The Energy Outlook for Canada

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1975 is a historic year for Canada. For, in 1975, Canada ceases to be an energy abundant nation and becomes energy deficient. The country has now become a net importer of petroleum and is about to take a near vertical plunge into an energy crisis that threatens to put an end to the rapid rise in prosperity of the past and bring an even more rapid decline. And, if not faced immediately and decisively, it can lead to still a worse situation. In fact the crisis is too close to be met effectively and even with the best plans and under the best circumstances large social disruptions and extreme inconvenience to the population cannot be avoided.

Abundant and cheap petroleum, and more recently natural gas, fueled the Canadian economy and the Canadian lifestyle and brought them to their present high level. Petroleum is now beginning to decline. Natural gas is soon to follow the same course. Imported fuel cannot be brought in in the huge quantities that are needed. The country's unfavourable trade position cannot support them. Local sources are not ready to provide enough and the economy is not ready to make use of new types of fuel.

In what follows we shall look into the future supply and demand for the two principal fuels, the possible consequences of the deficit and the new energy sources that must soon take their place. We shall see how Canada compares with the United States in the severity of the problem and the ability to solve it.

Canada now has the most energy intensive economy in the world. At 15 metric tons of coal equivalent per capita per year of primary energy, it is at more than three times the European level. For each unit of its economic product Canada also uses more energy than any other nation; two or three times more than such countries as Germany and France. The reason for this is its concentration in the extraction of natural resources, its climate, the lavish lifestyle of its citizens and their belief that its energy sources are inexhaustible.

Let us now look at the details. Figure 1 shows the production cycle of conventional oil in Canada. The projected supply has been estimated by the National Energy Board and is the total to be expected from the Alberta basin. This is equal to seven billion barrels of known crude and two of expected discoveries, enhanced recovery and natural gas liquids. No 'frontier' oil is included since none of commercial value has been found yet. Arctic oil has figured prominently in past projections of the Canadian oil supply. The Arctic and the continental shelves of Canada contain great volumes of sedimentary rock, where oil is found. In the past estimates of the oil to be found were made by multiplying the cubic miles of this rock by some average figure. But this method is invalid. The occurence of oil is highly non-uniform. For example, a very small area around the Persian Gulf contains half of the world's known oil. Extensive exploration and drilling in the Canadian north has revealed no commercial oil (but some gas). Exploration activity at present is at a low level. Possibilities of discovery are not exhausted, but to be useful any deposits that are found must be large,'elephants' not 'mice' as have been found in the past. And if under water they must be compact so they can be drilled from only a few platforms. These are severe constraints. Fields of the required size, 3 billion barrels and up, depending upon location, are rare. Only 4 or 5 such fields have been discovered in North America. In recent years estimates of possible commercial oil discoveries in the Arctic and 'offshore' have been declining steadily. Oil may still be found, even in large quantities, but it will not arrive soon enough to relieve the crisis which has begun. The country must have moved to another energy source by the time such oil arrives.

The projected demand for oil as estimated by the National Energy Board, grows at 4% per year in the next 10 years and less after that. The rate in the period 1960-1975 has been 6%.

The production cycle for natural gas is shown in Figure 2. The remaining reserves consist of the following components: 55 trillion cubic feet proven and 14 trillion cubic feet to be found in the Alberta basin, both numbers higher than past quotations as a result of higher gas prices; 6 trillion proven (after 10 years of drilling) and 10 still to be found in the MacKenzie Delta and Beaufort Sea. Experts' estimates vary from 10 to 20 or 25 trillion cubic feet for the total. These numbers add up to 85 trillion cubic feet for total Canadian reserves known and potential. No Arctic gas is included here although 12 trillion cubic feet have been found there. This gas is equivalent to two years supply for gas and oil in Canada. Much larger quantities are needed to justify construction of a pipeline which must cross deep Arctic waters full of ice and other hazards. The time needed for finding the necessary additional quantities and for pipeline research and construction may be of the order of 15 to 20 years. By then of course Canadian needs will have more than doubled. Therefore this gas will not affect Canada's energy problems which will have to be solved before then. The status of the Delta gas is also in doubt. Six trillion cubic feet (one year's supply of oil and gas equivalent at the present rate for Canada) is not enough to justify the building of the proposed 48 inch pipeline, a large investment. It will feed it for only 4 years. A part of the Canadian gas was committed for sale to the United States at a time when Canada was believed to have centuries' worth of oil and gas. The remainder of this committed gas is about 12 trillion cubic feet, equal to two years' supply of oil and gas energy for Canada at the present rate of use. Since the revenue from the sale of this gas may be used to buy the equivalent oil abroad, for which Canada now has a greater need, there is little to be gained by breaking these contracts, an act that would greatly anger the Americans since certain areas of their country depend critically on it.

Figure 2 is similar to Figure 25 in the report, *Natural Gas in Canada*, April 1975, by the National Energy Board but in this figure all the Arctic and part of the Delta gas of Figure 25 is omitted for the reasons given earlier.

Oil and natural gas are substitutes of each other in most uses (some exceptions: oil in mobile equipment, gas in the kitchen). It is therefore possible to combine the two by adding their heat contents to obtain one representative fuel, eg. 'oil equivalent'. This has been done to both the supply and demand and the resultant quantities are shown in Figure 3. The curves cross in 1976 and diverge rapidly from each other. By 1986 the supply is half the demand and only one seventh by the year 2000. The difference between the curves is the deficit that might be imported. This is plotted in Figure 4. Starting in 1976 it grows linearly at the rate of 12 million metric tons (90 million barrels) per year. With the price of oil at about $14 per barrel, the annual cost grows by $1.2 billion to $10 billion in 1985 and $30 billion in 2000. The cumulative cost of the deficit grows to $120 billion by 1990 and to $360 billion by the year 2000. By the year 2004 the cumulative oil deficit will equal the recoverable part of the tar sand oil. To the year 2000 the cumulative oil deficit will equal 3.60 billion metric tons (27 billion barrels) or 150 trillion cubic feet in gas equivalent. These are the numbers that must be kept in mind in judging the significance of new discoveries.

