A Paper

for the

Main Hearings

As Part of the Second Submission by

Fisheries and Environment Canada

to the

Ontario Royal Commission on Electric Power Planning

ELECTRIC POWER PRODUCTION AND TRANSMISSION

IN ONTARIO

FROM AN ENVIRONMENTAL PERSPECTIVE

May 10, 1977

7 November 1977

ERRATA SHEET

Fisheries and Environment Canada, "ELECTRIC POWER PRODUCTION AND TRANSMISSION IN ONTARIO FROM AN ENVIRONMENTAL PERSPECTIVE", May 10, 1977. (A paper for the Main Hearings as Part of the Second Submission by Fisheries and Environment Canada to the Ontario Royal Commission on Electric Power Planning.)

Please note the following changes or substitutions:

1. Page 29, second para., line 2:

    Delete: 99%

    Substitute: 99.5%

2. Pages 40, 41, 42:

    Delete:
    - pages 40 and 41 (Sections 3.3 and 3.4)
    - references [5] and [6] on page 42

    Substitute: pages 40 and 41 - revised October 31, 1977 (attached)

3. Page 72, line 7

    Delete: "Most" in "Most will enter ..."

    Substitute: "Some"

4. Page 108, lines 9-12:

    Delete: lines 9-12 inclusive ("but, because of ... east and southeast.")

    Substitute: "but, because of its location with reference to the major industrial areas of the United States, it probably receives more atmospheric pollution than it exports. The sensitivity of soil and water to acid rain damage in southern Ontario (south of the Canadian Shield) is slight in comparison to the "lightly buffered" (i.e., non-calcareous, soft water) remainder of the province. Other areas downwind of the province to the east and southeast such as Quebec (excluding the St. Lawrence Valley), the Adirondack area of New York State, and New England are also lightly buffered and, hence, sensitive to acid rain."

5. Page 109, lines 6 and 7:

    Delete: "over Toronto"

6. Page 118, Position Statement (9-2), line 5:

    Delete: "Utilies"

    Substitute: "Utilities"

7. Page 140, line 4:

    Delete: "and" in "single plant site and ..."

    Substitute: "on"

3.3 POWER GENERATION

(3-2) Steps should be taken to reduce sulphur emissions from power generating plants using residual oil. This could be achieved by expanding desulphurization facilities in order to produce low sulphur residual oil for burning in all generating stations.

Residual oil retains, in concentrated form, the sulphur and ash found in the original crude during the refining process. Residual oil burned in Ontario typically contains 2-3% sulphur and less than 0.10% ash. Consequently, burning of residual oil contributes to regional production of sulphur oxides and to the long-range transport of airborne contaminants. While the technology exists to remove sulphur from residual oil, the facilities for desulphurization do not exist on a sufficiently large scale to permit the use of low sulphur residual oil at all generating stations.

While natural gas is an extremely clean fuel, producing no particulates and scarcely any sulphur oxides, it is too valuable a commodity to be burned simply to provide thermal energy, unless no other possible use can be found for it in some special local situations. It cannot, therefore, be considered as a normal means of combatting air pollution from thermal power stations.

Because oil fuel has an extremely low ash content relative to the varieties of coal used in thermal power production, the use of oil fuel does not present a problem generally with respect to particulate emissions, though occasionally there are local transient nuisances caused by the deposition of acid smut from stacks connected to oil-fired boilers. However, it is probably that the constitution of these smuts consists chiefly of unburned carbonaceous material rather than incombustible material in the fuel.

With respect to sulphur dioxide, residual oil fuel gives rise to emissions which may be greater or less than those from a similar size of power generating unit using coal. The relative magnitude of emissions depends on the sulphur content and the heating value of each fuel, other things being equal. Consequently, switching from one fuel to the other may increase or decrease such emissions, depending on each fuel's sulphur, for a given situation.

The generation of oxides of nitrogen depends on the excess air required for combustion, the amount of nitrogen contained in the fuel before firing, the flame temperature, and the burner configuration, amongst other things. It is generally agreed that for a given power output, the largest NO_X emissions are usually associated with coal firing, declining markedly with oil combustion, and still more when natural gas is burned.

3.4 WASTE DISPOSAL

As both gas and oil have a substantially lower ash content than coal, the amount of ash formation and disposal would be significantly lower. In the light of comments in Section 2 on the environmental problems associated with landfilling of solid waste, both gas and residual oil show a marked advantage over coal in this regard.

INTRODUCTION

In the first submission by Fisheries and Environment Canada to the Commission (dated October 1976), the Department outlined a number of areas of concern relating to the current and planned electric power system. This current paper builds on the information base established in the first submission and provides more definitive statements on some of the more important areas of environmental concern which the Department feels warrant consideration in the Commission's decisions. A new section has been included on alternate energy sources such as solar, wind, and biomass.

In order to ensure that the contents of this paper are as brief and to the point as possible, a number of supporting documents are referred to which are being submitted under separate cover. These cover the following subjects:

1) Renewable Energy Resources;
2) "Economic Pre-Feasibility Study: Large-Scale, Methanol Fuel Production from Surplus Canadian Forest Biomass";
3) "The Utilization of Forest Biomass and Forest Industry Wastes for the Production and Conservation of Energy"; and
4) Energy and Climate.

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PART I

CONVENTIONAL AND RENEWABLE ENERGY SOURCES FOR ELECTRIC POWER PRODUCTION

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SECTION 1: HYDRO

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SECTION 1: HYDRO

1.1 INTRODUCTION

In the Department's initial submission, dated October 1976, the environmental impacts of hydroelectric developments were discussed according to: (i) reservoir development and operation, and (ii) downstream effects. A section was also included to relate these concerns to Ontario's last remaining, large-scale hydroelectric development possibility, namely, the proposal to develop the power potential of the Albany, Attawapiskat, and Winisk Rivers in northern Ontario. The statements submitted herewith are based mainly upon the information supplied in the first submission, and present some general positions and opinions of the Department.

1.2 HYDROELECTRIC POWER DEVELOPMENTS IN NORTHERN ONTARIO

1.2.1 Overview

(1-1) *Any decision to proceed with hydroelectric power development in Ontario should be made only with a full understanding of potential environmental, social, and economic impacts on the area. Environmental considerations should be incorporated at each stage of planning and development.*

Environmental implications of large-scale hydroelectric power development include the loss of large amounts of land and their associated renewable and nonrenewable resource potential; impacts on indigenous and migratory fish and wildlife through disruptions in habitat; and downstream impacts upon river and coastal zone ecosystems which currently include large numbers of fish and wildlife. Secondary environmental impacts will be generated by the development of transportation networks and other industry which are required to support the construction of large hydro developments or are attracted to the vicinity of the power plants.

Hydroelectric power developments must be assessed and reviewed as parts of integrated and cumulative energy systems, not as single developments on a one by one basis.

1.2.2 Reservoir Effects

(1-2) *A detailed inventory should be made of renewable and nonrenewable resources, and an understanding gained of significant ecological relationships, in areas designated for flooding. Reservoir management plans should, wherever possible, be designed to fit the reservoir into the natural ecosystem of the area.*

The flooding of a large area represents a drastic local change in environmental balances and habitats. In the northern boreal forest, such as the area of proposed hydroelectric development in northern Ontario, there may be a distinct difference in habitat between valley bottom (due to be flooded) and hillside (where displaced valley-bottom fauna must go). There is little specific information on the natural resources or their distribution in the area proposed for development, or the role that these resources and specific habitats play in the environmental systems and economic life of the region as a whole. Any decision to develop the hydro-electric resources for energy export to southern Ontario should be preceded by research or surveys to allow careful consideration of the impact of the changed terrestrial-aquatic balance, the displacement of terrestrial fauna from relatively productive bottom-land to less productive and already populated upland, the loss of marshes and aquatic breeding grounds, and the potential effects of increased human access. The permanent loss of nonrenewable assets, such as mineral deposits and archaeological sites, should be considered, and also the potential new asset of a recreational lake and fishery.

With good management, a headpond storage reservoir can become a productive part of a functioning ecosystem, but operation of the reservoir for energy purposes alone can cause it to become an ecological disaster. Sudden drawdowns to produce power can prevent establishment of a fertile shoreline with vital aquatic plants and prevent fish spawning or breeding of waterfowl. It may be necessary to design the reservoir with perched lagoons for spawning or breeding, or to restrict severely the rate of drawdown during critical periods of the year. The dedication of precious natural valleys to electric power production carries with it the responsibility to manage the artifically changed environment of those valleys for the maximum total natural productivity.

1.2.3 Downstream Effects

(1-3) *As an integral part of hydroelectric power development in northeastern Ontario, steps should be taken to ensure continued productivity of the lower rivers and the estuary and inter-tidal zone that may be affected by such development.*

The lower reaches of the rivers and estuaries, and the coastal zone downstream from the planned development area, is believed to be northeastern Ontario's most important area of renewable natural resources. The productivity of the coastal zone, where fish, migratory birds, and resident fauna populations supply a source of income for some local people, is attributable to a significant degree to the seasonal flushing of nutrients from the interior by natural river flow, as well as to the interaction of saltwater and freshwater in the estuarine environment. Ecosystems have become adjusted to, and dependent upon, the natural seasonal changes. Hydro development would disrupt these natural interactions with, as yet, unknown results on ecosystems and ultimately on human populations. Construction activities and river regulation would also affect indigenous fish populations by impeding fish migration, destroying spawning areas, and altering habitat and food supply. Draining or drowning of marshes could play havoc with migratory and resident waterfowl.

1.2.4 Associated Developments

(1-4) *Included in decisions on hydro power sites should be consideration of the environmental, social, and economic impacts of the infrastructures necessary to support the development site, as well as the impacts of the industrial activity and population growth which such developments will attract.*

The advantages and disadvantages of any site should not be looked at in isolation from impacts of the industrial activity needed to develop the site, i.e., transportation routes, housing, increased industrial capacity in the supporting urban centre, etc. Some aspects of those important factors are discussed in the first submission.

