BUSINESS PLAN

1990 - 1993

ENERGY RESEARCH LABORATORIES

25 July 1989

ENERGY RESEARCH LABORATORIES
Division Report ERL 89-50 (TR)

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ENERGY RESEARCH LABORATORIES (ERL)

1. ORGANIZATION

ERL is an organization of 172 people dedicated to the advancement of technology in the supply, utilization and conservation of energy, particularly hydrocarbon fuels. Highest priority is given to R&D projects which advance energy technology in an environmentally acceptable manner; indeed, these projects should demonstrate a marked improvement over current practice. Canadians have identified acid rain and the greenhouse effect as major environmental concerns. ERL is making every effort to tailor its R&D programs towards energy conservation and pollution abatement.

ERL includes four laboratories. Synthetic Fuels Research, Combustion and Carbonization Research, and Fuels Characterization Research are located in Bells Corners, near Ottawa. Energy Diversification Research, a new ERL laboratory, was announced in 1988 and will be located at Varennes, Quebec (near Montreal). This new laboratory will expand ERL's research activities into alternate energies and energy efficiency.

Of the 172 staff, 75 are scientists and engineers, 77 are technologists and 20 provide administrative support. ERL's overall budget is approximately $21 million which includes $6 million allocated to R&D contracts and projects jointly funded with industry.

2. MISSION AND OBJECTIVES

ERL engages in R&D on the processing and utilization of fossil fuels in an efficient and environmentally acceptable manner, and on the use of improved energy conservation methods. To maximize the impact of these activities, ERL works in partnership with industry under the guidance of external advisory groups to exploit opportunities for technological innovation and to develop technologies that address regulatory requirements.

Specific objectives of ERL's R&D initiatives are:

- To sustain the future competitiveness of, and to expand market opportunities for, the Canadian fossil fuel industry by developing the more advanced technologies that will be needed in the future for the efficient recovery, upgrading and use of Canada's bitumen, heavy oil, natural gas and coal.
- To support public health and safety by developing fuel recovery technologies, by improving fuel utilization processes, by promoting energy efficiency and diversification technologies that minimize impact on the environment, and by improving the quality and performance of fuel products and energy systems through contributions to national and international standards.
- To support the development and implementation of government policies related to energy and the environment.

Currently, it is estimated that 68% of resources are used on productivity R&D, 28% on protection R&D and 4% on policy R&D. Approximately 85% of the total R&D program has client support.

3. CLIENTELE

ERL's finds its clients in the fuel resource, utilization and conservation segments of the energy system. While maintaining the objectives of productivity, protection, and sound energy policy, the technological approach has to be tailored to the clients' individual needs.

For the **Oil and Gas Industries**, ERL's Synthetic Fuels Research Laboratory (SFRL) deals with the extraction, upgrading, and residue utilization of heavy crude oil and tar sand bitumen and with the production of synthetic fuels. The refining of synthetic crude oils, the clean disposal of heavy residua, and catalysis are typical of problems that use SFRL's skills. These skills apply to synthesis of liquid fuels from natural gas and to coprocessing of coal with heavy oil to form high quality refinery feedstocks, technologies that are near the threshold of industrial use. A growing industry centred on natural gas as a reliable source of easily processable carbon-based feedstock uses SFRL's knowledge of specialized catalytic processes.

For the **Coal Industry**, ERL's Combustion and Carbonization Research Laboratory (CCRL) is concerned with coal carbonization and combustion in efficient and environmentally acceptable ways. It provides the only Canadian source of knowledge and testing capability for coking coals which is vital to the maintenance of exports as well as to domestic integrated steel manufacturers. CCRL also has facilities to evaluate energy conservation and combustion performance strategies for a wide range of fuels. Fossil fuel users, from electric utilities to domestic furnace manufacturers, utilize this capability to develop boilers and burners, that provide more efficient combustion and less emission of pollutants. It serves industries ranging from cement manufacturers to disposers of municipal waste. Users of other fuels, such as waste products of the pulp and paper industry, refuse-derived fuels, or emulsions based on hydrocarbons or

coal, who need to develop methods of using these fuels cleanly, take advantage of this laboratory's skills and facilities.
Through its Fuels Characterization Research Laboratory (FCRL), ERL provides specialized analytical services to industries using fossil or carbonaceous fuels. FCRL offers a standardization service to the Canadian fuel industry and takes part in international standards activities on which all markets and research correlations are based.

4. EXTERNAL TRENDS

ERL's strategic issues arise from the current international drive towards a cleaner environment and from the uncertainty of future oil prices. Today's environmental concerns are over acid rain, polluted surface waters, and global warming (greenhouse effect). In the longer term, contamination by poisonous trace elements associated with the production or use of fossil fuels is likely to become a serious issue.

It is almost impossible to isolate Canada from fluctuations in world oil prices so ERL, as part of EMR's technical arm, must maintain knowledge and flexibility to lead Canada in the environmentally and economically appropriate direction as commercial conditions dictate.

