoming short-wave solar radiation, but they absorb and emit outgoing long-wave radiation and are thus able to influence the Earth's climate. Whereas carbon dioxide has long been recognized as the most important greenhouse gas, the combined role of the other gases is almost as important in changing the climate. It will take considerably more research and integrated analysis before we know the full implications of the changing levels of these gases in the atmosphere.



Henry Hengeveld at the World Conference on the Changing Atmosphere.

Prairie drought – the changing climate.



Solar panels in operation, a supply of energy.

RENEWABLE ENERGY RESOURCES-SOLAR

Our fossil fuel resources are finite, but technically accessible at economical prices. Our renewable energy resources are essentially infinite, but we are having technical difficulties in realizing their potential at reasonable prices. Researchers around the world are attempting to find ways to reduce costs so that we can increase the role that renewable resources–particularly the sun and wind–play in supplying our energy needs.

At first glance, solar energy does not appear to contribute much to our present energy supply. There are relatively few solar panels to be seen, except in demonstration projects and on some houses, factories and government buildings. There are even fewer apparent uses for photovoltaic systems, which change sunlight into electrical energy. However, these systems actually play a major role in remote locations, where they provide reliable power to equipment such as Canadian Coast Guard buoys and telecommunication relay stations. Passive solar energy contributes significantly to keeping us warm, and with the increasing application of new Canadian building techniques (such as the R-2000 home design and advanced technology in window design) our homes and businesses will be heated more efficiently with solar energy. Greater use of solar energy will permit reductions in the tremendous amount of energy used in the form of firewood, which is still one of the most important energy sources for rural homes and certain industrial sectors.

Unlike many of the other energy sources used in Canada, renewable energy–especially solar, wind and small-scale hydro–creates few environmental repercussions. In order to develop and utilize solar technologies further, we must understand our solar energy resources. This is one objective of the Atmospheric Environment Service. With PERD funding, the Service, through contracts with private companies and universities, has been developing detailed databases of the solar energy potential across Canada. These are now available for use in the design of passive solar systems for buildings and the design and orientation of active solar systems.

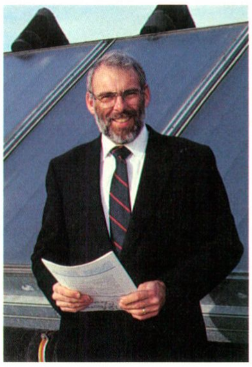
Solar research is carried out under the direction of Bob Morris of the Atmospheric Environment Service. The first comprehensive solar resource atlas and an easily accessible database for Canada are two recent products of this research.

SOLAR RADIATION DATA ANALYSIS

Hourly solar radiation measurements are available in the AES National Climate Archives for some 50 locations across Canada. These data are not ideal for the design of solar energy equipment, as they are recorded on a horizontal surface and there is no information on the amount of solar energy provided by direct solar beam or diffuse light. To determine the benefits and feasibility of solar collection systems for energy cost calculations for buildings, more detailed measurements are needed.

To meet these requirements, the Atmospheric Environment Service developed a computer model that estimates the direct beam and diffuse solar radiation amounts on any user-defined surface, such as windows and walls. The number of locations nationally where the data are available has also been increased from the original 50 to 130.

Statistical summaries and maps of monthly average solar radiation are published in the *Solar Radiation Data Analyses for Canada* by Environment Canada, and are also available on magnetic tape and floppy disk. The information has been incorporated into two solar collector and R-2000 building design computer programmes used widely in Canada: WATSUN and HOTCAN.



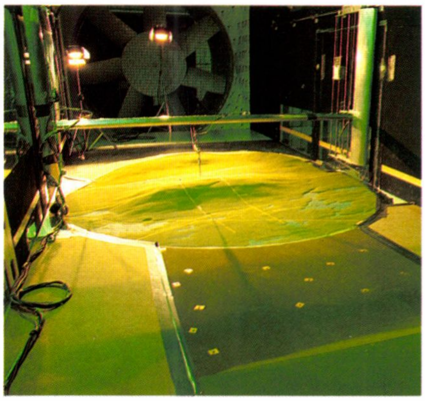
THE R-2000 HOME

Currently, energy-efficient houses (especially R-2000 super-energy-efficient houses) are being designed and constructed with passive solar energy as a primary consideration. PERD funding enabled the Atmospheric Environment Service to develop the solar information database required to support these projects across Canada. Site conditions permitting, a house is oriented toward the sun, with south-facing walls containing the most windows, and north-facing walls the fewest. Increasing the south-facing window area to between 8 and 10 per cent of the floor area allows an energy-efficient house to obtain 25 per cent of its heating requirements from the sun. Further, roof overhangs are positioned so that the sun's rays can shine unobstructed through the windows in winter, when the sun is lower in the sky, and yet be blocked in the summer.