To meet the projected demand, one plant of the Syncrude size (120,000 barrels a day or 6 million tons a year) must come on stream every 6 months, starting in 1976. The proposed Syncrude plant will come on stream some time in the eighties and more may follow. (A smaller plant producing 2 million tons a year has been operating for some years). But, as the saying goes, these will be "too little too late". It appears that, as things go now, there will be an oil deficit of the order of 2 billion tons in the next 25 years. Its cost will be $200 billion. Assuming that this oil is to be imported, where is it to come from and where will the money be found? The bulk of the oil must come from the Persian Gulf because that is where the oil is: Saudi Arabia, Kuwait, the Emirates. But these countries already have enough clients and do not wish to raise production, and more new clients are heading there; above all the USA. Canada must work hard to gain Arab favour and oil. As for the money, a place must be found in Canada's imports to accommodate the oil. Considering Canada's present trade deficit it is difficult to see how additional imports could be supported. Further, a large part of Canada's exports consist of oil and gas which is bound to decrease. There is perhaps $5 billion a year to be saved by eliminating consumer products and travel by Canadians abroad. Larger sums will have to come from increases in the exports of minerals and forest products. But these industries are highly energy intensive and their rapid expansion may not be possible. The process of expansion will require machinery which must be imported. It should be noted here that Canadian mineral reserves are not as great as generally believed. The present value of all minerals, excluding fuels, is about $100 billion (see the supplement to *The Industrial Materials of Man* for details). This would pay for only a third of the oil deficit to the year 2000. A possible solution might be to invite the Arabs to invest heavily in these industries and also in other industry and real estate and to bring their oil along as well. This would be an attractive deal for them and it has more than a passing chance of success. However $200 billion would represent a large part of the value of Canada. There is also the possibility that the Americans and Europeans, who need badly Canada's minerals and forest products, would come to the rescue and provide the necessary energy, even by reducing their own supplies, for the maintenance and expansion of these industries. But their aid would exact a heavy price: the abandonment by Canada of the job producing secondary processing of these raw materials.

And what would be the consequences of a large fuel deficit in the coldest country on earth? There are many possible scenarios with much in common. Let us look at some of these. A drop in the standard of living to begin with. Canada's oil and gas were like money in the bank. When it is gone one can hardly expect things to get better. Canada had high unemployment when its economy had an abundance of cheap fuel and could expand without obstacles. The shortage of fuel can only reduce activity and employment. And what about social peace? Would the hardships bring Canadians together or set them against each other? The present unrest is hardly reassuring. And when the prospects for improvement from economic expansion, that keep the majority of the population hopeful and patient, disappear where else could they turn their attention but to the income of the rich? The inevitable social strife would keep government too busy with day to day problems to think of the solutions that are necessarily long term. We see this already happening today. A vicious cycle would develop from which it would be very difficult to break out. In the worst case when a certain minimum quantity of fuel cannot be secured or when supply is interrupted and the economy collapses one could imagine Canadians trying to live like the early settlers or, may be, the Indians. But those braves were few, surrounded with wood, land and game and were willing and prepared for the rigours of the Canadian climate. Thirty million city and town people cannot suddenly take to the woods in 1985. They are too many, the wood has been cut and the buffalo roams no more. Or perhaps, they might give it all up and head south for warmer climates if they can get past the electronic fence. The Pandora's box of other grim scenarios will be left to the reader's imagination.

An important question begs an answer here: how much energy can an economy lose and still keep going? Many studies have shown that economic output is roughly proportional to energy used. But nobody knows what happens when a given economy loses a large part of its energy for an extended period. Economies are complex non-linear systems and their behaviour under large changes in their inputs cannot be predicted. Detailed mathematical simulation can provide some information.

It should be noted here that the much publicized energy crisis of the United States will not be as severe as Canada's in the coming years (we shall see about this below). It is conceivable that Canada will not act soon enough to avert its own crisis and the country will be in a worse position than the United States. Calls will be made in Canada to revive the Continental Energy Plan which was rejected in the past in the belief that it was a scheme by the United States to deprive Canada of its energy resources. The USA does have a great need for other resources, especially minerals, which it cannot meet from within its own territory. In exchange for these resources it could reduce its own fuel consumption by a small amount and meet Canada's minimum needs. This would fulfil the old prophecy that some day Canada's fuel will come from the 'frontier'.

The American energy problem is known to us all. How do the Americans fare and how does their problem compare to Canada's? The production cycles for oil and nautral gas for the United States are shown in Figure 5,(a) and (b). These cycles are essentially the same as those drawn by King Hubbert many years ago (see *Resources and Man*) except that the oil and gas from Alaska has been added. We note that both cycles go well beyond the year 2000. Figure 5 (c) shows supply and demand curves. The supply curve has been constructed by adding the oil and gas in (a) and (b), by heat content. The 1.5% growth rate in the demand implies constant per capita consumption and has been proposed as a desirable target and is easier for the USA to achieve than for Canada since the USA's economy does not have to expand into energy intensive sectors as Canada's must. The Americans have had an energy deficit for years but it is growing slowly relatively to the projected Canadian deficit. Their supply declines more slowly than the projected Canadian supply as well. Comparative curves for the two countries are shown in Figure 6. If the present trends continue the Canadian deficit will become relatively larger than the American by 1980. In Figure 7 the oil production cycles for the two countries are plotted together. The figure shows that the USA will be producing oil long after Canada's oil is gone. On a relative basis, with regard to reserves and population, Canada is extracting its oil at twice the American rate. However, Canada's dependence on oil as a fuel is almost twice as large as the USA's (60% vs 37%).

