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COAL ENERGY FOR CANADA

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APRIL 1978

ERP/ERL 78-39(OP)

ENERGY RESEARCH PROGRAM
ERP/ERL 78-39 (OP)

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by

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ABSTRACT

The ample resources of coal in Canada have attracted increased attention in recent years as a potential energy source. This paper reviews the extent and nature of Canada's coal resources, identifies the needs of the various energy market sectors and describes the limitations imposed by present or foreseeable technology on the application of coal in each market sector. Guidelines are suggested for energy strategy in the next few decades.

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INTRODUCTION

In the early part of this century coal and wood were by far the most common fuels for home heating while coal was almost the only fuel used by railways and by industry. In more recent times, the use of coal has declined to such an extent that many school children of today have never seen it. Sharp increases in the world price of oil, lesser but significant increases in the price of natural gas, and an increasing awareness of the limited resources of these fuels has renewed interest in coal as an energy source. As a result,a variety of schemes for increased utilization of coal has been advocated, including a return to coal-fired domestic furnaces, reconversion of the railways to coal-fired steam locomotives, and the development of coal-burning diesel engines.

This paper outlines a rational scenario for the application of coal to Canada's energy needs by considering in turn the extent and nature of our coal resources, the needs of the various energy market sectors, and the limitations imposed by present or foreseeable technology.

COAL RESOURCES OF CANADA

Canada's coal resources are presently estimated to be about 228 billion tons, counting only those seams which are five feet thick or more, and which can be mined by present technology. However, depending upon the method of mining which can be applied, that is, strip mining versus underground, only 60% to 80% of this coal is technically recoverable, and at present only about 15% is economically recoverable. A breakdown of coal resources by rank and province is given in Table 1. Substantial deposits of coal are known to exist in the Canadian arctic, but their extent is undefined and they are presently uneconomic.

The energy potential of our coal resources is perhaps more readily understood in the form shown in Table 2, where the major fossil fuels are compared in terms of potential for generating electricity, assuming 10,000 Btu are required to produce 1 kWh. It can be seen that the energy potential of coal is several times that of oil and natural gas, and exceeds even the oil sands.

TABLE 1

COAL RESOURCES OF CANADA BY RANK AND PROVINCE[1/]

(Millions of Short Tons)

Province	Measured (Known)	Indicated (Probable)	Inferred (Possible)	Total
		Bituminous		
Nova Scotia	335	649	557	1,541
New Brunswick	35	18	1	54
Alberta	9,150	-	30,850	40,000
British Columbia	8,039	10,912	48,542	67,493
RANK TOTAL	17,559	11,579	79,950	109,088
		Sub-bituminous and Lignite		
Ontario	240	-	-	240
Saskatchewan	1,652	2,955	3,788	8,395
Alberta	10,427	-	89,537	100,000
British Columbia	2,034	100	8,200	10,334
RANK TOTAL	14,353	3,155	101,561	118,969
GRAND TOTAL	31,912	14,734	181,511	228,057

[1/] From "1976 Assessment of Canada's Coal Resources and Reserves", Report EP 77-5, Department of Energy, Mines and Resources, Ottawa, Canada.

TABLE 2

ENERGY POTENTIAL OF CANADIAN FOSSIL FUEL RESOURCES[1]

(Billions of kWh)

	Proven Reserves	Potential Resources
Coal	19,600	238,600
Conventional Petroleum	5,430	46,400
Natural Gas	5,290	71,200
Oil Sands	16,800	185,400
TOTAL	47,120	541,600

[1] E. R. Mitchell, "The Future of Fossil Fuels in Canada", Canadian Combustion Research Laboratory, Fuels Research Centre Divisional Report FRC 74/70 Department of Energy, Mines and Resources, Ottawa, Canada.

TABLE 3

SUMMARIZED ASTM CLASSIFICATION OF COALS

Class Group	Fixed Carbon* %	Volatile Matter* %	Calorific Value** Btu/lb
Anthracite	86 min	14% max	
Bituminous			
Low Volatile	78 to 86	22 to 14	10,500 to 14,000
Medium Volatile	69 to 78	31 to 22	
High Volatile	69 max	31 min	
Sub-bituminous			8,300 to 11,500
Lignite			6,300 to 8,300

*Calculated on a dry, mineral-matter-free basis.