Passive solar features reduce heating and cooling requirements and help keep the house at a comfortable temperature year-round.

Don McKay, a solar radiation researcher at Environment Canada.

An energy-efficient R-2000 home.



RENEWABLE ENERGY RESOURCES – WIND

Wind energy may become a more important energy source in the future. It is clean and available indefinitely, but its diffuseness and variability make extraction of usable power expensive. In Canada, major emphasis has been placed on the "egg-beater" design of the Darrieus windmill, named after its French inventor. The Canadian work was initiated at the National Research Council of Canada, and research has concentrated on lowering costs so that eventually wind turbines will be able to compete with other sources of energy.

No wind sites can be selected or turbines chosen without detailed knowledge of the local wind "resource". The Atmospheric Environment Service has produced a mean wind speed map and mean annual wind energy density map as an initial evaluation of the wind energy regime in Canada. Data for these maps were gathered in 140 sites across the country over a period of ten years. Since characteristics can vary from year to year, the interpretation of wind climatology is difficult. Measurements are still being made at some sites on annual average wind speed, turbulence levels, seasonal wind patterns and daily changes in wind.

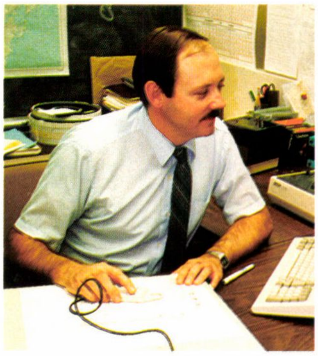
As part of the overall government effort to stimulate the development of wind energy, a number of large demonstration windmills have been funded across the country. The two largest are at Îles-de-la-Madeleine and Cap-Chat, both in Quebec.

WIND FLOW OVER A HILL: COMPUTER-GENERATED RESULTS

Although the data in a wind atlas can indicate the best regions in Canada for locating a windmill, they do not give sufficient information for selecting actual sites within that region. The wind climatology at a "standard" measurement site such as an airport is seldom adequate for sites located some distance away, because local topographic features can drastically alter the wind energy potential. It is obviously not feasible to make long-term measurements at all potential wind energy sites across the country. Instead, a major PERD-funded programme has been conducted by the Atmospheric Environment Service, under the direction of Dr. Hans Teunissen and Dr. Peter Taylor, to identify, understand, and attempt to model the effects of topographic features such as hills on the wind flow above them. These effects can then be taken into account for any site without necessarily having to make in situ measurements. Field measurements, wind-tunnel simulations and mathematical modelling of wind flow over hills have been carried out and have produced results and guidelines that are now routinely used world-wide to estimate wind energy potential at specific sites.