Canada will rely on its increasingly heavier and often more remote fossil fuel resources. Such heavier fuels need to be converted, by addition of hydrogen (hydrocracking) to make light transportation fuels. This mis-match of resources to demand offers challenges to industries and governments in Canada that ERL is in a unique position to tackle. Sulphur must be removed from fuels or from combustion products to minimize acid rain. Efficiency of use must be increased to contain global warming. The remoteness of many Canadian energy resources applies to heavy oil, coal, natural gas and hydroelectric resources. ERL has an important role to play in upgrading these resources so that transportation becomes a less serious factor in determining their commercial marketability.

External factors, of which only the most critical are quoted above, determine ERL's thrusts. The major challenge is to maintain an appropriate level of effort in technologies which today's economic conditions do not require, but which are likely to be needed in the future. ERL's response is to be as forward-thinking as its clients can support in enhancing industrial productivity, improving the environment, and using Canada's fuel resources.

5. MAJOR STRATEGIC ISSUES

ERL's strategic issues arise from external trends, federal policies and ERL's own capabilities. ERL's main challenges are: to define a long-term program appropriate to highly variable world energy prices; to combine environmental protection with efficiency in the use of fuel; to assist Canadian producers of coking coal and steel in the face of severe international competition; and, to select technologies for development in which ERL can make a significant contribution.

Bitumen Upgrading, Distillate Treatment and Catalysis Research

SFRL's expertise in the fundamentals of upgrading mechanisms and in reaction kinetics, and its experience in process development, put it in a good position to serve the developmental needs of the upgrading industry. This industry has grown rapidly over the past two decades and will continue to deal with such problems as catalysts adapted to particular Canadian feedstocks and reactor hydrodynamics. SFRL's high level of expertise in hydrocarbon fuel catalysis applies to CANMET's own hydrocracking process and to other processes such as diesel fuel hydrogenation or conversion of natural gas into liquid fuels, particularly the synthesis of isobutylene from methane.

One of the skills that SFRL has developed is the coprocessing coal with a range of heavy oils to manufacture high quality refinery feedstocks. Coprocessing may become economically viable in Canada before it does so in many other countries because of the unique situation in western Canada where resources of heavy oil, natural gas, and easily mineable coal, are located near each other.

SFRL does not always find it easy to draw support from prospective industrial clients because many of their products can be made more cheaply from conventional, imported crude oil than from abundant, Canadian, heavy hydrocarbon resources. Therefore SFRL's challenge is to continue in its developments with industry until world oil prices have risen enough to make Canada's heavy hydrocarbons attractive on the international market.

Fuel Characterization and Analysis

The FCRL backs up ERL's other laboratories with its specialized analytical techniques. The nearby availability of this laboratory's facilities is a vital component of ERL's strength. FCRL offers analytical services and provides linkage among CANMET and other organizations by participating in setting international standards related to fuels to ensure that Canadian interests are observed.

Metallurgical Fuels

ERL's services to Canadian coal producers are vital to their export market. The Carbonization Section has facilities for evaluating coking properties of single coals or blends and has the experience to interpret industrial application of their test results. This section is already tied into industry through the Canadian Carbonization Research Association. Its major challenges are to demonstrate the advantages of Canadian coals to world markets and to find methods for making good quality coke from lower quality coals.

Combustion and Conservation

The strength of ERL's combustion laboratory is in evaluating and developing innovative combustion systems. It provides a world-class capability in combustion processes and flame diagnostics. This expertise is very important in the development of efficient combustion techniques that suppress formation of oxides of nitrogen and other atmospheric pollutants such as unburned hydrocarbons.

Pilot-scale facilities for research in bubbling and circulating atmospheric-pressure fluidized-bed combustion have been set up and have proved useful to industry. Some of ERL's experience on atmospheric fluidized-bed combustion applies to pressurized fluidized-bed combustion, a technology of the future that can decrease carbon dioxide emissions per unit of electricity generated.

The Gasification Section has installed a new pilot-scale gasifier which can test reactivity properties of coals with potential for integrated gasification combined cycle (IGCC) generation of electricity. This work applies to the current world-wide pressure to reduce acid rain and control the greenhouse effect. The challenge here is to convert coal to electricity more efficiently, cleanly and produce less carbon dioxide.

Research is being actively pursued to increase the fuel efficiency in residential, commercial and industrial applications through improved combustion technology and optimization of operating conditions. The challenge is to drive the improved fuel-efficient technology into the market-place so as to enhance conservation of fuel and thereby lower CO_2 production.

Energy Diversification

The new Energy Diversification Research Laboratory (EDRL) is being established in Varennes Que. This laboratory will concentrate on new environmentally sound technologies related to energy upgrading and storage, such as heat pumps, fuel cells, thermal storage materials and processes, and batteries, that have been addressed by ERL only to a limited extent in the past. Fuel cells, alcohol fuels, hydrogen-based systems, and solar technologies are among the other EDRL interests. Energy utilization efficiency and alternative fuels leading to reduction of global warming, are of high priority. EDRL's principal challenge is the selection of technologies that have long-term promise but include elements that are attractive to industry.