**Moist, mineral-matter-free basis.

It must be remembered that coal is a natural product which varies widely in quality. For convenience, it is ranked according to its energy content or its chemical composition, as shown in Table 3.

In as-mined coal, the values in Table 3 are reduced by varying quantities of moisture and mineral matter, or ash. Any coal may contain up to 10% by weight of free water, but sub-bituminous coal and lignite also contain so-called inherent moisture, which is bound up in the coal structure and can only be driven off by heating. In sub-bituminous coal, inherent moisture is typically 15% to 20% by weight, and in lignite, 25% to 35%. Mineral matter content may be as high as 50% by weight, but is more commonly in the range of 10% to 20%. As a result, coal may have an energy value ranging from 14,000 Btu/lb down to 4,000 Btu/lb.

THE ENERGY MARKET SECTORS

Clarifying the role of coal in the Canadian energy picture is made easier by defining major sectors of the energy market as follows:

Domestic and Commercial Heating Sector:	Requires space heating for homes, businesses and institutions.
Transportation Sector:	Requires mechanical energy for transport of goods and passengers.
Industry Sector:	Requires space heating, process heat and mechanical energy for processing and manufacturing.
Electric Utility Sector:	Requires fuel or mechanical energy for generation of electricity.

The relative usage of the various forms of energy by sector is shown in Table 4. Coal has very little application in the domestic and commercial heating sector, and is not used at all for transportation. In the industry sector coal faces a number of competitors, although coking coals are secure in the metallurgical industry, which in fact provides a large export market for Canadian coal. In the electric utility sector, coal is well established but competes with hydro and the rapidly growing nuclear industry. The reasons this pattern of usage developed, and the prospects for the future will now be discussed.

TABLE 4

RELATIVE USAGE OF ENERGY SOURCES BY THE MARKET SECTORS

Energy Source	Domestic and Commercial Heating	Transportation	Industry	Electric Utility
Electricity	small	small	large	Not App
Natural Gas	large	none	large	small
Refined Oil	large	large	small	small
Residual Oil	none	none	large	medium
Coal	small	none	medium	large
Hydro	none	none	small	large
Nuclear	none	none	none	small

THE TRANSPORTATION PROBLEM

A map of coal deposits in Canada shows that the coal resources are remote from the major centres of population, where the greatest demand can be expected. While Alberta and Saskatchewan are able to supply most of their electricity requirements from pit-head generating stations, Canadian coal used in Ontario and Quebec must travel about 2000 miles from the west, or about 1000 miles from the east. The transportation cost per unit of energy may be very high, particularly if the coal is of low quality. For this reason much of much of the coal used in Canada is imported from the US.

Table 5 shows some typical transportation costs, calculated in dollars per million Btu. To these must be added the cost of the coal itself. For comparison, domestic furnace oil delivered to the home at a price of 50¢/gal, costs approximately $3/million Btu.

TABLE 5

TYPICAL TRANSPORTATION COSTS FOR CANADIAN COALS

	$/Ton	$/Million Btu
1. Cape Breton Bituminous Coal (12,000 - 14,000 Btu/lb)		
Sydney, Nova Scotia to Hamilton, Ontario		
1200 miles @ 0.4¢/ton-mile	4.80	
Seaway Tolls, Montreal to Lake Ontario	0.43	
TOTAL	5.23	0.19 - 0.22
2. Saskatchewan Lignite (6500 - 7500 Btu/lb)		
Estevan, Saskatchewan to Thunder Bay, Ontario		
720 miles @ 1.5¢/ton-mile	10.80	
Thunder Bay, Ontario to Nanticoke, Ontario		
825 miles @ 0.4¢/ton-mile	3.30	
Port Handling at Thunder Bay	3.00	
TOTAL	17.10	1.14 - 1.31
3. Alberta Sub-bituminous (8000 - 9500 Btu/lb)		
Halkirk, Alberta to Thunder Bay, Ontario		
1190 miles @ 1.5¢/ton-mile	17.85	
Thunder Bay, Ontario to Nanticoke, Ontario		
As in 2 above	3.30	
Port Handling at Thunder Bay	3.00	
TOTAL	24.15	1.27 - 1.51
4. BC Bituminous (10,000 - 14,000 Btu/lb)		
Michel, BC to Thunder Bay, Ontario		
1250 miles @ 1.5¢/ton-mile	18.75	
Thunder Bay, Ontario to Nanticoke, Ontario		
As in 2 above	3.30	
Port Handling at Thunder Bay	3.00	
TOTAL	25.05	0.90 - 1.25