A DARRIEUS AT CAP-CHAT

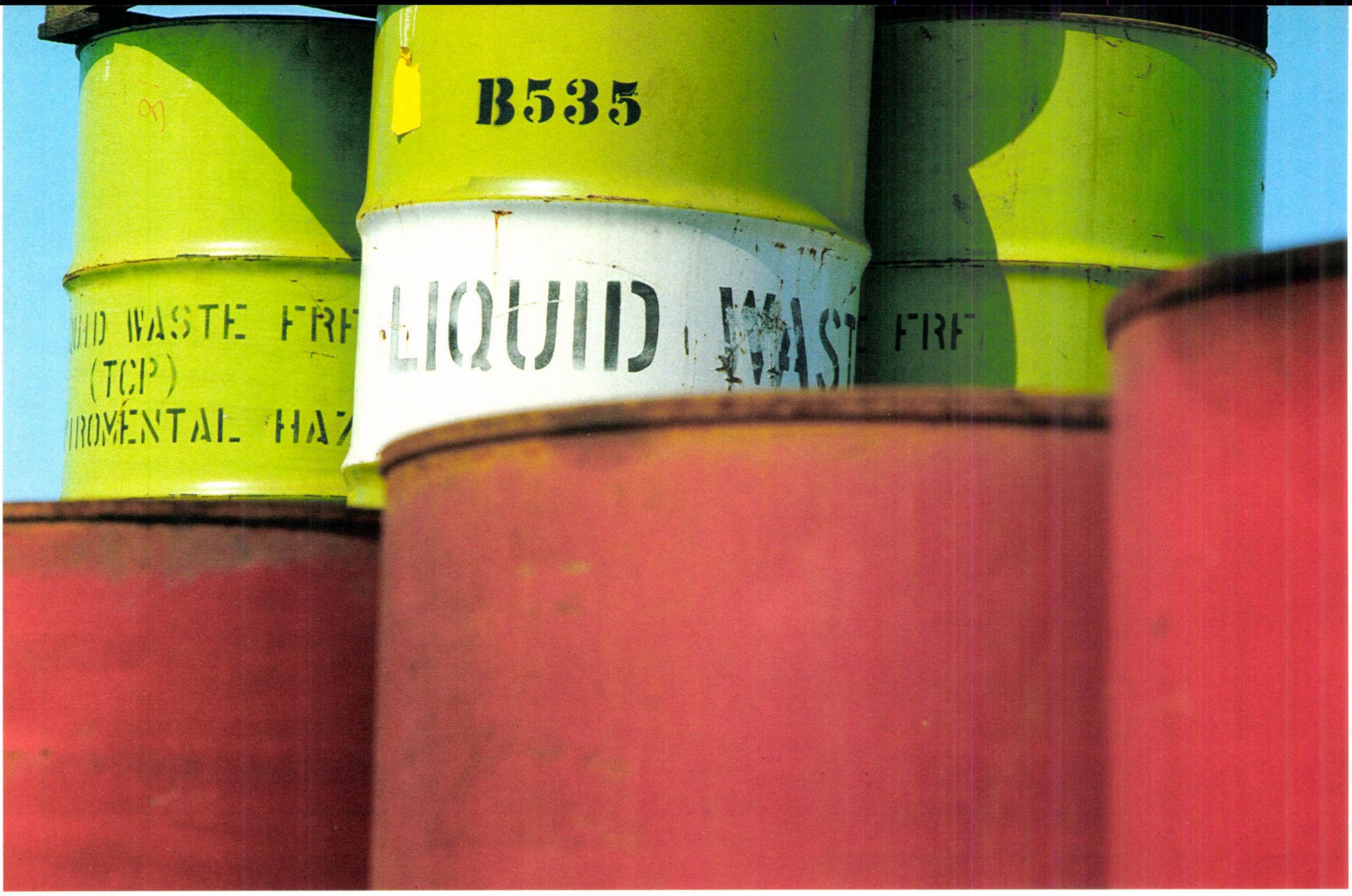
Demonstration of new large windmills began with an energy resource assessment carried out by the Atmospheric Environment Service, Hydro-Québec, and the National Research Council. Engineers from Lavalin and private consultant Dr. J.R. Salmon were also involved. Sixty-metre meteorological towers were installed at four sites to take advantage of the strong winds in the St. Lawrence valley and on the Îles-de-la-Madeleine. In 1982, the National Research Council of Canada and the Institut de recherche d'Hydro-Québec signed an agreement to share equally the $35-million cost of putting the prototype in place. Suppliers were Versatile Vickers, Canadian General Electric and Hayes Dana Corporation. The site selected was Cap-Chat. In 1986 the project was transferred to Experts-Conseils Shawinigan Inc. to commission and run commercially. During site selection and project design, the Atmospheric Environment Service, and particularly Dr. Peter Taylor, provided detailed micro-meteorological data on the wind regime.



A Darrieus windmill being mounted.

Wind flow over hill test in wind tunnel.

Bob Morris, a wind scientist.



Shredded tires – demonstrating an energy source at the Lafarge Canada Inc. cement plant in Quebec.

DEMONSTRATIONS OF RESOURCE AND ENERGY CONSERVATION

One important role of government is to help society adapt to changing conditions. New industrial technologies provide new products and reduce the costs of everyday items. Unfortunately, such changes also generate increasingly complex chemical pollutants and greater quantities of industrial and household waste. At the same time, the available waste disposal sites in many communities are nearly full, and new sites are difficult to obtain. While the business community is financing the development of new technologies, few are dealing with the resulting build-up of pollutants and garbage.

A major selection criterion for Environment Canada's Development and Demonstration of Resource and Energy Conservation Technology (DRECT) projects is energy conservation. This takes many forms; one example is the recovery and use of methane gas produced at the municipal landfill site in Kitchener, Ontario. Through PERD, DRECT is funding research on the recovery and recycling of various waste materials from industry. Processes have been developed, for instance, to recover chromium from metal plating wastes in the Thermonic plant in Boucherville, Quebec, and to recycle nitrogen waste from a fertilizer plant in Maitland, Ontario. In these installations, plant waste constituted a significant pollutant. The processes not only cleaned up the pollutants, but also resulted in energy savings and economic benefits both to the plant and to the industrial sector in question.