The most significant of the associated impacts would be the provision of increased access to and within the areas as a result of the roads, railroads, and airstrips installed for construction and maintenance purposes. Hunting, physical disturbance through change in habitat (a road with vehicles may disturb feeding patterns enough to cause undernourishment), noise, harassment by aircraft, and the burgeoning of an "instant" and locally unknowledgeable tourist business may do extensive damage to an ecosystem with little surplus energy or resiliency.

1.3 PUMPED STORAGE SYSTEMS

(1-5) *The environmental aspects of storing energy produced in off-peak periods by methods such as pumped storage, to provide additional power during times of high load demand, should be carefully weighted against the environmental aspects of providing expanded or stand-by systems.*

A great deal of Ontario's electric power production capacity is in place to meet peak power demands. Projections for future power demands show a continued high peak characteristic, and much of the planned future generation capacity expansion is to fulfil anticipated higher peak loads. Storage of energy produced during off-peak periods by generating capacity that would otherwise be idle is an alternative way of making available additional power when needed at times of peak load, without incurring the environmental impacts associated with the development of new or larger electric power generating facilities. Where suitable elevated storage sites are available, pumped water storage is an efficient and environmentally manageable method of providing peak power output from sustained average power input.

The environmental impacts of pumped storage are largely local. If the pumped storage reservoirs are small, rapid water level fluctuations preclude fish spawning or healthy aquatic life, but this may be an engineering advantage. In such cases the main environmental effect is on land use. Of the pumped storage schemes proposed by Ontario Hydro, the Matabitchuan River scheme could result in large flow variations in the short stretch of river between the plant and Lake Temiskaming which would reduce fish populations and cause some shoreline damage. However, schemes for pumped storage on the Great Lakes, such as at Delphi Point on Georgian Bay, should have minimal, localized environmental impacts.

Impacts on land consumption could, however, be significant. Trade-offs will have to be made between acceptance of localized environmental impacts and the avoidance of more wide-spread environmental damage. Further, environmental impacts of pumped storage should be compared to alternative ways of coping with peak loads, such as demand management.

1.4 SMALL-SCALE HYDROELECTRIC POWER DEVELOPMENTS

(1-6) *A full environmental impact assessment should be conducted before any small-scale hydroelectric sites are developed, as the environmental impacts of damming or disturbing the flow of small streams, while localized, may be very important to the productivity or environmental quality of the area. Opportunities for combining small-scale power development with sound environmental management or resource development should be considered, and decisions should not be based on electric power costs alone.*

Small-scale hydroelectric developments offer an alternative to expansion of large centralized electricity generation and transmission facilities. While many small-scale sites have been abandoned or passed over in recent years because they could not produce energy as cheaply as large-scale plants, these alternative sources of power will again become increasingly attractive as the costs of thermal generation rise. While some of the massive environmental impacts characteristic of major power development schemes are not likely with small hydroelectric plants, the environmental effects of small plants cannot be considered simply as scaled-down versions of the environmental effects of larger plants. Smaller rivers and their ecosystems are both more variable and more flexible from season to season and year to year; damming or disturbance of flow of a small stream may have a relatively more drastic effect on the immediate area than alteration of a larger river. At the same time, small-scale hydroelectric developments may offer more flexibility, at moderate cost, for implementation of positive environmental management, e.g., combined fish hatcheries or waterfowl rearing. Potential small-scale hydroelectric development schemes should be examined with respect to the optimum siting and design of each installation and related to the opportunities for balanced total development and environmental management of the valley or area. The assessments of costs and benefits should not be based on electric power considerations alone.

1.5 BIBLIOGRAPHY TO SECTION 1

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SECTION 2: FOSSIL FUELS - COAL

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SECTION 2: FOSSIL FUELS - COAL

2.1 COAL EXPLORATION, EXTRACTION, AND TRANSPORT

(2-1) *The environmental impacts of the use of coal as an energy source should be assessed on a comprehensive energy cycle basis. The assessment should take into account the effects of coal exploration, mining, beneficiation, and transportation on the environment, health, and land productivity, even though these impacts may not occur in the region where the energy is to be used.*

The use of coal on an increased scale for the production of electricity in Ontario will have significant implications for environmental quality, not only in Ontario, but also in those places outside the province where coal is mined, upgraded, transported, and stored. In these places, local environmental impacts are likely to be severe. They may include the preemption of land from other productive uses for periods of several years, or permanently, and possible contamination of air and water. Transportation of coal in large quantities poses a significant accident risk, and affects environmental management through changed land values along coal train routes. The conversion of coal to useful energy can be a major source of air and water pollution and can lead to solid waste disposal problems. Consequently, regulations to protect environmental quality in all areas where these activities occur will influence the price and availability of coal for power production and, thus, ultimately, will affect the cost and range of energy supply options available to Ontario [1].

2.2 COAL CONVERSION

(2-2) *Coal gasification or liquefaction techniques transfer some of the environmental impacts from the place of energy use to a centralized conversion plant, where they may be more amenable to efficient and economical environmental control. Decisions on the feasibility and desirability of coal conversion cycles should consider the relative costs and benefits of displaced environmental impacts, and the implications for the environment of other factors such as the use of water resources and changed transportation systems.*

New technologies such as coal gasification and liquefaction are emerging which give promise of making the energy in coal deposits available as a more convenient, concentrated, and environmentally desirable fuel. At present, none of these technologies can make fuel available in quantity for electricity generation in Ontario as cheaply as raw coal. However, increasing environmental and transport costs of using natural coal will make coal gasification and liquefaction an increasingly attractive future option. If pollution control measures were strictly enforced in Ontario and neighbouring provinces and states, there would be a positive incentive toward the evaluation of and investment in environmentally appropriate coal conversion technologies.

The high cost and net energy penalty of coal gasification or liquefaction make it likely that synthetic fuel from coals will be used at first for premium purposes, e.g., residential uses, mobile sources, or at those generation plants where environmental problems are most severe. However, presently feasible technologies appear to be strongly subject to economies of large scale, and it is probable that coal conversion, if undertaken to meet Ontario's energy demands, will not be introduced incrementally, but as a major step involving large power plants whose demand would justify the investment in plant and pipeline. In the decision for such a major step, environmental questions, both at the conversion plant and at the point of use, will figure prominently, and it will be necessary to assign a specific value to environmental factors.

The gas or liquid fractions extracted from the coal would be more amenable than natural coal to the removal of sulphur compounds. The product of such cleaning would probably be elemental sulphur, which could then be available as industrial stock or stockpiled as waste material with small risk of environmental damage. In most cases, the gasified or liquefied products could be transported by pipeline, with less environmental damage than would arise from the transport of coal by rail to central Canada. One must balance the fact that the rail lines are already in place (although additional tracking would probably be required), with most investment already made and some environmental adjustment successfully accomplished, while pipelines would have to be constructed, with consequent new environmental disruption [2, 3].

While at the point of final use, synthetic natural gas is more desirable than coal from the standpoint of pollutants released when these fuels are burned, the actual gasification process produces the same pollutants. The point of pollution is simply changed from the electric power plant (in Ontario) to the coal gasification or liquefaction plant (probably in western Canada). However, it should be both cheaper and environmentally more effective to remove these pollutants at the gasification plant than to control air emissions at each individual generating station.

The above benefits from reduced and transferred pollution would have to be weighed, together with other environmental factors, especially those where the gasification or liquefaction plant is located (probably in the Prairies or foothills). These include the use of large quantities of scarce water resources, which could require river diversions and directly affect irrigation schemes; the effects of thermal and toxic effluent on aquatic biota and migratory birds; and surface disturbance including the transport systems of dedicated mines feeding the conversion plants.

Environmental concerns of coal liquefaction are similar to those of gasification except that the energy efficiency of conversion is somewhat less, resulting in increased water consumption and increased thermal emissions and extracted pollutants for a given amount of useful synthetic fuel energy. Against this must be considered the greater capacity for storage of large amounts of developed, highly concentrated fuel of low environmental risk and its capacity for use in mobile units, with less emission of pollutants than from conventional petroleum fuels.

2.3 COAL TRANSPORTATION AND STORAGE

(2-3) *Environmental impacts should be regarded as an integral component of the costs of the transportation and storage of coal and should be related to the net benefits received from the energy at the point of use.*

(2-4) *Careful assessment should be made of the environmental advantages and disadvantages of using chemical or other binders to control coal dust during storage and transport.*

(2-5) *Coal rail car design and car washing techniques should give greater attention to the control of coal dust in transit and during loading or off-loading.*

(2-6) *Dust suppression methods at coal storage and handling sites should be improved, and monitored regularly, to ensure continued effectiveness.*

(2-7) *In view of the potential environmental advantages, including reduced accident rate, of slurry pipeline compared to rail shipment, and the social consequences of major changes in the mode of transport of bulk commodities, further study of all alternative coal transport methods, with assessment of the net economic and overall environmental aspects, should be carried out and discussed in public before further incremental investment in existing systems is made.*

The present method of bulk shipment of coal to Ontario is by rail from the United States, and from western Canadian coal fields by rail to Thunder Bay with trans-shipment to barge and then by barge down the Great Lakes. With the proposed increase in use of western coal to produce Ontario's electric power, the associated environmental impacts of shipping greater tonnage over this long system will be more severe, although just how severe has not been determined.

With the prospect of increased traffic in coal trains, plans have been put forward to double-track the main CNR line across the prairies. This will consume, in total, a considerable amount of agricultural land and grassland. Other environmental factors of the rail transport of coal relate to the control of dust. Coal transport in open rail cars can release particulates to the air and result in non-fertile particle fallout on nearby lands. The light coal particles in the soil are susceptible to surface washoff, greatly increasing local soil erosion and stream sedimentation. Coal shipments are routinely sprayed with petroleum or chemical "binders" to reduce dust losses; the environmental consequences of this practice are not known.