TECHNOLOGY FOR COAL UTILIZATION

For coal to compete with other sources of energy in the various market sectors, two conditions must be met. First, coal must be mined and transported to the user at a competitive cost per unit of energy, as already discussed. Second, economically competitive technology must exist by which coal can be used for the job that needs to be done. For example, a bag of coal is of no help to the man whose automobile has run out of gasoline. The subject of technology for coal utilization is complex and is perhaps best elucidated by describing the major technologies in turn.

Stokers

Stokers comprise a large variety of equipment designs which mechanically feed lump coal onto a grate where it burns, the necessary air being supplied through tuyeres in the grate. The hot combustion gases are passed over heat exchange surfaces which extract heat to produce steam, hot water or hot air.

A bewildering array of stoker designs appeared during the early part of this century, ranging from equipment suitable for heating single-family homes to large industrial units burning several tons of coal and producing up to 300,000 lb of steam each hour. By the middle of this century they had been developed to a substantial degree of automation but then were abandoned almost completely as inexpensive oil and natural gas became available. At present only a few remain in operation.

Even though stokers were adapted to serve all the market sectors except transportation where their use was limited to powering steam locomotives, a resurgence of their former popularity is unlikely. Capital cost is high, operating manpower requirements are greater than for oil or natural gas, maintenance is high, and efficiency of fuel utilization is only fair. In addition, the ability of any particular design to cope with changes in coal quality or properties is limited, and pollutant emissions are high. To meet present-day air quality standards stokers must be equipped with gas clean-up equipment which adds greatly to their capital and operating costs, and in most cases makes them hopelessly uneconomic.

Stokers, therefore, are viewed by the writer, at least, as an obsolescent technology which would only be pressed into widespread service under dire circumstances.

Pulverized Firing

This is a mature technology based on many years of development. It is by far the most important means for converting coal to useful energy and it is likely to remain so for the next two or three decades. Basically it involves grinding the coal to a very fine powder which is then burned in suspension under controlled conditions which yield a high efficiency of energy conversion. The final product is usually steam.

A flow diagram showing the main components of a pulverized-fired system generating electricity is presented in Figure 1. It is clear that the technology is complex, and this fact alone puts constraints upon its application. Equipment of this complexity is only economically viable in large unit sizes; for example, steam boilers generating from 300,000 to several million lb of steam/hr. Application is therefore limited to the large industry and electric utility market sectors. Even within these market sectors, pulverized firing faces a further handicap in that the process of combustion, when it involves a cloud of small particles, has proved to be very sensitive to a large number of coal properties. The most important of these are listed in Table 6.

TABLE 6

COAL PROPERTIES AFFECTING THE PERFORMANCE
OF PULVERIZED FIRED SYSTEMS

1. Unit Energy Content
2. Moisture Content
3. Size Consist
4. Volatile Matter Content
5. Petrographic Constituents
6. Grindability
7. Ash Content
8. Sulphur Content
9. Chlorine Content
10. Organic Nitrogen Content
11. Ash Fusion Temperature
12. Ash Composition
13. Ash Electrical Resistivity
14. Other Physico-Chemical Characteristics of Ash

Ways have been found to cope with variations in these coal properties, but they add substantially to the cost of the system. For example, a steam generator burning lignite may require two or three times the furnace volume of one burning high-quality bituminous coal, and the additional cost for the larger furnace alone may amount to several millions of dollars. Thus, pulverized firing technology shares to some extent a major disadvantage of stoker technology: a given system cannot readily adapt to changes in coal quality.