5.1 NEW DIRECTIONS FOR ERL

ERL must enter new technological directions in the period 1990-93 if it is to fulfil its mandates of productivity, protection and policy. The Technology Commercialization Group coopts skills and knowledge from ERL and external sources to examine potential new technologies and to select promising subjects for R&D. Topics considered include: Combustion Technologies for Pollution Abatement; Advanced (Expert) Systems for Process Control; New Coal-based Fuels; Utilization and Combustion of Refinery Residues; Biomass and Waste Fuels; Biotechnology; Strategies to Reduce Global Warming; Energy Efficiency in Industry. ERL seeks avenues for integration with industry in these new fields.

ERL is very cognizant of the concerns of Canadians for protection of the environment. Acid rain, ozone depletion and now global warming, mainly by CO_2 build-up in the atmosphere need to be addressed seriously by the world at large. ERL has been performing research and developing technologies to mitigate environmental degradation by energy processing and utilization for many years. These efforts truly cannot be listed as "new directions". However, a greatly increased emphasis on energy technologies which will improve the environment must surely be noted here.

Overall ERL has strength through its depth of knowledge of current and threshold technologies. This is evidenced by its growing level of cost recovery contracts with industry. However, ERL experiences difficulty in attracting industrial support for technologies that are promising for the medium-term future. This difficulty arises from economic constraints in government and industries and from the problems of intellectual property rights in technology transfer.

6.0 SUMMARY OF MAJOR TECHNOLOGIES

6.1 RECOVERY OF BITUMEN, HEAVY AND LIGHT OILS

Bitumen and heavy oil resources in the Athabasca, Peace River, Cold Lake and Lloydminster areas are vastly greater than the conventional oil resources of Western Canada. With declining production of light conventional oil, a greater supply of heavy oil and bitumen must be produced to maintain current Canadian oil production and economic activities. Recognizing the importance of enhanced recovery from conventional oil reservoirs to reserve additions, CANMET has expanded its programs to support R&D for developing EOR processes for several large Canadian reservoirs with adverse geology and reservoir properties.

The objective of this technology cell is to support laboratory critical gap, novel and field test research over a wide spectrum of areas through contract studies funded by various programs.

Although ERL does not conduct in-house research in this area, ERL's financial ($3M/year) and technical participation with industry, provincial research institutes and universities, encourages technology development in areas encompassing:

* horizontal well oil production technology,
* laboratory and field testing of steam-flood and fire-flood recovery technologies for bitumen and heavy oil,
* microbial enhanced oil recovery,
* physical and numerical simulation of enhanced oil recovery processes
* sand control.

Mechanisms to access ERL contributions include:

* CANMET's Energy Conversion Cost-Shared Program,
* the Canada/U.S. Memorandum of Understanding for Co-operation in R&D on Oil Sands and Heavy Oil,
* R&D Contract program/ERL Request for Proposals (RFP)
* cooperation with other agencies, such as the Saskatchewan Research Council, Alberta Research Council, and the Petroleum Recovery Institute in Calgary.

Major Outputs:

- To develop jointly with industry, research institutes and universities bitumen and heavy oil recovery technologies using horizontal wells (1990-1993).
- To develop jointly with several industrial participants integrated geotechnical models and field-scale simulators for conventional and horizontal wells to increase bitumen and heavy oil recovery and to reduce operating costs (1990-1993).
- To develop and transfer to industry a novel soluble-vapour gravity-assisted method and a steam-assisted in situ combustion process for efficient recovery of bitumen in Alberta and heavy oil from marginal reservoirs of Saskatchewan (1990).
- To participate with industry in developing of microbial enhanced oil recovery (MEOR) processes for heavy oil reservoirs (1991).
- To evaluate the effectiveness of foam propagation and the steam-foam process as diverting/blocking and mobility control agents to improve sweep and displacement efficiencies for enhanced recovery of bitumen and heavy oil (1991).
- To develop processes to enhance recovery of residual oil from large conventional reservoirs with adverse geology and reservoir properties (1991).
- To develop and apply improved waterflooding and steam recovery processes to heavy oil reservoirs (1991).
- To publish joint US/Canada R&D reports related to the bitumen and heavy oil characterization and recovery components of the US/Canada Memorandum of Understanding for Cooperative R&D in Oil Sands and Heavy Oil (1992).
- To contribute jointly with AOSTRA and/or industrial partners in development and field trials of novel technologies for the recovery of bitumen and heavy oils (1993).

6.2 BITUMEN AND HEAVY OIL UPGRADING

Energy self-sufficiency for Canada will depend on upgrading oil sands bitumen and heavy oil resources of Western Canada to feedstock for oil refining.

The objective of this technology cell is to generate more cost-efficient technologies for upgrading Canada's fossil fuel reserves in an environmentally acceptable manner.