Although it is not directly an environmental impact, the health consequences of increased transport of coal by rail is a land use concern. At present, level crossing accidents involving coal trains are the most serious health problem of the coal industry in the U.S., greatly exceeding the accidents occurring in coal mining. With increased coal transport, this problem can be expected to grow unless proportionally more investment is made and more land is dedicated to the construction of railways and highways.

An alternative to rail shipment is pipeline transport. While a slurry pipeline offers some environmental benefits in impacts avoided from rail transport, it has its own potential impacts associated with rupture of the pipe, water consumption, water and fines disposal, and land use for dewatering plants. Some coals may need chemical treatment of the slurry to prevent decomposition or excessive disintegration, and the removal of these substances or their oxidation during combustion could cause further problems. Coal-oil slurries may avoid some of these problems, but create others at the de-emulsifying plant. Much more study is warranted of the environmental aspects, including the potential advantages, of coal piping techniques.

The major environmental concerns related to developing enlarged trans-shipment facilities at Thunder Bay include land use requirements, dust and noise problems, and harbour dredging. Many of these concerns would be alleviated to varying degrees or avoided by the adoption of coal gasification, coal liquefaction, and slurry pipeline alternatives, but they may be traded for other concerns.

Shipping the coal down the Great Lakes is not likely to present a significant environmental threat in the event of a shipping accident. However, the possibility of the leaching of toxic substances out of spilled or lost coal over a period of time does exist which could affect fish habitats and spawning grounds.

The soiling of property due to wind blown coal particles during storage and handling (the so-called "windage loss") can be a severe local problem, and specific methods of dust suppression are necessary to keep it under control. There is the potential for dust from these sources to add significantly to the total particulate loading of the atmosphere over a considerable area. The extent to which airborne particles of coal dust can act as vehicles for transport and reaction of other chemicals released by a variety of sources is not known, and needs careful research.

2.4 POWER GENERATION FROM COAL: AIR EMISSIONS

The most serious environmental impacts from the coal energy fuel cycle occur at the power generation stage. The main impacts arise from air emissions and the release of heat to cooling waters. The effects of thermal emissions are discussed in Section 7. The impacts of the long-range transport of air pollutants are discussed in Section 8.

2.4.1 Sulphur Oxide Emissions

(2-8) *Where fossil fuels are used to produce power, the only acceptable solution to emission problems is the prevention of releases of environmentally damaging substances to the environment.*

(2-9) *Flue gas desulphurization technology should be adopted in all future coal-fired power generation stations in Ontario, where other abatement options are not employed.*

There is ample evidence to confirm that natural dispersal of pollutants in the atmosphere is not a satisfactory or acceptable means of preventing damage to the environment by products of combustion from power plants and industrial operations. The use of tall stacks to achieve greater atmospheric dilution and dispersal of pollutants, in order to prevent high pollution concentrations at ground level near the plant, has proven to be, to some degree, self-defeating, for it has resulted in an atmospheric "loading" that has reduced atmospheric and biological resiliency on a regional basis (see Section 8) [4, 5, 6]. The only acceptable method of maintaining environmental quality in southern Ontario and adjacent regions is to prevent pollutants from being introduced into the atmosphere.

There are several options available to keep air pollution from coal combustion within acceptable limits. Most of these relate directly to the sulphur and ash content and the mechanical state of fuel to be burned. General approaches are: (i) to use low sulphur or low ash fuel or to remove sulphur and ash before combustion - by desulphurization, production of synthetic gas, etc.; (ii) to use combustion techniques that absorb the pollutants; and (iii) to remove pollutants from the combustion products. All three approaches have application in Ontario.

In Section 5.2.3.4 of the first submission, atmospheric concentrations of SO_2 in Toronto, Nanticoke, and Sarnia were reviewed relative to the desirable level as specified in the regulations in the Clean Air Act.. It was noted that Ontario Hydro's generating facilities account for most of the Canadian emissions affecting these three cities. In the case of Toronto, the desirable level is now being approached, while in Sarnia present levels exceed the desirable limit. In addition to causing locally elevated levels of SO_2, these point sources contribute, along with other sources in Canada and the U.S.A., to regional or subcontinental pollution problems (see Section 8 on Long-Range Transport).

There are no technological barriers to the removal of sulphur dioxide from flue gas to currently specified levels of concentration. The technology is available and proven in operation to be reliable to the same degree as the rest of the plant.

The removal of sulphur dioxide, to high standards of efficiency, is a daily routine in many Japanese power plants which are generally oil-fired. The deleterious effect of fly ash on the performance of SO_2 cleaning equipment can be avoided by installing ash cleaning equipment, i.e., electrostatic precipitation, ahead of the SO_2 scrubber, though many systems are successfully removing the ash simultaneously. Large units are currently operating in the U.S.A. with high performance and reliability, using both low and high sulphur coal, with the capability of removing 90% or more of the SO_2 burden. Several very large U.S. flue gas desulphurization units have consistently attained reliability and utilization equal to that of the main components of the thermal generating plants. Some of these units are bigger than any currently operating in Canada.

As of December 1976, there were 6,476 MW of generating capability fitted with flue gas desulphurization systems in the U.S. In addition, there are 13,300 MW of additional capacity being fitted with such systems and a further 9,980 MW of capacity which have been arranged for under firm contract. Thus, the total generating capacity, either fitted or in the process of being fitted with flue gas desulphurization equipment, in the U.S., substantially exceeds the total electric power generating capacity from all sources in Ontario. There should be no technical reason why sulphur dioxide removal systems should not be incorporated into all future coal-fired stations. As things presently stand, the SO_2 output from one large Ontario station can exceed the total SO_2 emissions from a large American industrial city.

The Department is currently preparing sulphur oxide guidelines. Flue gas desulphurization is under active consideration as a specified abatement option. There is also the possibility of a Canada-U.S. agreement on transboundary pollution. Any such agreement may be expected to commit Canada and the U.S. to comparable or compatible pollution control practices.

Other options are available for the abatement of sulphur oxide emissions. Fuels of lower sulphur content will, of course, produce less sulphur oxide when burned. Fortunately, considerable reserves of moderately low sulphur coals are present in Canada. However, very low sulphur coals are in restricted supply and can be expected soon to be regarded as a premium fuel. As large electric power generation plants will be able, through sophisticated facilities and technical management, to achieve sulphur dioxide control more effectively and economically than other uses, it can be expected that, in the interests of the best net use of total fuel resources and environmental protection, there will be a restriction on the use of the lowest sulphur premium fuels by large power stations and encouragement of the use of more abundant fuels, with desulphurization or other sulphur control techniques. Other techniques such as washing can be used to reduce substantially the natural sulphur content of many coals. Coal gasification (or liquefaction) are further ways of producing low sulphur fuel (see Section 2.2).

The combustion of coal containing sulphur in a fluidized bed system, containing a sulphur reacting material like limestone, can contain the sulphur within the furnace itself. The principle has been known for decades,but no such unit of power plant size has been built. The drawbacks to the introduction of the technique appear to be initial cost and the need for sophisticated control adjusted to the composition of the fuel feedstock.

Experimental work in the U.S.A. and Britain on fluidized bed combustion indicates that substantial savings in capital and operating costs are possible, both for heat generation and pollution abatement equipment. The capital cost savings are derived mainly from the smaller unit needed to generate a given amount of steam because of the very high furnace heat release rate and the much greater effective heat transfer rate. As the combustion termperature is lower than in open grate or forced air furnaces, the volatization of minerals in the coal is minimized. Coal need not be pulverized, but merely crushed, thereby reducing the cost of coal preparation and reducing dust. The performance of particulate collection equipment is enhanced with large particles. British work has indicated power station size units would be 20% cheaper in capital cost and have annual operating costs 12-16% less for fluidized bed furnaces than for conventional power plants.

It has been calculated that reductions of SO_2 emissions of greater than 90% are feasible by mixing calcium or magnesium compounds with the fluidized material. NO_x reductions of 70% or more are also expected because of the lower temperatures.

The sulphur bearing waste, in the form of a dry solid, should present less of a disposal problem than the sludges associated with lime/limestone processes. There are systems under consideration which would regenerate lime from the residual calcium sulphate, the liberated SO_2 being converted to either acid or elemental sulphur.

The U.S. Energy Research and Development Agency is currently funding a 13 MW pilot fluidized bed plant. This unit will feature a pressurized atmosphere in the combustion space, enabling the flue gas to do useful work in a gas turbine. Such a combined system should have increased overall thermal efficiency, thereby reducing fuel consumption.

A non-pressurized fluidized bed combustion prototype furnace of 30 MW capacity is about to commence operation at a private U.S. utility, using ERDA funding. Several smaller bench scale units are operating in Britain and the U.S.

Because future Ontario coal-fired plants, except at Nanticoke, will be totally new plants and not additions to existing ones, there is an excellent opportunity for Ontario to study in advance and take advantage of these new developments in combustion techniques. It is recommended that the long-term environmental aspects of these techniques be given full and appropriate weight in decisions made.

2.4.2 Nitrogen Oxide Emissions

(2-10) *Increased research is required in the area of the effects of nitrogen oxide emissions and their control.*

Fossil fueled thermal electric generating stations, in general, are significant sources of nitrogen oxides [7]. In Ontario, because of the proportion of hydroelectric and nuclear energy, the contribution by Ontario Hydro to the NO_x load in the atmosphere is proportionately less than is the case in many other parts of the continent. Nevertheless, some 93,044 tons were emitted from power stations in 1976, comprising about one-sixth of the estimated total man-made atmospheric load (most of which comes from automobiles). Most of this is released in urban areas, and NO_x is mainly of concern in urban areas because of the toxic and corrosive qualities of some of the oxides and their derivatives. They are an essential component of the smog that affects populated parts of Ontario at some seasons of the year and which attacks painted, plastic, and some concrete or metal surfaces. The smog may contribute to respiratory diseases or infections. There is evidence that in the presence of other industrial effluents, such as ammonia, airborne nitrogen oxides may activate carcinogenic compounds. Washed from the atmosphere, they contribute to eutrophication of water bodies. Carried to the stratosphere, nitrogen oxides may have an influence on ozone balance. Thus, the release and distribution of nitrogen oxides is of environmental and health concern.