The USA's energy prospects are much brighter than Canada's. Canadians think they are energy abundant while Americans know they have a problem. The USA's oil will last longer, their deficit will be smaller, their coal reserves are very large and readily accessible, their coal industry is well established and can be expanded easily, they have undertaken large research projects to meet the problem, and they have warm parts in their country where they could relocate industry and population if that is needed. Further, they have large influence abroad and military power to protect or even obtain foreign fuel if that becomes necessary.

Since Canada is about to start drawing heavily from the world supply of oil let us see how things are there. In Figure 8 two production cycles for world oil are shown, corresponding to two values of the ultimate reserves. These reserves were estimated in the 1960's using very careful methods. These methods are described by King Hubbert in *Resources and Man*. Exploration activity in the last 10 years has been very intense but in 1967 production exceeded the average finding rate (a 5-year moving average) and is now much higher at 3 billion metric tons per year. It thus appears that the low reserve figure of 1350 billion barrels (185 billion metric tons) may not be reached and maximum production, only slightly higher than at present may be reached by 1985. It is possible to force production to higher levels but that can damage the fields and reduce ultimate reserves. By then, actually before then, the competition among users to get the available supplies could be so fierce that Canada's chances of getting all it needs may not be very good, even if the money is there. This prospective decline in world oil production bodes nothing good for the world economy. Canadians will have plenty of company for consolation if they want it.

ARE THERE ANY SOLUTIONS?

Conservation

We noted earlier that the Canadian fuel deficit which is to appear in 1976 will grow too rapidly to be met by new sources and that Canada's international trade position is too unfavourable to allow adequate fuel imports. Conservation therefore is inevitable, whether planned or forced.

How much can be saved? The Americans in their Project Independence Report state that a 15% reduction in use can be achieved. Beyond that economic disruption begins. From Figure 3 it may be seen that a 15% reduction in demand would shift the curve to the right by two years and would postpone the crisis by that amount of time. This is very valuable but not enough. Larger savings are needed to allow time to bring in new sources (which do exist as we shall see further on). Conservation in this case means reduction in oil cunsumption above all and then in natural gas. The saving must be permanent, since the present level of consumption of oil and gas is not likely to be reached or approached again. Let us see now what areas offer promise for saving.

Figure 9 shows the sources and uses of energy in Canada, for 1969. Proportions are roughly the same today. Electricity accounts for 14% of secondary energy. It is used lavishly in Canada and much could be saved so as to free coal which can replace oil in space heating. Saving will also reduce the need for further expansion and save capital which can be diverted to the main problem i.e. provision of fossil fuel. Most Canadian electricity is produced by water and beyond a certain point it cannot be 'saved', the water will overflow. However, it is unlikely that this point would be reached.

Industry offers comparatively fewer possibilities for overall energy savings. As a rule it does things more rationally and engineers have always been on the lookout for savings. However substitution of coal for oil and gas for the provision of process heat and other needs could save those fuels. But coal at the moment is not available. A large overall reduction of energy use by industry would cause shutdowns and unemployment. Energy use in industry must inevitably increase greatly in the near and intermediate future. The highly energy intensive mineral and forest industries that are now using about 20% of the country's energy are the only ones that can be expanded and provide secure exports (especially the forest industry), and make it possible to pay for the inevitable oil imports, among other things. The same applies to agriculture. Resource extraction and processing is Canada's only comparative advantage. It is what attracted its inhabitants to the coldest country in the world, the reason for the existence of the nation. Canadians cannot switch to doll making to save energy. Everyone else is doing that. Besides, Canada has an international obligation to provide essential minerals for the world economy and, more importantly, paper to make books for the billions of the world's inhabitants who have few other sources.

The residential and commercial sectors offer good promise for savings. Forty percent of all energy, 24% of the oil and 50% of the gas is used here. There are a number of steps that can be taken here: thermostats can be lowered, unused rooms can be shut off, buildings can be allowed to cool when not in use, insulation can be improved, building codes can be changed, and wood and coal (as soon as the latter becomes available) can be used as fuel in areas away from large city centers. Waste heat from thermal power stations that are located in cities can be used resulting in large fuel savings. Toronto has large quantities of such heat. In the long run cities will have to be redesigned if they are to be heated efficiently by district heating plants. A much higher population density than at present will be needed. The present low density sub-urban areas will have to be abandoned. Such areas have the additional disadvantage of being unsuited for service by mass transport. Steel and glass buildings also pose problems and should no longer be built.

The private car offers the greatest promise for oil savings. It consumes 26% of all oil and over 15% of all energy. It might be thought that going to small cars and driving less would be the answer, just as in Europe. However, this is no solution in the short run. It takes 10 years of production to replace all the cars on the road and such time is not available. A faster and greater reduction will be needed. How could this be achieved? There are two methods. Higher price for gasoline or rationing (or a combination of the two). The elasticity of demand for gasoline at the present consumption level is -0.3, meaning that a rise of 1% in its price could reduce consumption by 0.3%. If this elasticity is assumed to hold at other levels it can be shown that to achieve a 50% reduction in use, a tenfold price increase is needed. Thus a reduction through price increase would hit those with lesser incomes hard and drive them off the road. This cannot be done too suddenly. Therefore rationing is the answer, possibly combined with a price increase. The present average of 2 gallons per day could be reduced to 2 or 3 gallons a week with unlimited additional quantities available at, say $4 to $7 a gallon. Simultaneously mass transport networks could be established relatively quickly. The auto industry could switch to bus making and more buses could be purchased abroad. Regarding the long term survival of the private car the prospects are not favourable. With much higher population densities in the cities of the future, there may not be room for it, even if there is no fuel problem (the electric car may have been perfected by then). In the meantime if most people can no longer use their cars and must give them up would they not consider it a provocative display of wealth and a nuisance if a minority continued using theirs?

Fuel can also be saved by switching intercity truck freight to trains, which should be electrified where track is used heavily.

It is thus evident that large gains in fuel can be made by conservation mainly at the consumer end. Increases of energy consumption by the resource industry would reduce overall gains but there could be a significant reduction in the use of oil thus reducing the need for imports. Coal of course would have to provide much of the deficit and its production must be increased rapidly. We shall see about that further on.