At present, in Canada the limited extent to which coal services the domestic and commercial heating market and the transportation market is accomplished by pulverized-firing technology. This is via an indirect route, namely the generation of electricity for electric heating and electrified transport. However, a gross inefficiency of energy utilization is involved, for, as shown in Figure 1, of the energy entering the system as coal, only 25 to 35% comes out as electrical energy. This is a basic disadvantage of thermal power generation which is shared by all fuels. including nuclear. By comparison, conventional domestic furnaces burning refined oil or natural gas have an energy utilization efficiency ranging from 50 to 80%. A more efficient route by which coal can service the heating market is the technique of district heating, which involves a pulverized-fired plant, large enough to be economically viable, generating hot water which is pumped through a distribution network to heat surrounding homes, businesses and institutions. Alternately, district heating can be combined with power generation by heating water with low-pressure steam from the turbine, at a modest loss in the amount of electricity generated, and distributing the hot water as described above. The efficiency of energy utilization for such a combined system ranges from 50 to 80%. Many European countries have made extensive use of district heating for years. In Canada it is widely practised on an institutional scale, generally too small to justify pulverized firing of coal. There are only a few systems servicing home or business establishments on a commercial basis because as long as light oil and natural gas were inexpensive, the cost of the hot water distribution system could not be justified. Now, however, district heating receives much more interest and is actively encouraged by the Department of Energy, Mines and Resources.