Combining energy conservation with recycling maximizes the benefits that can be obtained from research. Another good example of this principle at work is the substitution of old tires for oil in the firing of industrial plants. The large number of car and truck tires discarded each year presents significant landfill, aesthetic, and safety problems for our cities. Funds from PERD have been used to design a system to burn these tires in cement kilns, reducing the amount of natural gas or oil used in this energy-intensive process. At the Lafarge Canada cement plant in St. Constant, Quebec, this research has been taken to the commercial stage.

RECYCLING, RESOURCE RECOVERY AND ENERGY SAVINGS

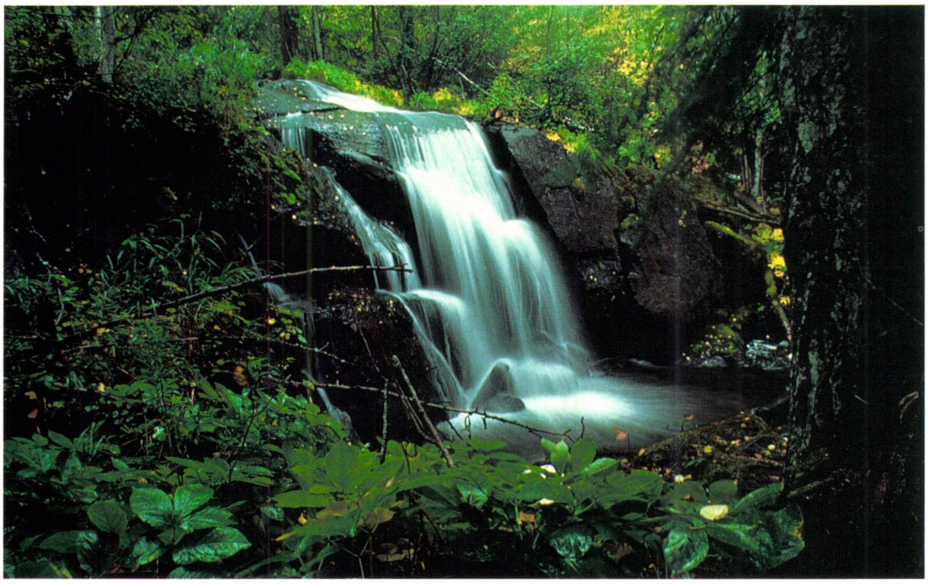
Through DRECT, Environment Canada stimulates the development of new technologies to solve pollution and garbage disposal problems. The programme, managed by George Hill, Dave Campbell and Adrian Ross, provides research funds for developing methods of recycling wastes so they no longer pollute, for removing pollutants before they enter the environment, and for reducing the energy used in industrial processes, in order to minimize the attendant environmental impact.

DRECT also provides funds and technical advice to such successful enterprises as the Canadian Waste Material Exchange, now coordinated by Ortech International, a non-profit organization, and Papersave, the federal fine paper recovery programme administered by Supply and Services Canada and Public Works Canada, and managed by Energy Pathways Incorporated.

Environment Canada seeks to ensure that taxpayers' money is used as effectively as possible. Rather than fund all the research, the Department uses small amounts to stimulate investments by provincial governments and industry. Thus, $22.6 million in other funds have been added to the $5.4 million in PERD R&D funds used for 39 projects since 1978. Provinces and municipalities contributed $6.6 million of this amount, and the private sector $16 million.

The use of PERD funds in such a truly cooperative R&D effort has been most effective. A broad range of research projects is producing new, commercially viable processes that save energy and help clean up the environment. The business community is converting these research findings into marketable technologies. It is estimated that the overall impact of the programme up to 1988 has been as follows:

- savings of 60 million barrels of oil-equivalent energy;
- 50 million tonnes of waste material recovered;
- the creation of over 2 000 permanent new jobs;
- the expenditure of over $200 million on capital projects;
- more than 2 500 new construction jobs.



ANACHEMIA DEVELOPS NEW TECHNOLOGY

Anachemia Solvents Ltd. of Mississauga, Ontario, is extracting solvents from paint and chemical manufacturing wastes and burning the remaining sludge to generate steam. The process uses hot sand to evaporate the solvents, which are then recovered by condensation. The waste, along with the sand, is then burned and the sand re-used. This new method provides a net economic gain to the companies that use the technology. Total potential energy savings in Canada from the application of this technology are estimated at 100 000 barrels of oil per year.

Recycling waste solvents for re-use.