Conservation in the amounts implied here would cause disruptions. But it could help avert worse things. The biggest obstacle to conservation will be public resistance. People are not convinced that all these unpleasant measures are needed. It may take much time and distress to create a climate in which these measures will become widely desirable. Unfortunately the available time is so short that heavy damage may be inevitable.

Alternative Energy Sources for Canada

Canada is well endowed with a variety of energy sources other than conventional oil and gas and even for these, large deposits may some day be found in the Arctic or in the East, in land or sea. The large area of the country and the small population should ensure that on a per capita basis there should be plenty. So it is in fact. There is no excuse for an energy crisis in Canada. The country will become the laughing stock of the world if it allows itself to drift into one. The problem of course is time: the time needed to develop the sources and to convert the large energy consuming economy of Canada so it can use other types of energy. This conversion problem will soon be faced by every country that uses oil on a large scale. Canada is only the first country that must do it in great haste. Could it be achieved quickly enough to keep ahead of the decline in oil and gas? Of course we don't know because the problem has not occurred before in this forced form. Economies and energy systems have large inertia and resist change. There are a million things to change, a million complications. The shortage of time available makes it so much more difficult.

Of Canada's several other energy sources many are minor, some are significant and one offers a nearly complete solution for a very long time. We shall consider the potential of the following sources:

Solar
Winds
Geothermal
Tidal

Wood, Biomass
Garbage
Water Power
Nuclear (electricity)
Tar Sands
Coal

Solar

There is no known technology for utilizing solar energy on a large scale and none is likely to be developed in the next 20 to 40 years. It may however be used as an auxiliary source for space heating. It could provide as much as 5 to 10% of Canada's total energy and possibly more. However the capital cost is too high at more than $1000 per annual ton of coal equivalent. Using coal instead would cost about $100 to $150 (It takes 6.5 tons of coal to heat the average Canadians dwelling for a year). Therefore in the coming rush to change over from oil it would be a wrong step to concentrate on solar power since it would divert capital from more promising directions.

Winds

The potential electricity available from wind in Canada is of the order of 10,000 billion KWH a year or thirty times Canada's present electrical output. This energy is mostly in the north, it has low reliability, the technology is not well developed and the capital cost is high. It may be used profitably in isolated communities and farms and could supply up to 1% of Canada's total energy needs in the near future. It has promise for the distant future but is no answer to today's problem.

Geothermal

Some small quantities may exist in the Rockies but would be of negligible significance.

Tidal

Enough tidal power is in the Bay of Fundy to supply electricity to the Maritimes and possibly more. The capital investment however would be too high.

Wood, Biomass

The annual growth of Canada's forests could provide about 100 million tons of coal equivalent or a third of Canada's needs. Wood of course is too valuable in other uses. Dead wood and wastes could provide some fuel for home use. Biomass in its broader sense could someday make a contribution. Photosynthesis fixes 5 to 10 times more carbon in Canada than the country's total energy use.

Garbage

It is sometimes stated that garbage could make a significant contribution to Canada's energy supply. There are 20 million tons of garbage per year in Canada. About half of this could be collected in the large centres and burnt in large incinerators. With a heat value of 4000 BTU's per pound, this quantity would provide 1% of Canada's primary energy needs. The capital requirements would be very high. Garbage of course has more value for things it contains and that could be reclaimed.

Water Power

Complete development of Canada's hydro potential would more than double present installed capacity. But it would contribute little to the solution of the main problem and is very highly capital intensive. It should be developed if the capital can be spared which is unlikely in the next 10 to 20 years.

Nuclear

The known uranium reserves of Canada, 190,000 metric tons, if used in Candu reactors at 1% burnup and 30% efficiency would supply all of Canada's present electric needs for 40 years and its total secondary energy needs for 6, assuming it were possible to use electricity everywhere. An additional quantity of equal magnitude to the known reserves is 'reasonably assured'; at a higher but acceptable cost. The ultimate uranium reserves of Canada can only be estimated by general methods, by considerations of crustal abundance. Thus if uranium were prospected as thoroughly as copper and zinc, 2 million tons might be found in Canada. (see the supplement to *The Industrial Materials of Man* for the justification) This would be enough for 400 years of Canada's electricity needs at the present rate and for 60 years for Canada's total energy needs (or for 28 years at 5% annual growth). There is of course thorium which should be more plentiful than uranium but the technology for its use has not been developed. There are also large deposits of very low grade uranium of 100 parts per million (ppm) or less and some deposits with more. The USA has large quantities but it is not known if Canada has any of that grade. It was thought that this uranium could be used and provide energy for centuries. Let us see what these numbers mean. One hundred ppm contains roughly 1 gm of fissionable material per ton. This equals, in energy content, 2.5 tons of coal. Thus to get these 2.5 tons, one must grind 1 ton of rock, concentrate it and use the expensive method of ion exchange to recover the pure uranium. This whole process will use a lot of energy probably more than 2.5 tons of coal. Research is currently underway in the USA to determine the actual energy costs. In the meantime these low grade ores cannot be considered as reserves as was the practice some years ago. Much of the hope of the world for plentiful nuclear power rested on these low grade deposits and on ordinary nuclear reactors. Breeder reactors of course would indeed use these ores since they use not that 1 gm of uranium but the entire 100 grams. For breeders fuel supplies would last for thousands of years and probably longer. However, the technology of breeders is not well developed. There are three now operating (UK, France, USSR) but it will be sometime (20 years) before they are commercial, if ever. Besides, there are very strong objections to them which we shall not discuss here.

Therefore it can be said that nuclear power is important for Canada's electric future but no answer to the main problem.

Electricity for Canada's Future?