At present, the emission of nitrogen oxides is not readily controlled by the addition of any specific apparatus. Some success in NO_x control has been achieved through such techniques as minimal excess air operation, flue gas recirculation, and staged air admission, among others.

Present techniques of NO_x control are not wholly beneficial. There is evidence that, while oxides of nitrogen may be reduced, there may be simultaneous increases in pollution due to carbon monoxide emissions arising from a reduction in boiler efficiency. This increase in pollution would constitute a local environmental or health hazard. It has also been observed that corrosion of heat transfer surfaces may rapidly increase when NO_x is low. Thus, modifications to reduce NO_x require careful design and control to avoid severe operating penalities. Japanese research into the removal of nitrogen oxides from flue gases shows some promise.

Some countries (Switzerland, Japan) are bringing forward strict legislation to control nitrogen oxides. It is recommended that concerted attention be given to the whole problem of the environmental and economic effects of nitrogen oxides, including the direct and indirect costs, and methods of control. The control of NO_x from electric generation stations is an important part of the problem, but it cannot be assessed from a power generation point of view alone.

2.4.3 Particulate (Ash) Emissions

(2-11) *In view of the significant environmental and health effects associated with particulate emissions, full use of available control technology should be instituted to ensure that objectives for particulate removal levels are realized.*

Bituminous, sub-bituminous, and lignitic coals all contain mineral inclusions, the nature and magnitude of which vary, both in the initial fuel charge and in the amount emitted, depending on the combustion temperature and process and on the ash collection systems. Some of these elements gasify in the furnace and escape in that form. Others may wholly or partly recondense. Most of the gasified elements tend to escape regardless of the furnace design or collector type [8].

In the case of furnaces of the type commonly used in electric power plants in Canada, which use precipitators for ash collection, it appears that, generally, most of the mineral content is retained with the ash. However, since some of the minerals have concentrations measured in hundreds of parts per million, important amounts of mineral elements, nevertheless, escape from the stack. For example, a large power station may consume over 1,500 tons/hour of coal. If an element, for example, fluorine in sub-bituminous coal, is present at 100 ppm, then 0.15 tons of fluorine per hour is entering the furnace. If only

10% escapes with the flue gas, as would be typical for a tangentially-fired furnace, then over 60 tons of fluorine per year is being released to the atmosphere, given normal station operation. Because of the short residence times, the condensing materials tend to concentrate on the smaller particles, since the surface/volume ratio increases with decreasing size. Some elements which can be expected to concentrate on fine particles are: sulphur, mercury, chlorine, fluorine, selenium, lead, molybdenum, nickel, boron, zinc, cadmium, chromium, copper, uranium, arsenic, and tin. Since their concentrations differ widely from coal to coal, and because the firing methods and ash collection devices vary, it is not possible to provide a general answer as to how much of these substances will be released to the environment from electricity production.

The current state of particulate control technology is such that the removal of up to 99% of particulates by the use of electrostatic precipitators is possible. Although, in absolute numbers, the control of particulates may be satisfactory, the remaining emitted particulates are largely in the respirable range and some are radioactive elements and their derivatives. There is evidence that mineral elements of heavy metals are concentrated in these lighter fractions of particulates [9], resulting in concern about possible biological and health effects. It is to be expected that higher efficiencies will be required for electrostatic precipitators, as western coals of low heating value and high ash content come into use. Claims of efficiency of 99.6% for modern units are made, which should enable all but the most inferior coal to be burned within acceptable limits for environmental standards of emissions of particulates. It is essential, however, that legal and monetary incentives be applied to ensure that these efficiencies are achieved in day-in, day-out, year-to-year operation.

2.5 SOLID WASTE DISPOSAL

2.5.1 Groundwater Contamination

(2-12) *In disposing of solid wastes from fossil fuel power generation stations, every precaution should be taken to protect both groundwater and surface water from contamination, either by leachate or runoff.*

Associated with the use of fossil fuels for electrical power generation is the generation of significant quantities of solid and semi-solid residues from combustion and from cleaning of stack gases.

The solid wastes commonly associated with fossil fueled generating stations are bottom ash, slag, fly ash from coal-fired plants, and a variety of chemical slurries from water treatment and conditioning processes. Wet scrubbing of stack emissions, used to reduce the sulphur dioxide content of flue gases, produces a by-product containing sulphur. In some parts of the world, this by-product is sold to offset operating costs. In the United States, the by-product is disposed of by lagooning or stabilization and by land fill.

The disposal of ash and scrubber sludge is a major concern because of the land required and the potential for the leaching of these residues, with subsequent contamination of the ground and surface waters. Possible water pollution sources result from either ponding or land-filling operations. Runoff water or leachate from such sources may contain soluble toxic substances. For example, significant concentrations of arsenic may be present in effluents from fly ash ponds. Excess levels of sulphate or chloride and compounds that lead to high oxygen demand may also be contained in the leachate.

Given a particular hydrogeological setting, and climatic conditions conducive to leachate generation, a significant environmental impact from contaminant loadings to receiving waters is possible. It seems clear that leaching and runoff must be minimized and controlled to assure that groundwater or stream pollution does not occur.

2.5.2 Use of Combustion Residues

(2-13) *Development and demonstration of technology for extraction of valuable materials from combustion residues of fossil-fired plants would have significant environmental benefits.*

(2-14) *The development of markets to increase the beneficial use of combustion residues from fossil fuel plants should be encouraged.*

Wide variations exist in the chemical composition of fossil fuels from different sources of supply. Elements such as vanadium, nickel, calcium, magnesium, manganese, iron, and copper are usually present in the ash in varying quantities, along with the prevailing carbon and silicon component. These elements all have valuable industrial uses. The recycling of these elements will reduce the environmental impact of mining and production of new quantities of minerals containing them. Difficulties in making use of these presently waste substances are as much managerial and attitudinal as they are economic and technological. It may be necessary for the utilities to adopt an accounting system broader than that concerned with energy production alone.

Another potential use of ash, which has been utilized in European countries to a considerable extent, is as a basic construction material. Power plant ash and "cinder" have been used in cement as an aggregate for cold asphalt, as a component in lightweight concrete products and as a road base aggregate. These are low value commodities, and the use of ash for such puposes is, in many cases, justified as part of the cost of waste disposal.

Technology is well advanced for the extraction of some materials, such as vanadium and carbon black, from those residues where concentrations are sufficiently high. Recovery of these elements from diluted ash, where the concentrations are lower, is more difficult. Technology development is progressing in this area, as well as for the other elements noted above.

Development of markets for combustion residues in Canada has been limited. A long-term effort is required to demonstrate reliability of supply and to enable users to accommodate variations in concentration and to convince designers to utilize such materials more widely in the construction industry.

The Department is currently investigating the feasibility of establishing a national industrial waste exchange market to facilitate the reuse of waste materials such as combustion ash [10].

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SECTION 3: FOSSIL FUELS - OIL AND NATURAL GAS

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SECTION 3: FOSSIL FUELS - OIL AND NATURAL GAS

3.1 OVERVIEW

(3-1) *Environmental impacts throughout the total energy cycle, from exploration and extraction through power generation and waste disposal, must be considered in assessing the use of oil and natural gas to produce electricity in Ontario. All environmental impacts should be considered, whether they occur inside or outside Ontario's provincial boundaries.*

Because of increasing cost and scarcity, oil and natural gas can be expected to play a relatively smaller role in the production of electric power in Ontario in the future. Although the use of these fuels to generate electricity will be small in relative terms, significant environmental impacts or risks will continue to occur both inside and outside Ontario. Potential impacts occurring in Ontario are associated with transportation and conversion of oil and natural gas, as well as waste disposal. Impacts outside Ontario are associated with exploration, extraction, and transportation of oil and natural gas, of which a part is eventually used to generate electricity. Whereas the environmental effects within Ontario are a direct cost of electricity generation in Ontario, those occurring in other regions as a consequence of Ontario energy demand can have potentially significant indirect consequences for the electrical supply system and the natural environment in Ontario.

Environmental regulations in other jurisdictions regarding extraction, exploration, upgrading, and transportation of oil and natural gas will directly affect the cost and availability of fuel for generation of electricity and, consequently, will have an effect upon the natural environment in Ontario. Increasing cost or reduced availability of these fuels as a result of environmental restrictions, for example, would encourage the substitution of electric power in place of oil and natural gas for space heating. It would also encourage the substitution of coal, uranium, and hydro as energy sources for electric power production. Thus, the environmental problems of oil and gas production and transport in, say, Alberta or on the high seas will affect both the demand for electric power and the means used to generate the power in Ontario. Both of these effects will, in turn, affect the environment of Ontario.

Provision of supplies of oil and natural gas to Ontario will pose special environmental problems in frontier areas. This is the case, particularly for energy exploration and transportation activities in the Arctic, but also for activities in northern Ontario, western Canada, the Great Lakes, and the continental shelf. Environmental considerations may necessitate relocation and rerouting, and the adoption of special design, timing or method of construction, and operational procedures. They may also require that the operator or customer accept responsibility for rehabilitation of disturbed land.

Environmental protection measures may affect the cost and availability of oil and gas for electrical power production. To ensure adequate environmental protection, together with minimum costs and restrictions to the availability of fuels, environmental research, assessment, and design should be an integral component of large-scale development planning. In environmentally vulnerable regions, environmental factors may be decisive. The natural components of the sensitive Arctic environment, their dynamic interactions and interdependencies, and their interrelationships with environmental processes on a continental and global scale are not documented or understood to a degree sufficient to ensure that northern energy developments can take place without serious and irreversible environmental impacts [1]. These impacts may not only affect the biological life and productivity of Arctic and sub-Arctic regions, they may also destroy the physical integrity and economic feasibility of the energy production and transportation system itself. More research is required, in advance of extensive further development, to ensure that increased energy supplies can be discovered, produced, and delivered from frontier areas without unacceptable or prohibitive environmental costs or constraints.