"Blue Box" recycling – waste reduction.

MUNICIPAL SOLID WASTE

One only has to look at the disposal cost for municipal waste over the last few years to appreciate that the garbage we produce represents an important and expensive land-use problem. Dumping fees, which used to range from $10 to $15 per tonne, are now over $50 in Canada, and over $100 in some parts of North America. The media recently highlighted the case of a barge carrying garbage that travelled around the western Atlantic and Caribbean for weeks before returning to the place where its journey began.

Solid waste disposal is a major issue in today's urban society. Transporting the waste further away to municipalities with more room for landfills has become an unacceptable alternative; however, many other solutions are available. Cutting consumption, reducing the throw-away component, recycling and incineration can all significantly lessen the quantity of garbage sent to the dump.

ENERGY FROM SOLID WASTE: THE POTENTIAL

Energy-from-waste in Canada has a great deal of potential; a major programme, if implemented in conjunction with waste recycling, would contribute significantly to reducing the immediate impact of solid waste and would also cut toxic waste pollution. The economic impact would be considerable, as the following points show:

- **we produce 16 million tonnes of refuse per year, which is equivalent to 18 million barrels of oil;**
- **over 30 new energy-from-waste plants would be required by the year 2000;**
- **this would involve over $10 billion in capital expenditures;**
- **the construction would provide 120 000 jobs;**
- **5 000 new permanent jobs would be created.**

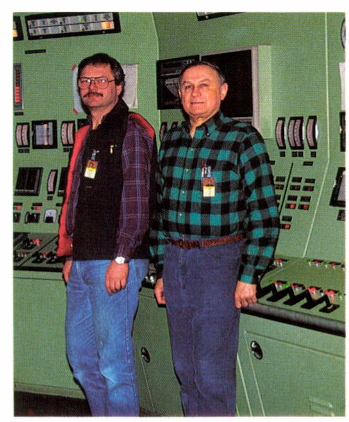
NATIONAL INCINERATOR PROGRAMME

Environment Canada has used PERD funds to establish the National Incinerator Testing and Evaluation Programme (NITEP) to investigate combustion, computer control, stack measurement and emission control technologies for waste incineration. This programme is managed by David Hay, Abe Finkelstein and Ray Klicius of Environment Canada.

The research results are being used as a database for a state-of-the-art computerized system that maximizes efficiency and reduces emissions by improving combustion. This information is being made available to interested parties across the country in order to speed the application of new research findings.

At the Parkdale, Prince Edward Island, energy-from-waste facility, research has developed effective ways of controlling burning, and a new furnace combustion chamber has been developed for the incinerator. Quebec City modified one of its incinerators, operated by Monterey Inc., for a full-scale demonstration of upgraded waste incineration. With the cooperation of Flakt Canada, two different pollution control systems were tested at a pilot plant built next to the City's incineration facility. The results showed a significant reduction in both organic and metal emissions. In fact, dioxin emissions from the modified furnace were well within established limits and 40 to 100 times lower than for the original facility. A similar decrease in particulate emissions was achieved. Since these results have proven so attractive, the Quebec Urban Community is currently converting the whole facility to this technology.

NITEP research on energy-from-waste has put Canada at the leading edge of world expertise in the field. A multi-million-dollar cost-shared test of refuse-derived fuel (RDF) burning is currently being undertaken in the United States by the U.S. Environmental Protection Agency and Combustion Engineering at a new RDF facility in Hartford, Connecticut. Methods for incinerator ash characterization and sound ash disposal practices have been developed under the programme.



Abe Finkelstein with Ted Brna (U.S.EPA) at Connecticut incinerator test site.

Proper incineration – improved combustion creates energy from waste.

MUNICIPAL AND INDUSTRIAL WASTEWATER TREATMENT

Water is essential to our lives. On average, we each use about 450 litres of water a day. We drink it, cook with it, wash and play in it. Water carries wastes from our bodies, our homes, our businesses and our industries. At one time, it was possible to discharge waste into waterways without treatment because, in reasonable quantities, it could be assimilated through a natural process called biodegradation. When waste quantities are too great, or when the waste is not easily biodegradable, water quality is reduced, restricting our use and enjoyment of water resources.

As industrialization continues and cities grow, the amount of waste increases, as does its variety and complexity. Typical sewage includes human and animal wastes, garburated vegetable matter, detergents and solvents, cooking oil and grease, nutrients such as nitrogen and phosphorus that accelerate the growth of algae, and a host of complex industrial products. Natural biodegradation cannot possibly cope with this load, and some form of treatment is necessary before the wastewater can be returned to the environment. As the waste becomes more difficult and costly to handle, alternative, innovative and cost-effective solutions must be found.