In addressing problems unique to Canadian resources, ERL supports research initiatives with industry, provincial organizations and universities through a variety of cost and task-shared agreements.

ERL's highly sophisticated facilities are specially designed to handle heavy crudes and their products and at present ERL's activities include:

* Upgrading Fundamentals - to create new fundamental knowledge upon which to launch breakthrough technology
* Process Development - to obtain reaction engineering data essential to scale up new technologies and to optimize commercial processes
* Residue Utilization - Increase the profitability of upgraders by improving the economic value of upgrading residues, in an environmentally acceptable manner
* Novel Upgrading - to support emerging technologies, especially those based on non-conventional energy sources and to develop novel low-cost upgrading technologies
* Catalytic upgrading - to maintain a national program on catalyst development which will enhance Canadian R&D and technology transfer

Major Outputs:

- Establish an industrial consortium to develop reliable feedstock reactivity correlations for bitumen upgrading (1990).
- Transfer reactor densitometry technology to industry for application in bitumen upgraders (1990).
- Complete initial assessment of technologies to upgrade pitch residue for use as electrode binder and transfer the technology to industrial client (1990).
- Develop pilot-plant reaction engineering and processability data for various hydrocracking applications (1991).
- Establish a consortium of industrial partners to develop novel and low-cost upgrading technologies (1991).
- Reports (confidential) on catalyst properties and processing conditions produced for the catalysis consortium (1990 to 1992).
- Process various client feedstocks to demonstrate the applicability of CANMET Hydrocracking technology in a world market (1991).
- Maintain a world-class large-scale reactor cold modelling capability in order to continue the transfer of this reactor engineering technology to industry (1992).
- Promote the application of vacuum pyrolysis technology for removal of environmentally sensitive refinery wastes (1992).
- Develop with industry, computer control software for medium scale research fossil fuel units (1992).
- Develop in collaboration with the Canadian Government Specifications Board (CGSB), the American Society for Testing and Materials (ASTM), petroleum and petrochemical companies and equipment manufacturers, a performance standard for conventional and high temperature capillary columns used for hydrocarbon type separations (1992).

6.3 SYNTHETIC CRUDE REFINING/RESIDUE UTILIZATION

An increase in supply of highly aromatic synthetic crudes from oil sands and heavy oil could lead to a deterioration in the quality of Canadian distillate fuels. The refractory nature of sulphur and nitrogen compounds in synthetic distillates from advanced primary processes also creates problems in secondary upgrading. Improved cost-effective refining technologies are essential to upgrade synthetic crude to transportation fuels.

The objective of this technology cell is to develop new technologies for synthetic crude refining and residue utilization.

ERL's experimental distillate upgrading facilities are equipped with some of the most advanced equipment for conducting studies of synthetic and conventional crude refining, catalyst surface and bulk analysis, and distillate and residue characterization. Research in this technology area involves:

* development of new refining catalysts
* kinetic and thermodynamic studies
* catalyst deactivation and poisoning
* catalyst regeneration studies
* development of new processing routes
* absorption/desorption and extraction studies
* development of membrane technology for separation of distillate streams
* development of new analytical techniques to characterize distillate fuels

ERL maintains links with the Canadian petroleum refining industry through cost-shared and fully funded research projects which address problems unique to Canadian industry.

Major Outputs:

- Report on the metal cluster catalysts for the conversion of middle distillate fractions in synthetic fuels (1990).
- Report describing the application of a pulse microcatalytic reactor for the kinetic modelling of catalytic cracking of gas oil (1991).
- Complete a technical study for the utilization of nitrogenous synthetic crude gas oil concentrates as additives in paving asphalts (1991).
- Participate in joint programs with the Petroleum Association of Canada for the Environment (PACE) on analysis and survey of transportation fuels for priority substances listed in the Canadian Environmental Protection Act (1991).
- Report on improved catalytic hydrodenitrogenation of Lloydminster synthetic crude distillates (1992).
- Complete a technical and economic study on a membrane process to separate distillates into saturate and aromatic rich fractions for diesel and jet fuel applications (1993).
- Report on the development of an integrated CANMET hydrocracking/hydrotreating process for production of high-quality transportation fuels (1993).

6.4 NATURAL GAS CONVERSION

Traditionally, natural gas has been used primarily as fuel for domestic and commercial heating, as well as for the manufacture of chemicals, mainly hydrogen and methanol. To a lesser extent, compressed natural gas has also been used as transportation fuel. Interest in converting natural gas into chemicals has been growing throughout the world because of the need to secure new dependable sources of raw materials for different processes.

The objective of this technology cell is to develop and commercialize processes for the conversion of natural gas into fuels, fuel additives and petrochemical feedstocks.

ERL has established a centre of expertise in natural gas conversion technologies. Its sophisticated facilities are designed to investigate a variety of processing concepts. Current efforts are concentrated on the following two projects: a consortium of industrial companies to perform multi-client research; and a "Methane to Isobutylene (MTI)" investigation.