3.2 TRANSPORT OF OIL AND NATURAL GAS TO ONTARIO

Transportation of oil and natural gas also may have serious environmental implications. The statistical risk of a spill from an oil tanker accident is substantially greater than that from a well blowout. As the transportation of oil out of the Arctic is not likely to take place for some years, there is some lead time available to develop improved technology and information and management systems, and also to develop and implement the necessary contingency plans. Toward this end, the Arctic Oil Ship Countermeasures Development Program is to be inititated by the federal government this year.

The bulk transport of oil on the Great Lakes is also of environmental concern, particularly with the possibility of increased oil tanker traffic transporting foreign crude and possibly crude from Arctic and continental shelf sources. The potential for a major oil spill is always present. A spill could have serious consequences. The Great Lakes are the largest composite body of fresh water in the world and a source of water supply to approximately 30 million people. A major spill could have devastating effects on fisheries, wildlife, recreational areas, and water supplies.

There has been significant progress in Canada's capability to prevent and deal with oil spills. However, the current state-of-the-art of oil spill clean-up cannot guarantee a satisfactory response to spills under many conditions, particularly those occurring in winter conditions or Arctic waters. The emphasis, therefore, must be on spill prevention.

Pipeline construction and operation through fragile Arctic and semi-Arctic ecosystems also poses risks to the natural environment [2, 3, 4]. Construction activities include the building and use of access roads and river crossings, and the mining of scarce granular materials for pipeline bedding, as well as the construction of the pipeline itself. These activites could cause considerable disruption to fish spawning activities, migration patterns, bird nesting areas, wildlife habitats, and the lifestyle of native people. An environmental concern with pipeline operation is the risk of a pipeline rupture, due to unstable foundations, faulty construction, or anti-social action. The spill from such a rupture could have serious effects on local aquatic or land-based ecosystems.

3.3 POWER GENERATION

(3-2) *Steps should be taken to reduce sulphur emissions from power generating plants using residual oil. This could be achieved by expanding desulphurization facilities in order to produce low sulphur residual oil for burning in all generating stations.*

(3-3) *The efficiency of removal of particulates from oil-fired boilers by electrostatic precipitators should be at least equivalent to the efficiency of removal of particulates from coal-fired boilers by the same means.*

Residual oil retains, in concentrated form, the sulphur and ash found in the original crude during the refining process. Residual oil burned in Ontario typically contains 2-3% sulphur and less than 0.10% ash. Consequently, burning of residual oil contributes to regional production of sulphur oxides and to the long-range transport of airborne contaminants. By contrast, gas turbine and boiler "lighting-off" fuel, being a refined grade, carries only about 0.2-0.8% sulphur and virtually no ash. While the technology exists to remove sulphur from residual oil, the facilities for desulphurization do not exist on a sufficiently large scale to permit the use of low sulphur residual oil at all generating stations.

In the absence of competing uses, it would be advantageous, from an environmental point of view, to use natural gas for power generation since the amount of sulphur oxides and particulates emitted would be substantially lower than from either residual oil or coal [5]. However, the amount of nitrogen oxides emitted would be almost comparable to those from residual fuel oil for a given size and type of boiler [6].

In comparing residual oil to coal as a fuel for thermal power production, there would be no advantage in using oil with respect to the emission of sulphur oxides. However, the emissions of particulates would be substantially reduced if the physical and chemical properties were such that the removal efficiency of these particulates in electrostatic precipatators was equivalent to that for removal of particulates generated in coal-fired boilers. An essential part of each particulate removal operation should be the monitoring and sampling of the released discharge plume.

3.4 WASTE DISPOSAL

As both gas and oil have a substantially lower ash content than coal, the amount of ash formation and disposal would be significantly lower. In the light of comments in Section 2 on the environmental problems associated with landfilling of solid waste, both gas and residual oil show a marked advantage over coal in this regard.

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SECTION 4: SOLID WASTE MATERIALS

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SECTION 4: SOLID WASTE MATERIALS

4.1 POTENTIAL SUPPLY AND FEASIBILITY

(4-1) *The use of municipal and industrial solid wastes for power production and process heat offers potential environmental benefits. These benefits may be direct, through reduced requirements for land for sanitary landfill and lessened problems of contaminated groundwater from waste disposal sites, or indirect, through avoided environmental impacts from the production and transport of primary fossil fuels and uranium. Both direct and indirect environmental benefits and costs should be considered when determining the economic feasibility of solid waste utilization.*

In Section 5.3 of the first submission, it was noted that, if all solid waste from large Ontario cities were utilized to produce electricity, this resource could provide approximately 4% of Ontario's 1974 electricity consumption. However, because of collection and transportation costs, and social inconvenience, the amount of energy recoverable in practice is considerably less.

A recent North American development in waste utilization technology has been to pretreat municipal waste by shredding, and to burn it in suspension in conjunction with pulverized coal in electrical generating stations (modifications to the Lakeview Generating Station to accomplish this are presently underway). It has been found that up to 20% of the boiler heat supply can be provided from waste without causing major problems [1, 2]. Other potential users of the municipal solid wastes as an energy source are the pulp and paper industry [3] and the cement manufacturing industry.

Wood and wood wastes from all stages of the forestry industry also represent a source of energy to produce steam for process and electricity generation purposes for use by pulp mills. Because of wood's relatively low pollution composition, this form of energy is attractive from an environmental point of view [4].

4.2 UTILIZATION OF WASTE MATERIALS: RECYCLING VS. POWER PRODUCTION

(4-2) *Careful consideration must be given to the environmental and net energy advantages of recycling or reuse before commitments are made to burn wastes for energy production.*

(4-3) *In promoting the use of waste materials for energy production, care must be taken to avoid a commercial commitment to, or a vested interest in, the production of solid waste materials.*

Municipal, industrial, and commercial wastes can be used to produce energy directly through burning, They can also be used to reduce energy requirements in industrial production processes through the substitution of recycled materials for virgin resources. For example, energy savings in the production process, when using recycled vs. virgin materials, amount to 34% in the case of newsprint, 30% in the case of steel, and 96% in the case of aluminum [5]. Utilizing recycled materials as a substitute for virgin materials simultaneously reduces environmental impacts associated with mining, processing, and transportation of raw materials. For example, paper recycling (rather than all paper being used only once) reduces the need for new paper and thus results in smaller environmental effects associated with tree harvesting and pulp mills. In addition, the use of organic municipal or industrial wastes as natural fertilizers and humus could help to close the food chain cycle and reduce the need for chemical fertilizers, with their adverse environmental effects.

Careful consideration must be given, therefore, to the environmental benefits derived from recycling as opposed to burning solid waste. Care must also be taken to avoid incentives for the creation of waste. Arrangements to recover energy or useful materials from waste should not obscure the fact that the most effective way to conserve energy and other resources, and to protect the environment, is to minimize waste production in the first place.

4.3 COLLECTION AND UPGRADING OF WASTE MATERIAL

(4-4) *Where production of waste is unavoidable, incentives should be provided to increase the opportunity for profitable use of waste materials. Various collection, treatment, and marketing mechanisms may be required to meet the demand for wastes, including separation at source and central processing facilities. Research and development of these mechanisms, together with research into the social and psychological factors that may be constraints on the use of solid wastes, should be encouraged.*

Environmental implications associated with the collection of waste materials for energy production purposes are, in general, no different from, for example, collecting waste materials for disposal at landfill sites, except for the local effects of differing transportation routes and the advantages of initial sorting, if it can be achieved, at the point of waste generation. Currently, experiments in sorting wastes, such as used paper, at source, are being carried out within the Federal Government.

4.4 POWER GENERATION AND SOLID WASTE DISPOSAL

(4-5) *In general, incineration of solid waste causes more air pollution, but less groundwater pollution and fewer solid waste management problems, if compared to other major options for waste disposal such as landfill.*

(4-6) *Airborne emissions associated with incineration of municipal solid wastes are roughly comparable in amount and concentration to those resulting from use of fossil fuels with respect to particulates, NO_x and CO; while chloride emissions are higher, and SO_2 emissions are considerably lower. Proper control technology can reduce particulate and chloride emissions to acceptable levels.*

(4-7) *The environmental monitoring program proposed for the Lakeview Generating Station when the refuse-derived fuels system is operating should be supported and, to the extent feasible, should include identification of the fate and effect of emitted substances.*

Average Canadian municipal solid waste has a very low sulphur content. Thus, the substitution of solid waste for other fuels would reduce the amount of SO_2 emitted to the atmosphere per kwh of electricity generated. Proper control, such as electrostatic precipitators and scrubbers, can reduce particulate matter and chloride emissions to acceptable levels.

The program to use municipal wastes as part of the fuel mix at the Lakeview Generating Station gives Ontario Hydro an excellent opportunity to obtain reliable and comprehensive information on the impacts on the environment of using municipal wastes for electric power generation. The proposed emissions monitoring program should be vigorously pursued and extended to include comparison of emissions with the composition of the fuel, and determination of the pathways and fate of pollutants produced. Tests at St. Louis showed that, compared to burning coal alone, burning pulverized municipal refuse in combination with coal (at up to 27% heat input from refuse) resulted in a 17% increase in chloride emissions, but did not significantly affect NO_x or CO emissions. In addition, the efficiency of the electrostatic precipitators was reduced, resulting in increased particulate emissions [6].

In recent studies completed by DFE, it has been found that PCB compounds are released to the atmosphere in very small quantities from municipal incinerators. Steps are being taken to eliminate PCB from industrial use and thus from wastes in the next few years, and known PCB is carefully disposed of (see Section 11). All precautions should be taken to prevent PCB getting into municipal waste. However, because the temperature is higher and the residence time for fuel is longer in the furnaces of large electrical generation power plants than in most "waste disposal" incinerators, any PCB present in the municipal waste has a greater chance of being totally destroyed if solid wastes are used for power generation. Thus, it is considered that there is only a remote possibility that thermal generating stations could become a source of PCB emissions by burning refuse-derived fuel.