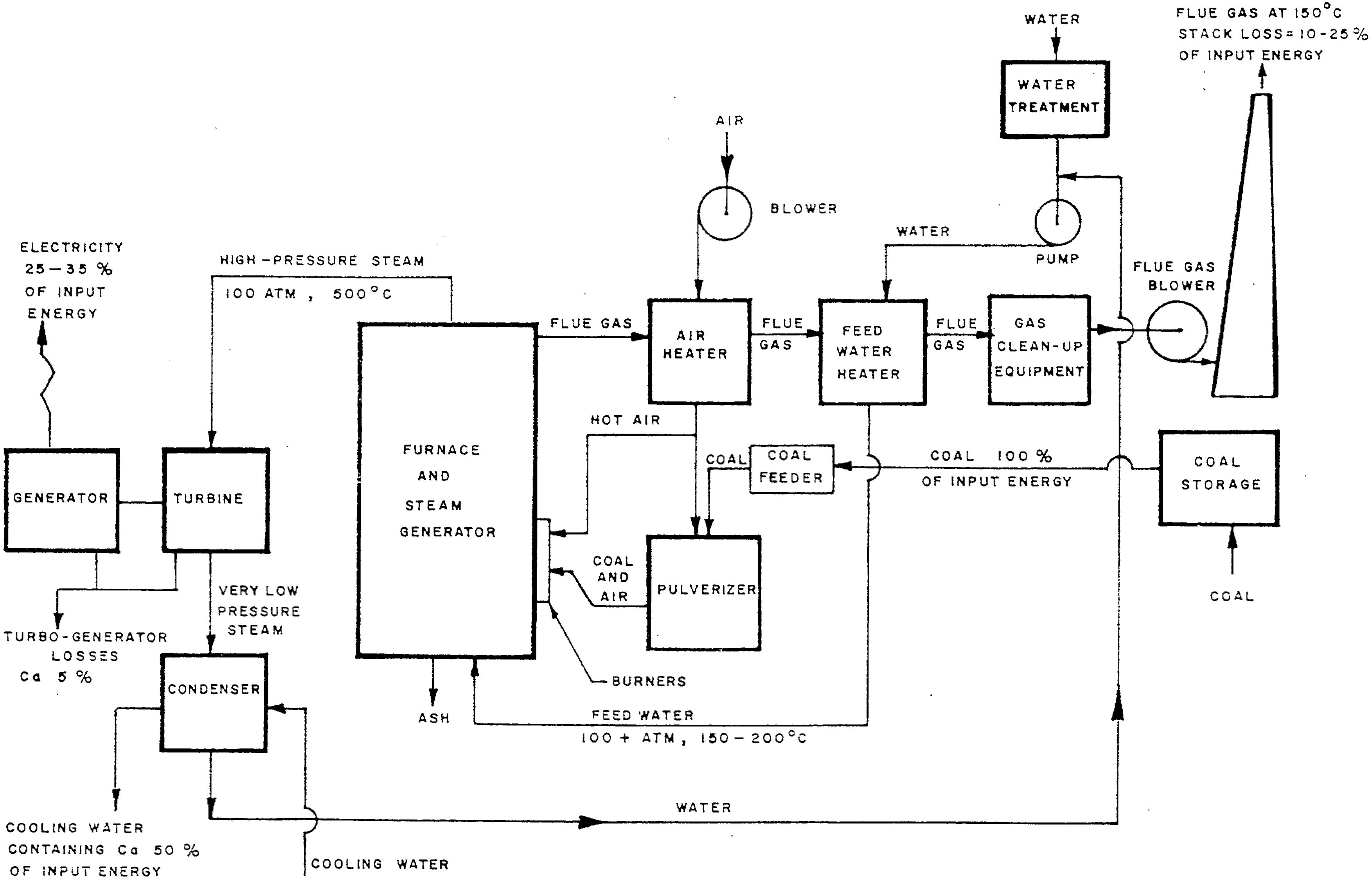

Figure 1. Flow Diagram for a Pulverized-Coal-Fired Thermal Generating Station

Fluidized-Bed Combustion

This is a new technology which is just now being developed for a variety of industrial applications. It offers the advantages of economy, efficiency, low pollutant emission, and perhaps most important of all, insensitivity to coal properties. Like pulverized firing and stokers, the final product is steam, hot water, or hot air.

The fluidized-bed combustor is based on a simple principle long used in the chemical industry where intimate contact between gases and solids is required. A bed of granular material is contained in a cylinder closed off at the bottom by a perforated plate, through which gas is forced upward in sufficient volume to fluidize the bed material. That is to say, the bed material assumes a motion similar to a boiling liquid as it is repeatedly lifted by the bubbles of gas passing up through it. The result is vigorous mixing of the bed material and, if there is a thermal gradient, rapid heat exchange.

Figure 2 schematically shows a fluidized-bed combustor applied to a small boiler. Since oxygen is required for combustion, the fluidizing medium is air. Also the bed material, which may be sand, ash or limestone, must be heated by some means to the ignition temperature of coal. Sufficient oxygen and temperature being present, any fuel introduced into the bed will burn, and because of the intense mixing, burn rapidly, even through its concentration relative to the bed material may be less than 1%. Herein lies the major advantage of a fluidized bed. The heat generated by combustion of the coal is rapidly absorbed by the large mass of bed material and is transmitted to heat exchange surfaces, such as boiler tubes, making it easy to maintain the bed temperature well below the temperatures normally encountered in a pulverized-fired furnace. Bed temperatures of 800 to 900°C are high enough for the ignition and complete combustion of all but the most unreactive coals, yet are below the ash fusion temperature of most coals, thus avoiding all the problems relating to slagging of the ash which plague pulverized-fired systems.

There are other advantages as well. The coal does not have to be pulverized - it need only be sufficiently crushed and dried to permit easy handling. Swelling and agglomeration of the coal pose no problem because of the massive dilution by inert bed material, and ash content is unimportant