Activities include: catalyst development and screening; development of novel synthesis routes to petrochemicals and fuel additives; secondary conversion such as olefin conversion; studies of reaction mechanisms using in situ characterization techniques; and investigation of catalyst poisoning.

Major Outputs:

- A report on the development of catalysts for the oxidative coupling of natural gas (1990).
- A report describing opportunities and constraints for the conversion of natural gas in Canada (1991).
- A report providing experimental data which can be used for reliable material balances for the Methane to Isobutylene process (1992).
- A report containing experimental results on the conversion of natural gas in an electrochemical cell (1993).

6.5 COPROCESSING

Coprocessing is the simultaneous processing of mixtures of coal and heavy oil in order to liquefy the coal and upgrade the oil. Being a combination of coal liquefaction and heavy oil upgrading technologies, coprocessing has significant industrial advantages. It is technically and economically superior to direct coal liquefaction because it eliminates the process-derived recycle solvent. This results in higher reactor throughput and lower operating costs. Compared with hydrocracking, coprocessing can increase operating margins by replacing expensive heavy oil with lower cost coal. Depending on the combination of oil and coal, benefits also occur because of the coal's capacity to adsorb heavy metals in the feed and any coke formed during reaction. Further, the potential exists for synergy in terms of increased process yields due to interactions of the coal and oil. The above advantages, coupled with the fact that in Western Canada, coal and heavy oil are in close proximity, could make coprocessing a viable option as an emerging technology for synthetic liquid fuel production in Canada.

The objective of this technology cell is to establish an industrial R&D consortium to further develop coprocessing. The consortium will generate a database that can be used in the design and construction of a larger scale pilot plant. This will allow the transfer of coprocessing technology to consortium members for eventual commercialization. The consortium R&D approach will make it more feasible to implement the technology by sharing of resources and risks among consortium members to address common problems towards developing better technology for application in Canada.

Current projects for the consortium are being formulated in consultation with industry members and potentially will include:

* Process performance for specified feedstocks
* Coal and slurry preparation
* Catalyst/additive development

* Product upgrading
* Reactor behaviour
* Residue utilization
* Process development unit studies

Major Outputs:

- Completion of the second year's objectives of Phase I of the coprocessing consortium program. Projects selected by the consortium management committee include feedstock evaluation, reactor behaviour and product characterization studies (1990-91).
- Completion of the first phase of the technical program as defined by the consortium management committee. This will address coal/oil synergy, mathematical modelling and design of process configuration (1991-92).
- Completion of the technical program selected for the first year of Phase II of the coprocessing consortium. This will involve catalytic secondary upgrading, economic assessment and starting the engineering design of a larger scale pilot plant (1992-93).
- Collaboration and exchange of information with U.S. DOE under a Memorandum of Understanding (1990-93 and beyond).
- Completion of a test of Canadian coal under the Canada/Japan S&T Agreement (1990-91).

6.6 COAL GASIFICATION

Gasification technology offers the advantage of converting any solid organic material to usable fuel. Established routes for the conversion of synthesis gas from coal gasification include conversion to petrochemicals, hydrogen, ammonia and liquid fuels. Recently, integrated gasification-combined cycle (IGCC) emerged as an important technology for the production of electricity from coal. In this application, most of the acidic species and particulates are removed, thereby minimizing environmental hazards.

International interest in gasification technology is seen in the number of commercial applications that exist. In Japan, serious consideration is being given to utilizing gasifier gases in the production of electricity, hydrogen and iron - developments which could considerably increase exports of Canadian coals.

The objective of the gasification research program is to improve and optimize technologies for gasification of solid feedstocks such as coal and oil sand coke for the clean production of electricity, and to develop low-cost sorbents to remove acidic components from gasification products at high temperatures.

Major clients are the Canadian coal mining companies, large consulting companies and utilities; e.g., TransAlta Utilities, Calgary; who foresee coal gasification-combined cycle as a future clean coal generator of electricity. Indeed, CANMET projects address priorities recommended by the Canadian Coal Gasification Technical Committee, an advisory group drawn from the private sector, provincial research and development agencies and the federal government.

Major Outputs

- Evaluation, on a pilot plant scale of CANMET developed adsorbents for hot-gas clean-up of gasification products (1991)

- An engineering cost study comparing electricity generation via integrated gasification, combined cycle (IGCC) using CANMET's hot gas clean-up process, with conventional technologies (1992).
- Gasification process data on coals submitted by major Canadian coal companies and utilities, performed at their request and on a cost-recovery basis (1992).
- A method to remove alkali metals and other harmful elements from gasifier products (1993).

6.7 METALLURGICAL FUELS

Canada exports about 22 million tonnes of coking coal annually and uses a further eight million tonnes domestically to produce coke for blast furnaces which produce iron for steelmaking.