The burning of refuse-derived fuel, in itself, produces solid wastes, which are of no further use as fuel and are usually disposed of in sanitary landfill sites. The reduction of waste volume of 95% during combustion in a power plant greatly reduces the amount of land required for municipal waste disposal and is, in itself, a powerful argument for controlled power plant incineration, quite aside from the energy produced. The leachate from refuse-derived fuel ash is characteristically high in soluble salts and alkalis, and thus must be controlled to avoid contamination of groundwater.

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SECTION 5: RENEWABLE ENERGY RESOURCES

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SECTION 5: RENEWABLE ENERGY RESOURCES

5.1 OVERVIEW

(5-1) *Renewable energy resources can be used either to generate electricity or to substitute for the generation of electricity. While no energy supply technology is without environmental impact, renewable energy resources can provide energy while avoiding some of the environmental impacts associated with other energy technologies. Research into the technological, economic, environmental, and net energy aspects of the utilization of renewable energy resources should receive substantial support.*

(5-2) *Examination of the environmental impacts of energy supply systems, including the use of renewable energy sources, should be comprehensive and include the indirect environmental implications arising from the impact of each system on demographic patterns and on the nature and location of industrial activity.*

Renewable energy resources--solar, wind, and biomass--can be used to supply human needs. It is, as yet, very difficult to compare the technical, economic, environmental, and social aspects of increased or widespread use of these supply options. Most of the proposed systems, such as wind energy production by turbines and home space heating by solar flat plate collectors, have not yet been established on a sufficient scale for economic feasibility to be determined. Some techniques, such as utilization of wave energy, have not yet been proven to be technically practical as a means for producing significant amounts of power in Canada. The environmental acceptability of any of these systems if applied in Canada has not yet received thorough investigation.

Environmental impacts associated with renewable energy systems are of two kinds--direct impacts associated with the deployment and operation of the renewable energy system itself and indirect impacts associated with the processing of materials required to manufacture, construct, and operate renewable energy systems [1]. While all energy supply technologies require material inputs and generate indirect environment impacts, for renewable resources, the magnitude of these impacts is generally more significant relative to the scale of environmental impacts associated with the total energy production cycle than it is for conventional thermal energy systems. A detailed discussion of the direct and indirect impacts of solar and wind energy is contained in a supporting paper that is being submitted separately to the Commission.

The renewable energy production systems which, at present, appear to be promising for implementation in Ontario, and the prime purposes to which they may be put, are [2, 3].

a) space and water heating--solar flat plate collectors;
b) on-site residential or industrial electric supply (production at point of use)--photovoltaic cells, wind turbines; and
c) centralized generating stations--solar photovoltaic, solar thermal, wind turbines, and forest biomass.

It should be noted that this discussion of renewable energy technologies considers only solar, wind, and biomass energy, and does not include hydro-electricity (Section 1), which is the most used and highly developed of all "renewable" energy systems.

5.2 SOLAR AND WIND ENERGY

5.2.1 Nature of Environmental Impacts

(5-3) *Use of solar and wind energy can provide environmental benefits in terms of avoided environmental damage associated with the activities necessary for the production of energy from fossil fuel and uranium, and should receive substantial support in energy research and development programs.*

(5-4) *Research is needed to improve upon current methods of comparing different energy alternatives with respect to their resource consumption and environmental impacts. Where possible, environmental impacts should be quantified by relating to the site specificity of installation and to the possible rates of implementation.*

It is apparent that many information gaps exist in the knowledge base necessary for assessing and comparing the environmental implications of different energy production alternatives. In some cases, the environmental impacts cannot be assessed totally because the technology is still evolving very rapidly. In other instances, there has not been enough effort directed to the quantification of environmental impacts. Furthermore, even if a complete accounting of these environmental implications were possible, there exists no satisfactory methodology for comparing impacts of a different nature, such as land use impacts vs. biological damage resulting from sulphur dioxide emissions. Yet, in the end, such comparisons are necessary to make well informed, intelligent choices between different methods of supplying future energy needs.

In general, environmental impacts associated with renewable energy systems arise from materials production required to support manufacturing and capital construction, and from space and site requirements for the system itself. Once a solar or wind energy system is constructed, there is relatively little environmental damage associated with annual operation (with the possible exception of biomass utilization). For instance, the amount of copper required in manufacturing solar space and water heating equipment for 10,000 single-family dwellings would be about 0.2% of Canada's 1976 copper production. The production of this material alone would consume a significant amount of fossil fuel energy and electricity. Significantly large quantities of other materials could also be required during manufacturing and construction, but operational requirements would be almost nil [4].

Although evidence is not completely satisfactory, it appears that the pollution emitted in manufacturing (exclusive of mining and mineral processing) solar flat plate panels is of an order of magnitude similar to the pollution resulting from two to four years' operation of a fossil fuel plant capable of supplying a similar amount of energy. Thus, on environmental grounds alone, one may be tempted to conclude that a solar heating system is initially polluting, but is environmentally attractive over its operating life, although such a conclusion may be premature.

Wind turbine systems generally consume fewer resources and incur less pollution in the manufacturing process than other renewable energy alternatives. Associated with wind turbine systems are rather demanding siting requirments for the turbine itself, environmental impacts and space requirements for energy storage systems, and noise and bird kills associated with turbine operation.

Materials requirements and associated energy requirements should be examined for each renewable resource option. An energy alternative which consumes more resources than others in producing the same amount of energy would likely have large environmental and resource management implications. It is often believed that renewable energy alternatives consume more "natural" or primary energy than conventional alternatives to produce equally useful energy output. However, a comparison of net energy efficiency among alternatives has not been possible because of the absence of reliable data on renewable energy alternatives.

5.2.2 Research, Development, and Demonstration

5.2.2.1 Solar Space and Water Heating

(5-5) *Current research efforts and demonstration projects on solar heating systems should be continued and expanded. Further research should address the operating problems of corrosion, leakage, and freezing. Research on annual heat storage systems should be expanded.*

The use of solar energy for space and water heating for residential dwellings, and for low grade heat in industrial applications, appears to have a high potential for implementation in Canada in the near future. It is reported to be nearing economic feasibility for single-family dwellings, and may be even more economically attractive for multiple-family dwellings [3]. Presently, it appears that mixed conventional and solar heating systems, utilizing short-term heat storage to supply only a portion of the heat load, have an economic advantage over systems which utilize annual heat storage to supply all the heating load, because of the capital expense and design problems of the large energy storage volume needed for annual systems. While the use of solar heating for these purposes does not directly contribute to electrical power production, it is an important energy source since it reduces electrical power demand and increases thermal efficiency by saving electrical energy for high grade uses. In contributing to reductions in fossil fuel and/or electricity consumption, solar energy can provide benefits in terms of avoided environmental damage, while generating few serious environmental impacts itself.

The mixture of solar and "conventional" heating systems, as well as other system characteristics such as the size and specification of heat storage units, should be optimized from an environmental point of view. The mix of a 50% solar and 50% fossil fuel system assumed in the supporting paper is not necessarily the most environmentally appropriate.

5.2.2.2 Photovoltaic Cells

(5-6) *The environmental and economic implications of utilizing photovoltaic cells at residential dwellings or industrial locations, as well as in a centralized generating site, should be assessed.*

The cost of photovoltaic cells must be reduced as much as ten to one hundred times their present cost in order for them to be economically competitive with presently used sources of electricity. Some optimism has been expressed that such large cost reductions are possible in the near future. It appears there are no significant economies of scale for photovoltaic power plants; thus, many advantages of decentralized power production may be realized[5, 6, 7, 8]. Electricity from photovoltaic cells is "quiet" and subject to precise control, unlike that from other renewable sources such as the wind, where control of phase and voltage is a problem.

The utilization of photovoltaic cells should not result in very significant on-site impacts, although considerable space and aesthetic implications could be involved. Since the engineering technology of photovoltaic electricity generation is still rather uncertain, it is difficult to predict with accuracy the environmental implications of large-scale or widespread application. Waste disposal or pollution problems could result from the use of such substances as cadmium, arsenic, or selenium in the cells [9].

5.2.2.3 Wind Turbines

(5-7) *It is recommended that further research, development, and testing of wind turbines be carried out. The environmental implications, especially with regard to birds, safety, and noise should be studied.*

Studies indicate that wind turbines may, at present, be economically advantageous in some remote communities that rely on diesel generators or do not have electricity [10]. However, neither large wind turbines for centralized electric generation nor small turbines for individual home use are competitive in cost nor can they compare in reliability with conventional electricity in the area of Ontario presently served by the central grid.

Advanced designs of wind machines for electricity production have recently been developed, but rigorous testing has been limited. The theoretical potential for increased efficiency in extracting energy from moving air is moderate. Advances are needed most in design for low-speed start-up or over-speed protection, in icing protection, in power stabilization methods, in size optimization, and in methods of electrical energy quality control. In addition, the selection of an optimum specific location for a wind turbine, to take best advantage of prevailing and storm winds, is still an art rather than a science. Techniques for modifying the landscape or turbine structure to enhance the available energy within the turbine disc are still at the trial and error stage. Any of these factors could have environmental implications.

The land use and aesthetic implications of wind turbines, including noise problems, could be considerable, but will be very site specific. The climatic impacts are likely negligible. In some places, bird kills have been a serious problem with existing windmills; research may be needed on methods of protection or bird diversion. It so happens that at some places where wind power may be most practical in Ontario, such as at communities along the Hudson Bay and James Bay shore, bird strike problems may be severe.

5.2.2.4 Solar Thermal Electric Generation

There appears to be little or no potential for, or likelihood of, the production of electricity from centralized solar-powered thermal generators in Ontario.