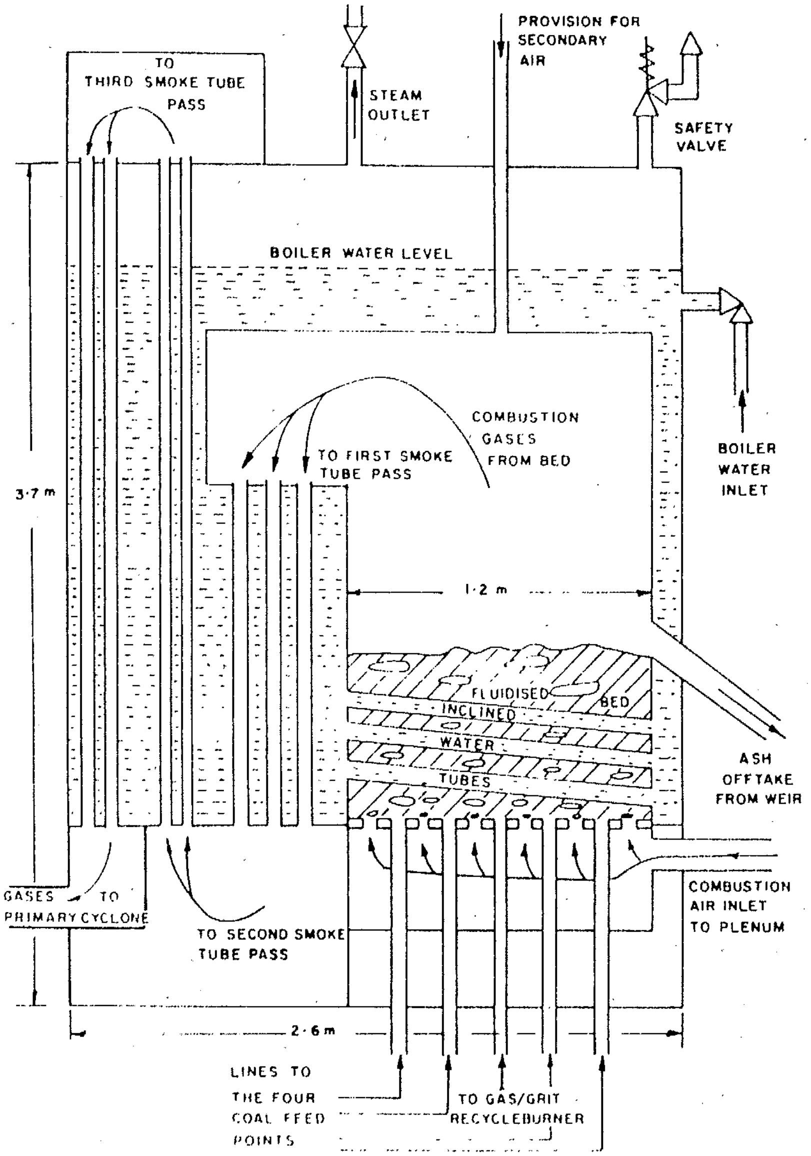

Figure 2. Schematic of a Fluidized-Bed Combustion System.

for the same reason. Coals with up to 70% ash have been burned successfully, the only noticeable difference in performance being an increase in the amount of bed material that must be removed to maintain the proper bed level. The formation of nitrogen oxide pollutants is minimized because of the relatively low combustion temperature, and for the same reason, emission of heavy metals is low. If crushed limestone is injected into the bed it will react with and capture most of the sulphur in the fuel. Thus, the fluidized-bed combustor offers a powerful technique for reducing sulphur dioxide emissions.

The main disadvantages of fluidized-bed combustion are

a) the high energy requirement for providing combustion air at moderate pressure,

b) large quantities of ash entrained by the gases leaving the bed, and therefore a substantial investment in dust collection equipment, and

c) limited load-following capability.

As stated earlier, fluidized-bed combustion is a developing technology and its applicability to the various energy market sectors is not yet clear. It has been in commercial use for about fifteen years to incinerate waste products such as bark and sewage sludge, but to date it has been applied to coal only on an experimental basis, in small pilot plants and in a few steam boilers. The development of domestic furnaces burning coal in a fluidized bed is unlikely, and the potential application to the transportation section appears to be limited to the propulsion of steamships, and the generation of electricity. However, potential for servicing the small industry market, and the domestic and commercial heating market via district heating, appears to be exciting. The Department of Energy, Mines and Resources is presently sponsoring conceptual design studies for conversion of a federally-owned stoker-fired heating plant to fluidized-bed combustion, burning coal and wood waste. The application of fluidized-bed combustion equipment to suit the electric utility market is still a few years away at best, but many agencies around the world are working in this direction because of the potential for reducing sulphur oxide emissions. In Canada a number of demonstration projects are under consideration.

Coal-in-Oil Slurries

This is another technique by which coal can replace some of the oil presently used to generate steam or hot water for institutional heating, for industrial processes and for thermal generation of electricity. Combustion of coal-in-oil slurries was experimented with briefly before the second World War, and now is receiving renewed attention, primarily in the USA, Japan and Canada.