The Metallurgical Fuels Research Group studies and develops technologies to:

- improve the coking behaviour of coals to produce high-quality coke while ensuring safe and efficient industrial operation;
- enhance coal properties for carbonization;
- use coke and alternative fuels in blast furnace and other metallurgical processes;
- demonstrate the advantages of Canadian coals to world markets.

Major clients are the Canadian metallurgical coal producers, steelmakers and coal by-product users. Of significant benefit to these clients is ERL's internationally accepted coke-oven test facilities that are operated cooperatively with industry through the Canadian Carbonization Research Association.

Major Outputs

- Ten to fifteen reports per year on coal and coke evaluation for both coal mining and steel companies on a cost-recovery basis.

- Transfer to industry, a method to distinguish the boundary layer between metallurgical and thermal coal during surface mining (1991).
- In conjunction with the Coal Association of Canada, and the Standards Council of Canada participate in deliberation of the United Nations Economic Commission of Europe (UN ECE) concerning the proposed ECE international classification for coal (1991).
- Development of a method to simulate industrial coking in small test ovens (1992).
- Evaluation of optimum coal properties required for pulverized coal injection into the blast furnace (1992).
- Development of a method to reduce handling and coking problems associated with the fineness of western Canadian coals (1993).

6.8 INDUSTRIAL COMBUSTION

Canadian industries and utilities are converting from premium fuels to indigenous and often low-quality coals. In many cases, these coals are from newly developed deposits for which reliable data on their combustion, heat transfer, slagging and fouling, and emission characteristics are not available. ERL operates a pilot-plant boiler rated at 2.5 GJ/h and a calorimeter tunnel furnace (1m dia. x 4.25 m long) to obtain such combustion characteristics, often on a cost-recovery basis. Advanced techniques, such as a laser-based Coherent Anti-Stokes Raman Spectroscopy (CARS) are being developed to rapidly measure temperature and species concentration in flames.

The use of coal to replace premium fuel such as gas and oil is restricted by the inconvenience of handling solid fuel and by environmental implications. New coal utilization technologies, such as combustion of coal-liquid mixtures and micronized coal, allow easy, economic coal handling with minimal environmental impact. These are viable options for using coal in oil-designed units.

Coal-liquid mixtures (CLM) could potentially replace oil or natural gas in existing boilers and industrial combustors while avoiding most of the cost of burner retrofit and on-site facilities for coal

storage, handling and preparation associated with conventional pulverized coal technology. ERL has collaborated with NRC to develop a coal-water fuel burner system using ceramic burner tips. This technology is now being commercialized.

Major clients are the Canadian coal producers, electric utilities, cement companies and industrial boiler users.

Major Outputs:

- Publish a second volume of combustion performance and emission characteristics of commercially-important Canadian coals (1991).
- To expedite, through technical support, the conversion of a greater than 100MW_e oil-designed utility boiler to coal-water fuel (1992).
- Develop a laser-based probing system for application to practical flames (1993).

6.9 COMBUSTION TECHNOLOGIES FOR POLLUTION ABATEMENT

Clean combustion innovations are urgently needed to operate existing utility and industrial furnaces, and in the design of advanced processes for burning low-grade fuels. In recent years, ERL has addressed pollution abatement in a variety of ways. Modifications to combustion systems and burners have been developed to suppress nitrogen oxides and soot formation, in-furnace injection of sorbents to control sulphur oxides have been developed, and lately, a program to analyze for trace elements in fuel and fuel ash residues has been undertaken.

A major ERL research program aims to develop fluidized-bed combustion technology through pilot-plant testing and technical support of major demonstration projects. This technology combines the capacity to use low-grade fuels while controlling emissions of acid gases which are precursors of acid rain.

Major clients are the coal burning utilities, especially the New

Brunswick Electric Power Commission, Canadian Electrical Association, the Department of National Defence, and AOSTRA/oil sand mining companies who are most concerned about utilization of their upgrading residues.

Major Outputs

- Develop and validate a computer modelling technique for designing sorbent injection systems for SO_x control in wall-fired boilers (1991).
- Identify, evaluate and promote technologies which minimize NO_x and SO_x emissions from utilities and industrial combustion systems (1992).
- Commission in late 1989, and operate a 1 MW_{th} pilot-scale circulating fluidized-bed combustion unit capable of burning 300kg/hr of low-grade fuel (1990).
- Develop a database for the fluidized-bed combustion and emission performance of coke and pitch residues from oil sands/heavy oil upgrading (1992).
- Complete in cooperation with industry groups such as the Canadian Gasification Technical Committee, the TransAlta Rockwell Low NO_x/SO_x (LNS) burner steering committee, and the CANMET-industry catalyst/residue consortia, the development of remote chemical sensing techniques in support of technologies to demonstrate SO_x and N_xO_y control, gasification characteristics of Canadian coals, residue utilization and hydrocarbon processing (1993).