5.3 WOOD AND OTHER BIOMASS

5.3.1 Ontario's Forest Biomass Potential

(5-8) *The production of methanol or other liquid or gaseous fuels from wood should be given serious consideration as a potentially important, domestically produced, substitute for increasingly scarce fossil fuels.*

(5-9) *Research should be undertaken to establish the environmental implications of the "energy forest" concept and to develop resource management methods that will maintain environmental quality and ensure long-term sustained yield.*

Ontario's forests have substantial potential as an energy source. To provide information on the adequacy of forest resources for providing raw material for liquid fuels, and on the economics of using forests and wastes from forest industries to produce energy, the Department of Fisheries and Environment is tabling with the Commission reports of two recent studies:

1) Inter-Group Consulting Economists Ltd., "Economic Pre-Feasibility Study: Large-Scale, Methanol Fuel Production from Surplus Canadian Forest Biomass" (study prepared for Fisheries and Environment Canada), 1976.

2) A. Carlisle, "The Utilization of Forest Biomass and Forest Industry Wastes for the Production and Conservation of Energy" (based on discussions in a Canadian Forestry Service Workshop), Petawawa Forest Experiment Station, Chalk River, Ontario, 1976.

It must be emphasized that these are not definitive studies, nor are their conclusions endorsed by the Department. However, they do show that the potential for Ontario's forests to produce fuels that could, in part, fill the place occupied by liquid and gaseous fossil fuels, and on a continuous harvest basis, is very real. We have by no means exhausted our options.

The question of how large a contribution forest resources can make to the supply of energy in Ontario cannot be answered with an estimate of available quantities. Unlike energy supplied from deposits of nonrenewable resources (where the reserves may be looked at as a stock concept), energy from biomass is a question of annual or periodic yield (a flow concept). Little information is as yet available on the economic, environmental, and technological factors that will determine the sustainable practical "flows" of energy from the forest.

Forest biomass production may be characterized as an input/output system. If Ontario's forest lands continue to be managed on an "extensive" basis for timber production, i.e., with a relatively low level of inputs expended over a large land base, then the potential output or availability of forest biomass for energy or other purposes may be estimated as follows [11, 12]:

- Current nonutilized logging residues	5.084 (10^6 tons)
- Current nonutilized mill residues	.748
- Utilized roundwood	2.312
(a) estimated associated mill residue	.185
(b) estimated associated logging residues	1.295
	9.624 (10^6 tons)

Under existing technologies, this output could supply fuel for 50 power stations of 50 MW capacity each. Alternatively, it could support annual production of 4.375 million tons (about 1 billion gallons) of methanol.

If an intensive "energy forest" approach were taken, it is estimated that on 10% of Ontario's presently exploitable forest land, under carefully tended short-rotation management, three or four times the above amount could be provided [13]. This amount would be enough for perhaps 10,000 MW of installed generating capacity, or for the production of 15-20 million tons (4 billion gallons) of methanol per annum.

The "energy forest" concept poses a number of problems in terms of forest management and environment degradation, but the problems are not insurmountable. Perhaps the main initial obstacle is achievement of a change in attitude about forests and their management.

The Inter-Group Report referred to above analyzes the economics of converting surplus forest biomass to methanol on the basis of present and estimated costs. Work is now in progress to develop a long-range plan for a more complete evaluation and, if feasibility is established, for development of this technology. Large volumes of methanol produced from forest biomass could be blended with gasoline as a motor fuel, reducing the need for imported fuel and/or reducing the pressure to develop frontier oil resources, with their serious environmental impacts. The process uses resources which are now surplus, and which otherwise do not contribute directly to the economy. The concept of waste avoidance and full, but sustained, use of renewable resources is particularly attractive in an environmental context. It should be noted that the production of liquid fuels from Ontario's resources to meet Ontario's energy demands places the onus for environmental management on Ontario, rather than posing a threat to the environment of frontier regions or of oceans remote from Ontario.

The techniques for production of liquid or gaseous fuels can also be applied to other biomass, such as agricultural waste (straw, chaff, etc.), as well as to some solid wastes and to coal. The quality and reliability of supply, problems of collection and seasonal variation, and the effect on agricultural productivity of using agricultural wastes for energy production requires further study. The liquefaction of coal has been discussed earlier (Section 2).

A plant for production of methanol or methane from biomass would produce some environmental problems, different in detail, but similar in severity to those posed by petroleum refineries. On the whole, however, there appear to be fewer toxic residues from Ontario coniferous wood reduction and refining than from the use of petroleum or coal.

Perhaps more significant from an environmental point of view would be the potential disruptions of the forest ecosystem by intensive wood harvesting. A "Biomass Forest" or "Energy Forest" would be a short-rotation (5-10 years) forest. Whole trees would be consumed, leaving little litter to decompose and maintain soil quality. This could pose problems of nutrient reduction, loss of minerals, deprivation of soil organisms, and some changes in the number and variety of wildlife species the forest may support. These concerns will be assessed as part of the future work on the feasibility of the methanol process.

In some parts of Europe and Asia, intensive silviculture has been practiced for centuries.

5.3.2 Thermal Energy Production

(5-10) *The economic feasibility and environmental aspects of the use of wood as a substitute for fossil fuels to produce thermal energy for the production of electric power, process heat, and space heat should be re-examined in the light of current energy and environmental considerations, and the advances in silviculture and forest management.*

The economic feasibility of wood-based thermal power seems limited at present, as it is more expensive than oil-based thermal power, even in remote locations where wood is readily available. In part, this is because of passive approaches to the management of woodlots and forest for fuel uses. The situation is changing because of the increasing cost of energy and improved tree breeding and harvesting techniques.

The environmental impact of wood-fired thermal plants would be similar to coal-fired plants, except that both the sulphur dioxide and ash problems would be less for wood-fired units. Wood ash is of some value when used directly as a fertilizer, but the loss of the most important ingredient--nitrogen--limits its usefulness. Some light metals and alkalis are concentrated in the ash, but contamination of water supplies from wood ash deposits is not a severe threat.

The most important present and potential users of wood for heat are the forest industries themselves, which can use their own wastes to generate process heat. Wood can also be burned for domestic purposes. Most homes in Ontario can only use this option to a limited extent, if at all, without expensive "retrofitting". The additional household labour to maintain heat in a house heated by wood, while not great, would be a burden to families accustomed to a switch and a thermostat. However, recently, there have been dramatic increases in the efficiency of stoves and fireplaces, and there could be a substantial expansion in the use of wood for domestic heating, although it is unlikely to serve more than a minor portion of the total need for space heat.

5.3.3 Animal Fodder

(5-11) *The use of wood to produce animal fodder should be investigated as a means of reducing the requirements that other foods place on non-renewable energy sources.*

In a pure sense, feeding animals is capturing energy. Wood can be processed to separate the lignin from the cellulose, thus making the cellulose digestible to ruminants. Similarly, agricultural biomass such as straw and bagasse can be broken down. Also, tree foliage can be used as fodder, usually with less treatment.

At present, these methods of producing edible food from trees are costly and the products are not competitive with forage and grains. The processes also use energy, although perhaps less fossil fuel energy than present agriculture. However, there is considerable potential for increases in efficiency in this area. In view of the present inefficiency of using farmland to grow grain to produce animal protein, these processes might have agricultural land conservation value, as well as energy conservation value, in avoiding the high energy costs associated with fertilization and transportation in modern agriculture. Planning for the future use of energy resources should take into account these developments.

5.3.4 Role of Wood Products in Energy Conservation

(5-12) *Wood products can be used as structural materials and as insulation, substituting for more energy intensive materials.*

The substitution of wood for more energy intensive materials can provide substantial energy savings with corresponding environmental benefits.

Wood products can be used as structural materials, insulation, furniture, and other consumer goods. In many of these uses, wood competes directly with metal products and plastics, both of which require large amounts of energy in their manufacture. Wood has been gradually displaced from these uses over a period of falling relative energy costs. However, with rapidly increasing energy prices and intense competition for scarce energy supplies, wood can be expected again to be more widely used in these applications.

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PART II

NUCLEAR ENERGY FOR ELECTRIC POWER PRODUCTION

SECTION 6: NUCLEAR POWER

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SECTION 6: NUCLEAR POWER

6.1 OVERVIEW

(6-1) *Environmental impacts of nuclear power production must be assessed on a comprehensive basis, taking into account the potential impacts of the entire nuclear fuel cycle, and ancillary activities such as heavy water production, on both current and future generations. The assessment should cover aspects of the nuclear fuel cycle not currently in operation in Canada, such as fuel recycling and long-term waste disposal. Because environmental impacts are related to the scale of development, analysis of single facilities is inadequate. Impacts of nuclear power production must be examined on a system wide basis, including their influence on the location and concentration of population, economic activity, and the production of effluents.*

(6-2) *Assessment of the environmental impacts of nuclear energy should be made in the context of a consistent evaluation of the environmental impacts of all types of energy supply options, including renewable energy resources and conservation.*

(6-3) *Research programs aimed at increasing knowledge with respect to the behaviour and effects of radioactivity on the Canadian environment and ecological systems should be supported. This would include a comprehensive program for monitoring radioactive materials in the environment.*

(6-4) *In order to contribute to assessment of the risks and benefits associated with nuclear power production, information should be assembled on the potential environmental consequences of a wide range of nonroutine events that might affect the operation of a CANDU reactor.*

(6-5) *Risks to the environment from both the present operation of nuclear facilities and from long-term management of radioactive wastes should be minimized.*

(6-6) *Important nonradioactive effluents associated with nuclear power production include toxic hydrogen sulphide associated with the production of heavy water, and waste heat resulting from reactor operation. Hydrogen sulphide poses a risk of severe damage to the environment in the event of an accidental release. Waste heat from power production, where large centralized stations are involved, is sufficient to cause local environmental damage, but also may present opportunities for beneficial uses.*

(6-7) *Research is required into those aspects of the nuclear fuel cycle, both planned and currently operational, for which the environmental aspects are not fully understood. Areas of particular concern for research are, in order of immediacy:*

1) *fuel reprocessing;*
2) *high level waste disposal;*
3) *uranium mining and milling wastes;*
4) *radioactive discharges from CANDU reactors; and*
5) *maximum radiation exposure limits.*

The Department of Fisheries and Environment is concerned with the environmental impacts, both radioactive and nonradioactive, of all phases of the nuclear fuel cycle. Thus, it is concerned with all activities connected with the production of nuclear power, from exploration and development of uranium supplies to radioactive waste management, including the production of heavy water, and with their effects on the environment, whether arising from the routine operation of nuclear facilities or from accidental events.