At Environment Canada's Wastewater Technology Centre (WTC) in Burlington, Ontario, scientists are developing and demonstrating new processes to deal with wastewater produced by industrial processes and municipalities. Business and industry, municipalities, provincial agencies, universities, consultants, Environment Canada and other federal departments all play a part. If industrial and municipal waste treatment processes can be modified to use fewer chemicals, and waste can be re-used or treated more efficiently by using less energy, the end result will be cost reductions and a cleaner environment. This is a major theme of the Centre's PERD-supported programme.

OIL FROM SEWAGE SLUDGE

Sewage sludge is a by-product of the wastewater treatment processes used to render industrial and municipal wastewater less harmful to the environment. Canada alone produces over 500 000 tonnes of sewage sludge each year. Disposal of these vast amounts of sludge is cumbersome and expensive. The sludge from large cities is often incinerated, but it is also widely used as fertilizer in agricultural applications, or occasionally disposed of in landfills. Some municipalities dispose of their sewage sludge by dumping it into the ocean. Whatever the method used, the annual costs of disposing of sludge are often as high as 50 per cent of the annual cost of treating wastewater. Annual sludge disposal costs for Canada are approximately $100 million.

In 1982, Trevor Bridle and Herb Campbell of the Wastewater Technology Centre initiated a programme to study the conversion of sludge to usable energy. They examined a process that had been identified at Tübingen University in Germany. The process involves heating dried sludge to temperatures of 300° to 350° Celsius, for about 30 minutes, in an oxygen-free environment. The conversion process produces several by-products: oil, char, reaction water, and non-condensable gas. The main product is oil, but the gas and char also have energy value and can be used as fuel for the drying/conversion process. This technique produces fuel oil in much the same way that nature produces crude oil, but the process is accelerated so that it is completed in 30 minutes, instead of millions of years.

The WTC process has many benefits. Both raw and digested sludges can be used, and the oil produced is storable and transportable, unlike energy recovered from methane or steam, which must be used quickly on site. The product is suited for use as fuel oil, and may be upgraded to transportation fuel. The oil can be sold, creating annual savings of $15–20 million from the 700 000 barrels of oil Canada could thus produce each year. This revenue could be applied to offset wastewater treatment costs. Although capital costs of conversion equipment are comparable to those of incineration, operating and maintenance costs for the conversion process are lower. For example, up to 95 per cent of the thermal energy present in the sludge can be recovered.

The conversion process currently can be applied only to municipal sewage sludges, but may eventually be applied to sludges from industrial processes as well. This process is so economical and innovative that it is of interest to municipalities all over the world, especially in Europe, where disposal costs are particularly high. Recent surveys have shown that Canada, the U.S. and Europe spend $2 billion annually on sludge disposal–and sludge production is expected to double in the next decade. Large sums expended on disposal can undoubtedly be saved through the sludge conversion process.

The WTC technology of producing fuel oil from sewage sludge has been patented by Canadian Patents and Development Ltd. At present two full-scale demonstrations of the technology are being planned in Canada.

CONTROLLED AERATION OF SEWAGE

When industrial and municipal wastewater is biologically treated to render it less harmful to the environment, part of the process usually involves aeration–the provision of oxygen. Aeration is an energy-intensive operation, and can account for a major portion of a sewage treatment plant's energy budget. With support from PERD, Gord Speirs of the Wastewater Technology Centre, in cooperation with Canviro Consultants and McMaster University, initiated a demonstration at the Tillsonburg, Ontario, water-pollution control plant. It was shown that automated control of an aeration system results in energy savings, improved operations, and reduced maintenance requirements. In addition to reducing operating costs, automated control creates significant capital cost savings by optimizing the treatment capacity of existing facilities and deferring plant expansions. At Tillsonburg, the automated aeration train is now capable of handling the entire plant, effectively doubling the facility's previous aeration capacity.

Herb Campbell with Gary Smylski (left), researchers of sludge technologies.

Iona Island wastewater treatment plant, Vancouver, British Columbia.

PULP AND PAPER

Canada's forests are its most abundant and extensive renewable resource. The pulp and paper industry is in a unique position in Canada. Although it is one of the largest consumers of energy of any industrial sector in the country, it also has the potential to increase its internal energy production considerably. In many cases, this improvement in energy utilization could be achieved with significant additional benefit to the environment. Research undertaken by Environment Canada as part of the PERD programme is designed both to increase the efficiency of energy use in the industry and to decrease the total discharge of pollutants from pulp and paper mills. This research was conducted in cooperation with the industry, represented by David Paavila of the Canadian Pulp and Paper Association's research group. John Betts of Environment Canada was the scientific authority for the programme.