6.10 ENERGY CONSERVATION TECHNOLOGY

The efficient use of fuels is an important way to reduce emissions of pollutants, lower operating costs and increase productivity. Increasing efficiency is also the most effective way to lower emissions of carbon dioxide, the dominant force in the Greenhouse Effect. At ERL, research is being actively pursued to increase fuel efficiency in residential, commercial and industrial applications, through improved combustion technology and the optimization of operating conditions.

ERL puts a major emphasis on the development of technology and strategies to increase the efficiency of residential heating systems. By developing new designs to improve burner/furnace performance, while reducing potentially unsafe operating conditions, major efficiency improvements are possible. The program has assisted Canadian appliance manufacturers in becoming world leaders in oil- gas- and wood-fired residential heating equipment, while Canadian consumers have benefitted from having dramatic reductions in these heating costs.

Retrofit techniques have been developed to improve efficiency and minimize emissions of existing residential combustion equipment. Some examples are: retrofit condensing heat exchanger for residential gas furnaces giving a 20%-30% fuel saving, now being marketed in Canada and the U.S.A.; an oil burner retrofit package which has been adopted nationally by the industry as standard equipment on new burner systems; techniques and technology to reduce the emissions from existing wood-burning appliances.

Significant efforts are devoted to the safe venting of the combustion gases, ensuring that combustion pollutants are not released to the outdoor environment and thus maintaining good indoor air quality. This work has resulted in major changes to Canadian building and appliance installation codes and practices.

ERL has provided detailed input and guidance to standards and regulatory agencies, particularly the Canadian Standards Association, along with ULC, CGSB and CGA, and provincial and federal agencies so that Canadian standards reflect the new technologies in a safe and environmentally proper manner.

With the new policies of electric utilities which focus on efficiency and improved load factor, energy storage is assuming greater importance, and joint projects on ice storage and ice slurry transport are being pursued, along with the bringing together of different energy sources and uses in combined systems, such as cogeneration and district heating.

In response to CANMET's overall thrusts, namely the development of expert systems, ERL will initiate a program to develop an expert systems technology for combustion processes. This will allow energy use to be optimized with minimal environmental impact.

Major Outputs:

- Develop, in conjunction with standards organizations and equipment manufacturers, retrofit systems for residential appliances to improve efficiency, decrease emissions and allow utilization of low-grade fuels (1990).
- Develop guidelines for overall optimized combustion systems design and use in low energy housing (1990).
- Develop complete system to utilize biomass cleanly in commercial combustion systems (1991).
- Identify and develop strategies to reduce the generation of "greenhouse" gases during combustion processes (1992).
- Develop guidelines and technology for ice slurry generation and storage in district cooling applications (1992).
- Develop guidelines for advanced district heating systems utilizing energy cascades and low-grade or waste energy sources (1993).

6.11 ENERGY DIVERSIFICATION RESEARCH

As a result of increasing environmental concerns, the need to conserve energy resources and provide energy options, ERL has established the Energy Diversification Research Laboratory (EDRL).

EDRL is developing advanced technologies for:

- the upgrading of low grade and waste heat so that system energy efficiencies may be increased,
- thermal, chemical and electrochemical storage so that system efficiencies may be improved and alternative energy options expanded as a result of increased cost effectiveness and system compatibility,
- increasing conversion efficiency of natural gas and liquid fuels in electrical power and co-generation operations using fuel cells,
- increasing the utilization of biomass materials and burnable wastes so that the resource base may be effectively exploited and adverse environmental effects arising from their disposal mitigated.

Major clients include Canadian electric and gas utilities (including CEA), chemical manufacturers, electrochemical industry, provincial research organizations, heat pump manufacturing industry and provincial and municipal governments.

Major Outputs:

The following are the projected outputs which will be confirmed after staff and facilities are established.

- Development of a national fuel cell test facility (1990).
- Assessment of municipal solid waste and sludge processes at the bench and pilot scale state of development (1990).
- Evaluation of non-azeotropic fluids as replacements for CFC's (1991).

- Evaluation of catalyst and process modifications required for the production of hydrogen from natural gas, methanol and diesel for fuel cell applications (phosphoric acid, solid polymer electrolyte, solid oxide, alkaline and molten carbonate) (1991).
- Heat pump system evaluation and optimization using simulation (1992).
- Assessment of absorption chiller and conversion to heat pump (1992).
- Evaluation of novel heat pump designs (1992).
- Initiate within the framework of CANMET's Service Program for the Evaluation of Characterization Standards (CASPESCO), an industrially supported intra-laboratory Sample Exchange Program (ISEP) for biomass and waste fuels (1992).