We hear often that in the future electricity will provide a larger part of our energy, perhaps even all of it. Nuclear energy would make this possible. Electricity is the most luxurious and expensive form of energy. For every unit of it that is consumed three units of fuel are used to make it, with a lot of expensive equipment in between. Canada now has 60 million installed kilowatts producing 14% of its energy. In the USA it is 10%, elsewhere less. If Canada went all electric today the required installed capacity would have to go up to 600 or 700 million kilowatts since the load factor would decrease from 55% to 40 or 35% in order to provide peak load during the coldest part of the year. That would be 50% higher than the present capacity of the USA. Space heating alone would need 250 million kilowatts. An all electric USA would need 6,000 million kilowatts while an all electric world would need 20,000 million, and, among other things, it would require twice the known world reserves of copper. The known world reserves of uranium would last 15 months if they fed this system. The future energy needs of the world, supposed to be 5 to 10 times greater than today's might someday be served by cheap fusion. The reader can fill in the statistics for the needed installations. These absurd numbers should help place electricity in the proper perspective. Electricity should be used only where it is without substitute: in lighting and in driving electric motors and other electrical equipment. Many great electrical generating projects are under construction today in Canada and still greater numbers are in planning, presumably as a response to the energy crisis. While making only a small contribution to the main problem these projects swallow up colossal amounts of capital.

Tar Sand Oil

The saga of the tar sands is known the world over; 300, even 900 billion barrels of oil sitting there, ready to fill the needs of the free world well into the distant future and teach the Arabs and OPEC a lesson if they don't behave. Americans, Germans, Japanese are ready with big money and big plans to tap it and settle their worries. And in keeping with grand tradition they would bring along 50,000 Koreans (Chinese are not available today) to do the dirty work.

The recoverable part of the tar sands, i.e. that part accessible by surface mining, is 36 billion barrels, according to detailed studies by the Alberta Conservation Board. No technology exists for recovering the remainder that is deeply buried. These 36 billion barrels could meet Canada's projected deficit in oil and gas to the year 2004. To achieve that plants of the projected Syncrude size (120,000 barrels/day or 6 million metric tons a year) would have to come on stream one every 6 months starting in 1976. A lead time of 10 years is needed for construction. Therefore tar sand oil will make no difference to Canada's deficit in the next 10 years and little after that considering the projected huge oil deficit by then. Canadians must be prepared to pay $200 billion or more to the Arabs in the next 25 years if the economy is to keep growing as it has been in the past and oil is to be the fuel and can still be found. The tar sands will provide only temporary relief to Canada's large energy needs. Even if they could now be developed to meet the entire needs of the country, planning would have to begin in the next decade to convert a much larger economy to some other more permanent source. Canada would be jumping from one energy crisis to another. This massive conversion will be easier the sooner it is made. There is also a good case to be made for saving the tar sands. They are a deposit of liquid hydrocarbons, the only one that will still remain after conventional oil in the world is gone, not too far from now. It will be a precious source of raw materials for chemistry and essential liquid fuel. The alternative would have to be oil from coal, a very expensive and wasteful process.

The question of what part of Canada's energy need is to be filled by liquid fuel should be decided at the earliest. On a per capita basis, 2 metric tons, or even 1.5, of oil per capita per year should be adequate for the use of the petrochemicals industry, for essential mobile equipment and for some other uses where any other fuel would be unsuitable. Many industrial countries manage well on less. Assuming two metric tons, and with the use of Figure 1, it is possible to estimate the amount that would have to come from tar sand plants, to provide these minimum needs. The quantities, number of Syncrude-size plants, and the corresponding years are given in Table 1.

Table 1

Year	1980	1985	1990	1995	2000
Population	26	28	31	34	38
Total number of plants	0	2	6	9	11
Total output	0	12	36	54	66

TAR SAND OIL AND PLANTS NEEDED TO SATISFY MINIMUM CANADIAN OIL REQUIREMENTS (2 metric tons per capita per year)

Population in millions, 2% annual growth, output in million metric tons/year.

The requirments in plants will be smaller if some conventional oil is conserved or if new deposits are found and developed in time.

Coal

Coal is the complete and only solution to Canada's energy problem. According to the Geologic Survey of Canada, the country's known (measured, indicated, inferred) resources of coal are 110 billion metric tons and the prospects are very favourable for greater quantities to be found in the western provinces, the Yukon and the North West Territories. Estimates by the U.S. Geological Survey have given Canada's ultimate mineable coal reserves as 600 billion tons. Estimates for coal are much more reliable than those for oil and gas. The recoverable part of the known resources is 45 billion metric tons. This is obtained by taking 50% of the accessible coal (90 billion metric tons), the other 50% being lost in the mining process. Enchanced recovery is possible so the recoverable part could be increased.

The recoverable 45 billion tons of coal could provide cheap energy for Canada for 200 years at the present rate of use of fossil fuels. The expected additional discoveries could provide even more. Coal will allow Canada's industry and agriculture to expand and make full use of the country's renewable resources and more thorough use of the non-renewable. It would also provide time to realize the full potential of conservation and achieve the highest possible efficiency of energy use and thus reduce consumption and prolong the lifetime of the reserves, thus laying a secure base for the country's prosperity for a very long time into the future. This would also give time to bring in renewable energy sources such as solar and winds and perhaps fusion, all of which need long times (50 years) for development. Eventually coal itself could be saved for the needs of chemistry and as an essential fuel, just as oil could before it.

Canada's coal is in Alberta and British Columbia. From there if must be transported to all parts of the country. Two thirds of the total production will be used east of the Lakehead. It must be taken to the Lakehead by train and by boat from there eastward.

The conversion to coal involves more than mining and transportation. Many changes must be made at the user end. Machines, ways of doing things and even psychology must change to adapt to the new fuel, and to the profound changes it will bring to the country's lifestyle. Coal is more polluting than oil and gas. It cannot be burned the same way. Pollution control will be one of the major problems. But people's attitude towards it will change. Coal will no longer be regarded as the dirty fuel but will be recognized for what it is, the guardian from grimmer things, the lifegiver. With this in mind, coal smoke will be accepted, indeed welcome, as the sign of prosperity and security and will have a finer aroma than the most expensive perfume.