To make a slurry, coal is first pulverized, then blended with 50 to 70 wt % of residual oil. Once the slurry is prepared, it is crucial that the coal particles not have an opportunity to settle out before it is burned; therefore if storage or transportation are involved, emulsifying agents are required to stabilize the mixture. At the expense of some additional pumping power the slurry can be fired through conventional oil burners, and performs very much like an oil flame. The ash is entrained by the combustion gases as in a pulverized-fired system, making the installation of dust collectors necessary.

The advantage of slurry firing is that it enables a combustion system designed for oil to use coal for 25 to 40% of its fuel requirement, at a modest cost for dust collectors and modifications to the burners. In many cases this is preferable to tearing out relatively new oil-fired equipment and replacing it with equipment designed for coal. Slurries have considerable potential for application in the Atlantic provinces, which are heavily dependent on imported oil. A demonstration project is now under way in a small electric utility steam generator in New Brunswick, with sponsorship by the Department of Energy, Mines and Resources, Ottawa, Canada.

Coal Gasification

Some processes for making gaseous fuel from coal were developed over one hundred years ago and were widely used around the world until recent times, even in Canada. Converting coal to fuel gas has three advantages over direct combustion. First, the gas can be conveniently distributed by pipeline. Second, gas is a convenient, ash-free fuel eminently suitable for cooking, domestic and commercial heating, and industrial processes, such as limemaking, which cannot tolerate an ash-bearing fuel. Third, sulphur in the coal can readily be removed in the gasification process.

However, our present-day requirements are for a fuel gas with an energy content equivalent to natural gas, otherwise long-distance transport via pipeline is uneconomic. To make synthetic natural gas from coal requires improvement of the old technology. Research and development is being carried out on several fronts in the USA and Europe and several viable processes have been demonstrated on a modest scale, but the economics are still marginal at best.

A major disadvantage of gasification processes is that they involve an energy penalty ranging upward from 20% of the energy in the coal feedstock. Many of the processes are also sensitive to coal quality. Capital costs for large-scale gasification plants are high, roughly comparable to oil sands extraction plants. The low-rank coals found in Alberta and Saskatchewan are good feedstock for gasification, but commonly occur in areas where water is not plentiful, and gasification plants require enormous quantities of water. Also Canada enjoys a better ratio of natural gas reserves to consumption than many countries. It therefore seems unlikely that we will make wide use of coal gasification in this century.

Coal Liquefaction

Coal liquefaction is the only technology by which coal can fully service the transportation market. Processes for manufacturing synthetic oil from coal were developed prior to World War II, primarily in Germany. They are presently used on a large scale in South Africa to produce gasoline.

In general, coal liquefaction enjoys the same advantages and suffers the same disadvantages as coal gasification. For liquefaction, the technology is not well developed. The energy penalty is substantially higher, but could be overcome by combining a nuclear steam generator with a liquefaction plant, the nuclear plant making up the heat losses and increasing the yield from the coal. However, for coal liquefaction to proceed in Canada it will have to be economically competitive with oil sands extraction.

ENERGY STRATEGY GUIDELINES

Coal, by virtue of its abundance, is an energy resource of great importance to Canada's future. Although it is not as versatile in application as oil or natural gas, technology exists, or hopefully soon will, by which it can make a significant contribution to most of the energy market sectors.

From the foregoing discussion, the following general conclusions can be drawn concerning an energy strategy for Canada:

1. To protect the transportation system and the petrochemical industry, the use of refined oil in other sectors should be minimized.
2. Natural gas should be progressively reserved for those applications where it is most difficult or most expensive to replace, namely domestic and commercial heating, certain industrial processes requiring clean fuel, and as feedstock for the chemical industry.
3. District heating systems should be encouraged for domestic and commercial applications, using fluidized-bed combustion of coal, coal-in-oil slurries, heat-recovery incineration of garbage, waste heat from thermal power stations, and possibly solar energy.
4. Electricity should be generated using the most advantageous mix of coal, nuclear, hydro and heavy oil.
5. Gasification and liquefaction technology should be adapted to suit Canadian coal, and brought into service as required.