7. SUMMARY TABLE OF RESOURCES

ERL RESOURCE ALLOCATION

Technologies		89-90	90-91	91-92	92-93
Recovery of Bitumen and Heavy Oil	K$(PY)	285(3)	285(3)	285(3)	285(3)
	Contracts	2040	1740	1740	1740
Bitumen and Heavy Oil Upgrading	K$(PY)	2775(39)	2575(37)	2450(35)	2400(34)
	Contracts	690	690	690	690
Synthetic Crude Refining	K$(PY)	1530(19)	1480(18)	1480(18)	1480(18)
	Contracts	740	740	740	740
Natural Gas Conversion	K$(PY)	820(8.5)	780(7.5)	780(7.5)	780(7.5)
	Contracts	350	350	350	350
Coprocessing	K$(PY)	490(6)	490(6)	490(6)	490(6)
	Contracts	200	200	200	200
Coal Gasification	K$(PY)	638(5.5)	638(5.5)	638(5.5)	638(5.5)
	Contracts	300	300	300	300
Metallurgical Fuels	K$(PY)	1285(20)	1285(20)	1285(20)	1285(20)
	Contracts	100	100	100	100
Industrial Combustion	K$(PY)	1225(14)	1225(14)	1225(14)	1225(14)
	Contracts	540	540	540	540
Combustion Tech. for Pollution Abatement	K$(PY)	1945(15)	1845(15)	1745(14)	1595(13)
	Contracts	660	650	600	600
Energy Conservation	K$(PY)	935(12)	885(12)	835(11)	835(11)
	Contracts	420	400	400	400
Energy Diversification	K$(PY)	990(9)	2000(18)	2400(25)	2400(25)
	Contracts	445	640	700	700
ERL Mgt and Administration	K$(PY)	1410(21)	1410(21)	1410(21)	1410(21)
	Contracts				
Totals	K$(PY)	14,328(172)	14,898(177)	15,023(180)	14,823(178)
	Contracts	6,485	6,350	6,360	6,360

Note: Resources allocated to individual projects within the eleven Technologies change to reflect program priorities, even though the total annual allocation to a Technology may appear unchanged. Note a shift of resources to Energy Diversification.

8. KEY PERFORMANCE INDICATORS

The performance indicators identified in Table 8.1 has been established to monitor industry's participation in ERL's technology programs.

TABLE 8.1

ENERGY RESEARCH LABORATORIES

INDUSTRIAL PARTICIPATION TARGETS

INDICATORS	1990-1991	1991-1992	1992-1993
Cost Recovery ($ Thousand)	1,700	1,915	2,125
Secondments (PY Allocation)			
- From ERL	4	4	4
- To ERL	2	3	4
Leverage of Funds ($ Thousand)	4,000	5,000	6,000
Industrial Cost Sharing of Contracts as Percentage of ERL Contract Expenditures	53	55	55
IRAP Agreements	3	3	3
Patents and Licences	9	9	9
Seminars	3	3	3
Client-Supported Work (% Staff Time)	90	90	90

9. MECHANISMS FOR COOPERATIVE R&D

ERL's is responding to CANMET's policy to operate in partnership with industry by offering the following programs and mechanisms for cooperative R&D.

Contract R&D

ERL has approximately $6 million per year committed to contracted energy research. ERL is encouraging participation in its contract research program by offering industry mechanisms for levering its R&D funds. In view of industry's positive response to ERL's contract program, effort is being made to increase ERL's commitment towards contracted R&D.

Access to ERL's contract R&D funds is through CANMET's Energy Conversion Program and responding to ERL's request for proposals (RFP). CANMET's Research Program Office is responsible for administering ERL's contracts.

ERL's Research and Development Consortia

To help facilitate collaboration with industry, ERL is developing, marketing and managing research and development consortia. The consortia arrangements allow industry to pool its funds in supporting ERL in-house research activities in areas which are of particular interest to a group of companies. In return, such agreements keep ERL's projects and programs closely aligned with industry's needs.

Joint Agreements

For a number of reasons some clients prefer not to join a consortium. For these clients ERL conducts cooperative research under a joint agreement. This mechanism offers the flexibility to design a program to suit the specific needs of a client. ERL offers agreements for cost-shared research, that is ERL shares the cost of doing research with a client. ERL also offers task-shared agreements

where tasks relating to a project are divided between ERL and a client. Upon completion of the project, information is exchanged between parties. If a project is of benefit only to a single client, ERL enters into agreements wherein a client pays 100% of the cost to have the research done.

External Services

ERL encourages secondments to and from industry to help facilitate technology transfer and to improve the industrial experience of our scientists.

In addition, our scientists provide consulting services to assist in industrial research and technology commissioning activities.

ERL has a very powerful networking capability in that ERL has developed close relations with a network of research scientists in many countries. ERL helps industry examine and take advantage of the best available technologies regardless of their source and helps clients expand into new markets. As an active member in the International Energy Agency, ERL continues to pool Canadian R&D resources with member countries to discuss and develop energy technology needs for the future. ERL also represents Canada on some twenty or more international committees and where appropriate also enters into cooperative agreements with other countries to share technology advancement in areas of particular interest to Canada.

Industrial Research Assistance Program (IRAP)

As technologies approach commercial reality, ERL encourages its clients to participate in the National Research Council's IRAP Program. The program supports technology transfer from government laboratories which show excellent commercial promise but are not proceeding because of high technical risk.