All the tasks of conversion must be carried out in parallel and in great haste since the decline of oil and gas does not allow much time. The task is very complex and massive and requires the most sophisticated techniques of management, systems analysis, simulation, etc. However some of the main steps could be sketched here.

1) Analysis of the problems and planning. Determination of the needs, the tasks, the available means and who is to carry out the tasks. Setting of priorities on projects that would compete for capital, including other energy projects. Determination of damages that will result from the conversion. Simulation of the task. Existing models of the economy such as 'CANDIDE' would be used heavily in this case. The effort will tax the managerial and technical capabilities of the country.

2) An information campaign to convince the population of the need for conversion. Federal-provincial conflicts, confrontations and lawsuits could be endless but things cannot be done as in the past. There is no time for the present pace of settling disputes.

3) Opening of mines and raising production. This is one of the major tasks, especially so since the coal industry in Canada at present is very small. Attracting, training and keeping miners could prove the most difficult part of this task. Coal mining is dirty and unhealthy work. To keep men on the job the pay must be high and the hours short, the living conditions pleasant and the status high. The coal miner must be made the folk hero of Canada.

The levels of necessary production can be estimated from the oil deficit of Figure 4, after subtracting the tar sand output of Table 1 and multiplying by 1.57 to convert oil to coal by energy content. Output per man is taken as 6000 metric tons per year (40 tons a day, 150 days). Two thirds of production goes east of the Lakehead. Necessary production and crude estimates of manpower and capital requirements for mine development and transportation of the coal moving to the east are given in Table 2. These production figures assume no attempt to conserve any of the conventional oil and gas. If conservation were to start soon coal production would have to be higher expecially in the early years.

Table 2

COAL PRODUCTION, MANPOWER AND CAPITAL REQUIREMENTS NECESSARY TO FILL THE CANADIAN FUEL DEFICIT

(fuel units in million metric tons per year)

Year	Oil + Gas deficit	Coal equivalent	Coal east of Lakehead	Miners	Capital $ billion
1980	48	76	50	13,000	5.5
1985	94	148	99	25,000	11
1990	127	200	133	33,000	15
1995	178	280	188	47,000	18
2000	232	364	243	61,000	26

Total capital cost (excluding living facilities and roads) would be about $80 per metric ton and would be distributed roughly as follows: mine development $50, rolling stock and track $20, port facilities $5, and ships $6. This is a low capital investment as energy projects go. Tar sand energy in the same units would cost $200 to $300 and electricity from $1000 to $1500. However, these cost are not the only ones. There are costs at the user end, the costs of conversion, which will not be estimated here.

4) A double track railway from Alberta to the Lakehead. The existing rail lines can carry an additional 50 million tons a year. A new line will be needed after 1980. The double line should be adequate to the nineties. Electrification will further raise its capacity.

5) Port facilities at Thunder Bay and a shipping fleet to carry the coal from there to southern Ontario and further east.

Adjustments at the user end will also be needed. Changes in transportation were mentioned under 'Conservation'. Coal will replace oil and gas in nearly all residential, commercial and industrial uses. To keep pollution low in cities and large towns, coal should be burned in dsitrict heating plants which can be controlled more efficiently. These requirements would imply the following steps to be taken in parallel with the above:

6) Building of coal burning district heating plants and steam distribution networks in cities and larger towns.

7) 'Contraction' of cities since low density residential areas cannot be served well by district heating and by mass transport. They must stop growing and may have to be abandoned eventually. In the meantime heating of such housing could be done normally by coal in favourable weather and by oil in unfavourable weather (eg. in low wind and temperature inversions). New housing must be high density either downtown or in satellite cities or in entirely new cities that must be designed to meet the new conditions.

The list of changes is long. The reader may think or more if he so wishes.

The impending changes demanded by the necessary transition from the convenient fuels, oil and natural gas, to coal will be forced and rapid when compared with the mormal evolution of the past. It took more than 50 years to build the present way of life and it must now be remade in 15 or less. To achieve this successfully, the change must be made with military speed and discipline. The stresses and the inconvenience that this change will bring will be large but the reward will more than compensate.

With the secure foundation of cheap and plentiful energy Canadians can look forward to greater prosperity and security, a prospect available to very few other nations, and at the same time do the invaluable service to the world of providing it with very scarce essential resources.

In due recognition, let us salute the Coal Age. It is upon us!

The Energy Outlook for Canada (a supplement to *Man's Dependence Upon Energy*)
Queen's University at Kingston
October 1975