The capacities of many kraft pulping mills are limited by the performance of the spent liquor recovery boilers, in which the heavy lignin waste that remains after wood pulping is burned for pollution control and energy recovery. Since the cost of an additional boiler can be in excess of $60 million, alternative approaches to relieving the bottleneck are needed. A major research thrust is consequently centred on the recovery of the spent liquor, and the control of the foul odours often associated with the operation of kraft recovery boilers.

Inefficient combustion in these boilers is the most important cause of energy losses. It is also to blame for the odours produced by incomplete destruction of organic compounds. Improvements in combustion can generate a 3-per-cent increase in constant load energy, and up to a 30-per-cent increase in the capacity of the boiler itself. It has also been estimated that a comparable increase in national production capacity would represent over $100 million in profit.

At Castlegar, British Columbia, a major pulp mill is demonstrating the new approach to improving the mixing of air and combustible gases in the lower portion of the firebox for a kraft recovery boiler, at a cost of $6 million. The federal government contributed $2 million to the project; the contractor, Sandwell Swan Wooster of Vancouver, $100 000; and the B.C. Science Council $90 000. The balance was provided by the pulp mill.

The handling of boiler soot is another area of concern, as soot accumulation in the recovery boilers reduces energy efficiency and increases operating costs. Soot removal can often cost a plant $60 000, plus $300 000 in attendant shutdown costs; there is also the loss of energy during operations from boiler inefficiencies caused by soot accumulation. New sensor equipment developed under this research programme is now in commercial production and is part of a programme to develop computer controls to maximize the economic efficiency of recovery boiler operations.

ANAEROBIC WASTEWATER TREATMENT

Wastewater discharged from pulp and paper mills contains various toxic and inhibitory compounds, in addition to large quantities of biodegradable pollutants. The traditional aerobic approach to treatment requires substantial energy expenditures to aerate the wastewater in large ponds. Anaerobic technology provides a more energy-efficient alternative for the treatment of higher-strength pulp and paper wastewater. Under anaerobic conditions, organic pollutants are recovered as a fuel-grade biogas, and the energy required for aeration is reduced.

Environment Canada's Wastewater Technology Centre (WTC) has worked extensively to support industry in the development and application of anaerobic treatment technology in Canada. In particular, Dr. Eric Hall and his group have assessed the technical potential for anaerobic treatment in the pulp and paper sector by experimentally screening the treatability characteristics of effluents from 21 Canadian mills. Under contract to Environment Canada, NovaTec Consultants of Vancouver has summarized the costs of anaerobic treatment to identify the most economically attractive applications for the technology. The WTC has also worked with MacMillan Bloedel to evaluate several pilot-scale anaerobic systems prior to the selection of a full-scale process for treating semichemical pulping wastewater at Sturgeon Falls, Ontario. Similar systems have been chosen for pilot testing or construction at 8 other pulp mills from New Brunswick to British Columbia.

Environment Canada's programme, with the help of PERD funds, is continuing to explore even more novel applications for anaerobic technology in the pulp and paper sector. Current research is concentrating on the optimization of anaerobic treatment for the removal of toxic compounds in pulping wastewater that has serious environmental effects. PERD funding allows the WTC to forge links between basic research undertaken by other government and university laboratories (Waterloo, McMaster, Manitoba) and potential industrial users of new treatment technologies.

ENERGY SAVINGS FROM SLUDGE PRESS

Under the DRECT programme discussed earlier, CIP Inc. of Gatineau, Quebec, has installed a new dewatering press to further reduce the water content of waste sludge so that it can be incinerated rather than landfilled. The new technology, developed at the Centre de recherche industrielle du Québec (CRIQ) near Quebec City, dries the sludge to a solids content of 50 per cent. Energy recovery from the incineration of the dried sludge generates a fuel saving of 20 000 barrels of oil per year for the mill. If applied nationally, the CRIQ press could reduce pollution from sludge landfills and save 200 000 barrels of oil annually.

Dr. Eric Hall of Environment Canada studies anaerobic technology.

Pulp and paper plant at Elk Falls, B.C.

Our Canadian forests – a renewable resource for pulp and paper, and biomass for energy.

R&D Programme Coordinators (left to right):

John Reid, Wayne Richardson and Bob Boulden.