FIGURES

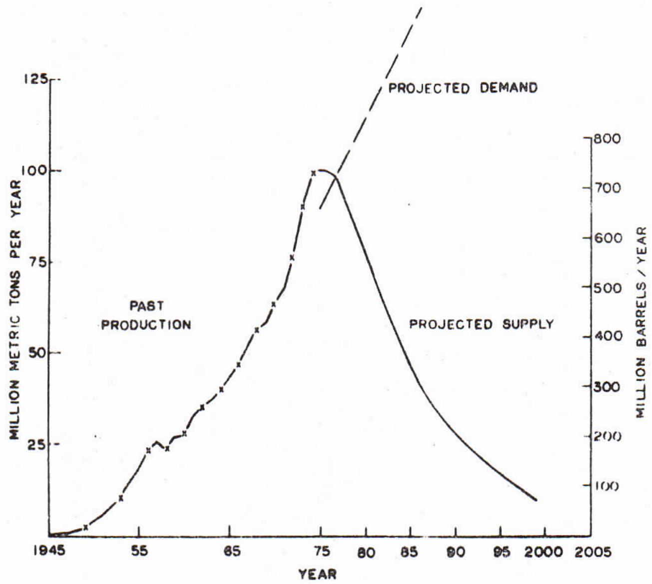
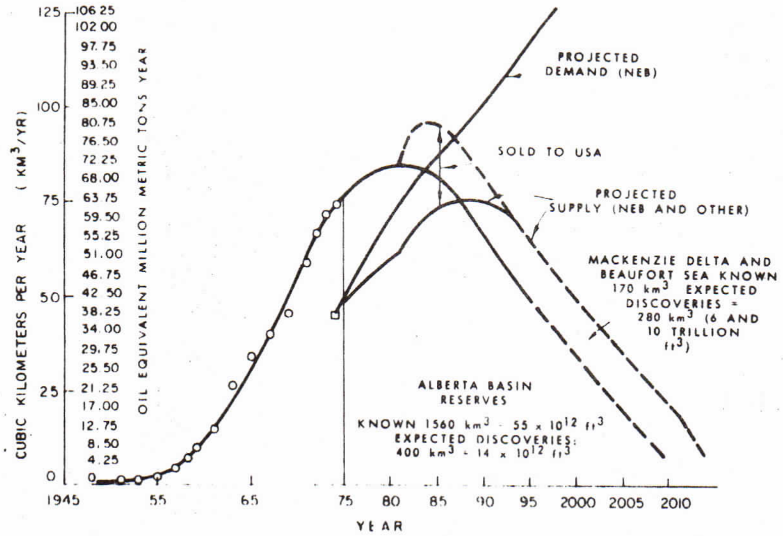
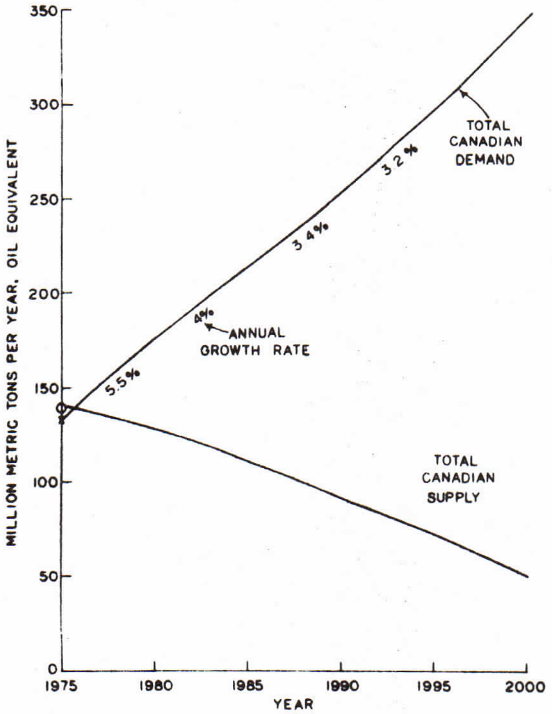


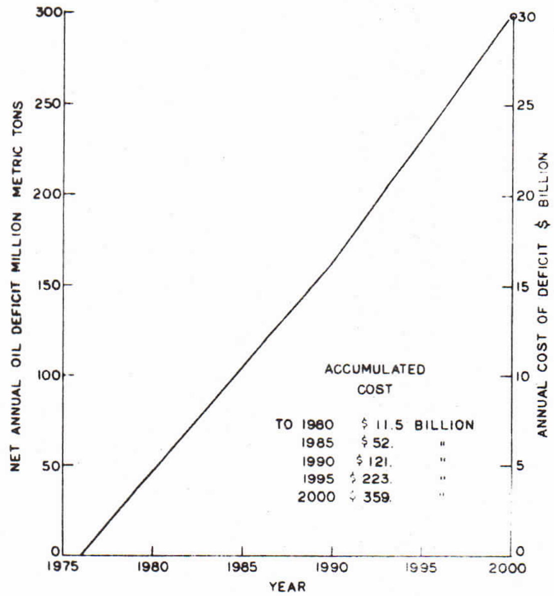
FIGURE 1: CANADIAN PETROLEUM PRODUCTION CYCLE
(including natural gas liquids)
(ref. *In the Matter of Exportation of Oil*, National Energy Board, Oct, 1974.)



<u>FIGURE 2:</u> CANADIAN NATURAL GAS PRODUCTION CYCLE



<u>FIGURE 3:</u> PROJECTION OF CANADIAN SUPPLY AND DEMAND FOR OIL AND NATURAL GAS



<u>FIGURE 4:</u> PROJECTED NET CANADIAN OIL DEFICIT AND ITS COST IF IMPORTED AT 1975-76 PRICES ($100 a metric ton delivered to Canada)

U.S.A. OIL AND GAS PROJECTIONS

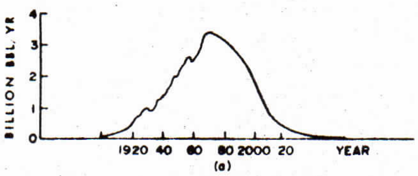


FIGURE 5a: PETROLEUM PRODUCTION CYCLE (incl. Alaska)

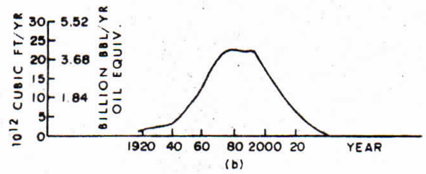


FIGURE 5b: NATURAL GAS PRODUCTION CYCLE (incl. Alaska)

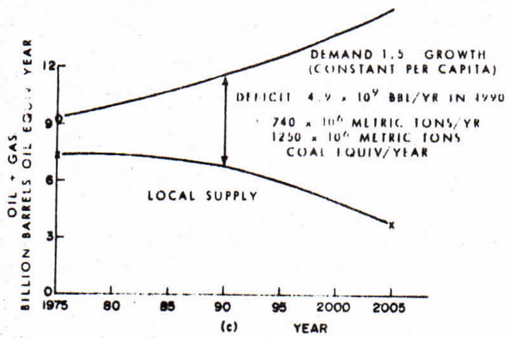


FIGURE 5c: U.S.A. PROJECTIONS OF SUPPLY AND DEMAND FOR OIL AND GAS

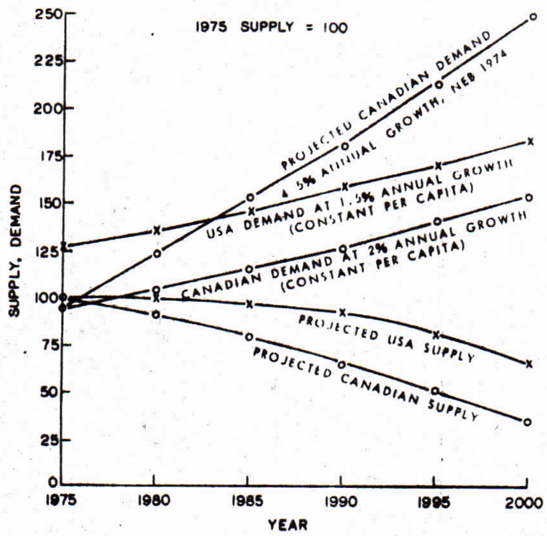


FIGURE 6: COMPARATIVE DEMAND AND LOCAL SUPPLY FOR OIL AND NATURAL GAS FOR CANADA AND U.S.A.

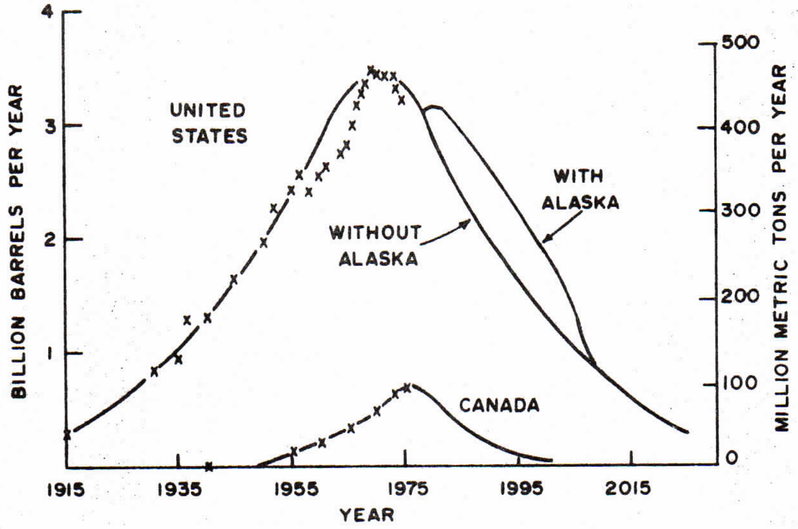


FIGURE 7: PETROLEUM PRODUCTION CYCLES FOR CANADA AND THE U.S.A.

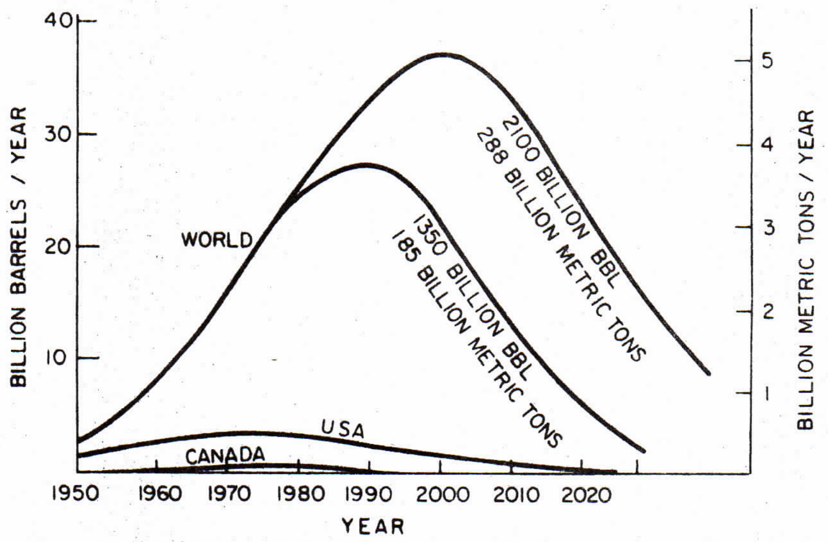


FIGURE 8: PETROLEUM PRODUCTION CYCLES FOR CANADA AND THE U.S.A. AND THE WORLD, WITH TWO VALUES FOR THE WORLD ULTIMATE RESERVES

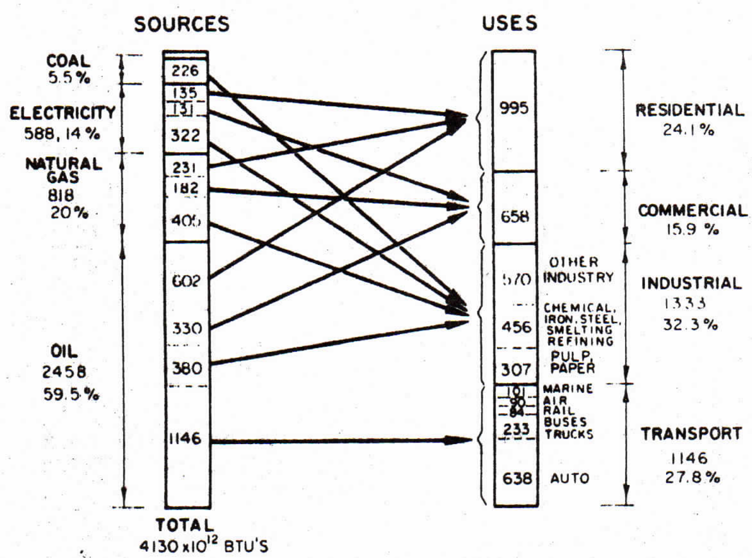


FIGURE 9: SOURCES AND USES OF SECONDARY ENERGY IN CANADA, 1969 (in trillion BTU's)
(source: *Energy Policy for Canada, Vol. 2*, Govt. of Canada, 1973)