MANAGEMENT PERSPECTIVE

Environment Canada wishes to ensure that its available research funds are used to maximum effect, and that the findings are applied and implemented. The Panel on Energy Research and Development (PERD) furthers both these aims. It also promotes partnerships among industry, universities and government, thereby supporting a major priority of the federal government.

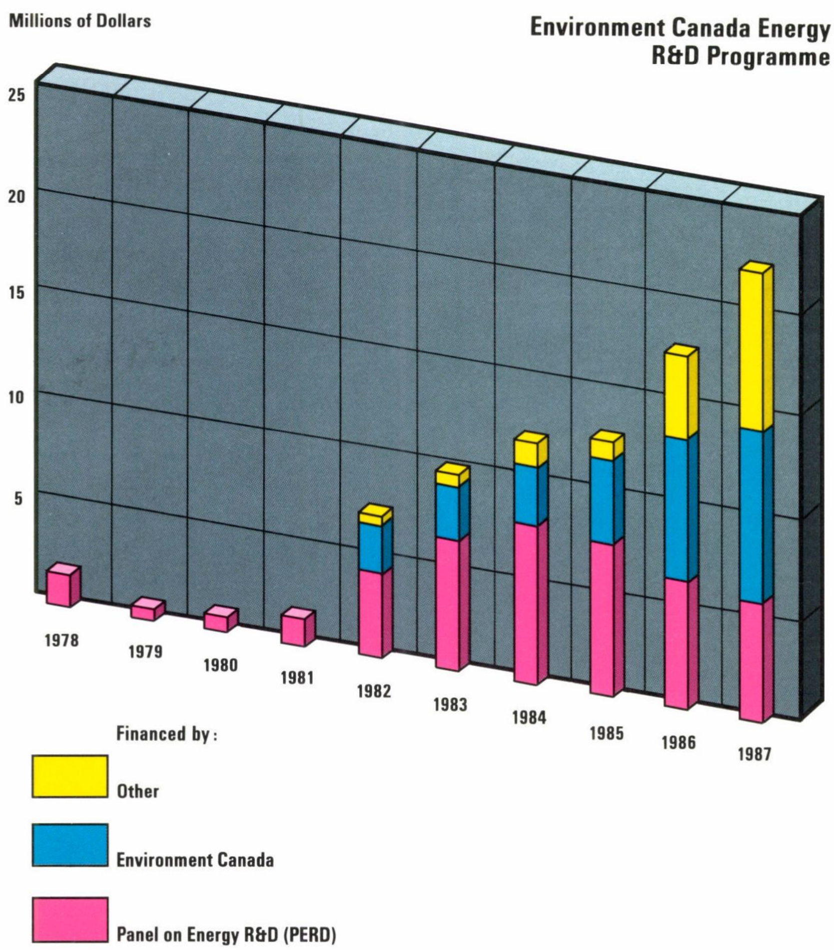
Most of Environment Canada's PERD projects are funded jointly with one or more other organizations, including other governments, federal departments, provincial agencies, universities, and private companies. In 1987-88, Environment Canada received $6 million from the federal PERD budget. The Department provided another $8 million, and research partnerships supplied a further $8.5 million. Environment Canada's annual PERD-related resources have grown over the years, as shown in the accompanying diagram. The total for 1987-88 ($22.5 million) reflects a larger federal allocation to the overall programme, increased participation by the private sector, and careful management by the Department.

The judicious selection of projects is critical in ensuring that R&D results will be implemented. Environment Canada encourages research that can be applied in the private sector, as it is through this sector that actual changes will be made in energy production or use. Projects are funded if they have significant potential for increasing the efficiency of production or use, or for reducing environmental effects. The private sector plays a major role in project selection and in reviewing results.

Another priority of the PERD programme is the development of knowledge that will allow the government to regulate industry more efficiently and fairly. Research of this kind is always conducted in cooperation with regulators and industry representatives, to enlist the input and support of the industries concerned.

The research results and knowledge base from Environment Canada's PERD programme also contribute significantly to policy-making on energy developments in Canada, and on major global issues such as climate change.

Environment Canada's Energy Research and Development programme is managed by Wayne Richardson (Corporate Policy Group). Coordination in the Department has been provided by Bob Boulden (Conservation and Protection) and Dr. John Reid (Atmospheric Environment Service). Some departmental scientists and engineers responsible for specific research projects funded under PERD have been named in this report. These individuals and the many others not mentioned by name continue seeking ways to increase energy and production efficiency and to reduce the environmental impact of energy developments. Theirs is a vital contribution to Canada's sustainable development.


Millions of Dollars
Environment Canada Energy R&D Programme
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