The primary concern of the people of Canada regarding the development of nuclear power is the risk to human health from the discharge of radioactivity to the environment.

Radioactive effluents are released to the environment at a number of stages of the nuclear fuel cycle. The critical environmental impact is that of the entry of radioactivity into terrestrial and aquatic ecosystems. Individual radionuclides move through the environment at different rates and by different pathways, determined for the most part not by their radioactive characteristics, but by their chemical and physical characteristics. Most will enter biological systems and ultimately reach the human population. Their ionizing radiations damage living cells and can result in both somatic and genetic effects to the organism, depending on the intensity of the radiological dose received.

The risk posed to humans by the release of radioactivity to the environment cannot be quantified precisely, though more is known about the effects of radioactive effluents than about any other toxic substance. The International Commission on Radiological Protection has recommended a maximum whole body dose of 5 rem per year for an employee of the nuclear industry and 0.5 rem per year for the general public. This limit has been incorporated in regulations under the Atomic Energy Control Act, although guidelines issued by the Atomic Energy Control Board require the licensee to limit doses to the public to 1% of the maximum at the site boundary. Studies of the health impacts of low level radiation suggest that the effects of radioactivity on the environment and on human health at levels below the permitted dose should be further researched and continuously monitored [1].

Nonradioactive hazards to the environment associated with the nuclear fuel cycle are similar in nature to those of other industrial and energy generating activities, although they differ in detail and specific magnitude. Of particular concern are the release of large amounts of waste heat (discussed in Section 7) and the use of large amounts of toxic hydrogen sulphide gas in the production of heavy water (see Section 6.4). Especially important from an environmental point of view is the large size of proposed nuclear facilities and their proximity to urban areas, and the consequent effect that the centralized production of large amounts of power will have on the distribution and growth in population and economic activity, both of which will, in turn, place demands upon the environment. These demands would be different if another technology or a more diversified energy system were used. Thus, it is essential that the environmental impacts of nuclear power be considered on a comprehensive, system wide basis as components of integrated energy systems with their associated indirect results. They should not be assessed as individual developments on a one by one basis.

The general radioactive and nonradioactive impacts of the nuclear fuel cycle on the Canadian environment were discussed in some detail in the first submission.

6.2 URANIUM MINING AND MILLING

(6-8) *Epidemiological research and data gathering on uranium miners should be increased and continued to provide a basis for reviewing the current exposure limit of four working level months (WLM) per annum.*

(6-9) *Research efforts should be supported on the fixation of sulphides and radioactive materials in uranium mine and mill wastes so that treatment systems can be designed to reduce substantially the release of radionuclides to surface waters.*

In the process of extracting the raw material for nuclear fuel from the ground, uranium miners are inevitably exposed to inhalation of cancer-causing ^{222}Rn decay products [2]. Recent evidence has indicated that the risk of lung cancer increases with exposure, and that it is not possible to define a threshold of exposure below which the risk is zero. Although the regulatory exposure limit has been lowered in recent years, there is a need to increase studies on the health-related aspects of uranium mining.

The leaching of isotopes of radium and thorium from uranium mine tailings by surface runoff, made acid by biological and inorganic oxidation of sulphides in the tailings, has contaminated surface water supplies in the Elliot Lake area [3]. Immediate action is required to develop better methods to treat the mill waste streams for radium and thorium removal and to fix the chemically sensitive minerals and the radionuclides in the tailings so that they are less susceptible to leaching through weathering and low pH drainage.

6.3 URANIUM REFINING AND FUEL FABRICATION

(6-10) *A detailed study of the hydrogeological characteristics of all proposed sites for waste disposal from uranium refining and fuel fabrication operations should be mandatory before sites are approved, to ensure that harmful leachates from these wastes have no chance of reaching aquifer recharge areas.*

Since the bulk of the long-lived radioactive contaminants associated with natural uranium are removed at the mine site, the refining process which produces reactor-grade uranium does not discharge a great deal of radioactive waste. On the other hand, quantities of nitrates, ammonia, and fluorides have to be disposed of. These must be prevented from contaminating groundwater supplies.

6.4 HEAVY WATER (D_2O) PRODUCTION

(6-11) *Continued research on the toxicological effects of hydrogen sulphide on aquatic ecosystems is required.*

Potential environmental impacts associated with heavy water production arise from the production of heat and the possible release of hydrogen sulphide [4]. Waste H_2S discharged to the atmosphere is first oxidized to SO_2 and, therefore, adds to the global problem of the long-range transport of sulphur oxides (Section 8). No changes to aquatic life in the vicinity of the site have been detected which could be attributed to routine H_2S releases in Ontario, which have been regulated by the Ontario Ministry of the Environment since operations started in 1974. However, continued monitoring is required. Problems associated with waste heat are discussed in Section 7.

6.5 POWER GENERATION

(6-12) *The radioactivity water quality objective for the Great Lakes should be a maximum annual radiological dose of 1 millirem. This dose is not much higher than that obtained by drinking water from Lake Ontario, with present day levels of contamination, which results largely from fallout from weapons testing. This objective has been recommended by the Canadian and United States Advisory Group on Water Quality.*

(6-13) *A realistic evaluation of the environmental and health consequences of a major accident at a CANDU nuclear generating station should be made by involving scientists from the environmental and health agencies, along with Ontario Hydro personnel, in a joint task force. Such a task force could also review contingency plans for minimizing the environmental effects of a major accident.*

The Great Lakes have been considered an excellent heat sink for thermal generating stations and a number of nuclear stations are operating on their shoreline. There are plans for many more stations, all using lake waters for cooling. As radionuclides are continually released during plant operation, the levels of long-lived radionuclides in the lakes gradually increase, producing an increasing radiological dose to humans drinking the water and eating fish caught in the lakes. The dose of 1 millirem per year has been selected as the basis for defining a refined objective for radioactivity water quality in the Great Lakes for the Canada/U.S.A. Agreement [5].

In the case of CANDU type reactors, the major contribution to these releases is from tritium (^3H), which is discharged as tritiated water to both the atmosphere and the cooling water. The quantity of tritium released annually from a typical CANDU nuclear generating station is about 40,000 curies [5] compared to a total of 2 to 3 curies of other long-lived fission products. Two-thirds of this tritiated water is released to the atmosphere, where it rapidly exchanges with atmospheric moisture and precipitates in the neighbourhood of the source, contaminating the surface waters, soils, and vegetation. The remainder of the tritiated water discharged from the station is diluted by the condenser cooling water and dispersed into the lake. An estimate of the build-up of tritium in the Great Lakes from Ontario Hydro's future nuclear operations predicts Lake Ontario ^3H levels to increase from the current 400 pCi/l to about 2,000 pCi/l by the year 2,000 [6]. Even though the radiological dose to an individual drinking the water will only increase by 0.3 mrem, this will be a major increase in concentration. In addition, stagnant pools of tritium could collect near discharge areas on a calm day (such pools have been observed off Pickering) and be carried by lake currents to public water supply intakes, thus inflicting a higher, short-term dose on the public.

Tritium releases will be involved in the transboundary movement of pollutants from Canadian and U.S. waters. As U.S. reactor systems discharge only minor quantities of ^{3}H, their effect on lake ^{3}H levels will be negligible, so that a future concern may develop in the U.S.A. over pollution of U.S. waters by Canadian nuclear generating stations.

Next in order of magnitude in aqueous discharges after ^{3}H are the radioisotopes of cesium: ^{134}Cs and ^{137}Cs. Although this element is bioaccumulated by plankton, which, in turn, provide food for other species at higher trophic levels, it is scavenged fairly rapidly from the water column to the sediment [5]. It has been calculated that ^{137}Cs inputs to the Great Lakes from U.S. and Canadian nuclear stations through the year 2050 will result in levels in the water similar to current levels produced by fallout [7].

With the exception of localized areas near cooling water discharges, the radionuclides emitted from all nuclear stations predicted to be built around the Lakes until the year 2000 should not have a major effect on the water quality of the Great Lakes. It is important, however, that local effects continue to be monitored carefully by provincial and state environmental and health authorities, and that all information be coordinated by the International Joint Commission through its surveillance plan for measuring compliance with the objectives of the Canada/U.S. Agreement.

The probability of an accident in which there is both loss of coolant and failure of the emergency core cooling system in a CANDU nuclear generating station is very low [8]. Nevertheless, the consequence of such an accident could be the release to the atmosphere of a large fraction of the 10^7 curies of ^{131}I contained in the fuel. Depending on climatic and weather conditions and location of the generating station, the ^{131}I cloud could adversely and perhaps catastrophically affect the health and genetic stability of a very few or a very large number of people. Thus, no matter how small may be the statistical chances of a serious accident, the utilities and authorities concerned have a responsibility to evaluate thoroughly the potential environmental and health effects, to make the results of such evaluation public, and to consider contingency plans as well as accident prevention designs and practices.

6.6 RADIOACTIVE SOLID WASTE MANAGEMENT

(6-14) *Criteria and standards for protection of the environment against contamination by high level wastes must be developed, starting immediately, to assure the lowest possible risk to the health of present and future generations. These criteria and standards should be in effect before a disposal site is chosen and be applied to site selection as well as operation.*

Radioactive wastes arising from nuclear power stations are in liquid, gaseous, and solid forms. The liquid and gaseous forms are considered in Sections 6.2 to 6.5 above. The solid wastes consist of spent fuel bundles with high levels of radioactivity, and materials such as spent ion-exchange resin columns and contaminated equipment which have much lower levels of radioactivity. The low-level material from Ontario Hydro's reactors is stored at the Bruce site in covered concrete-lined trenches. Control of surface water, which could leach radioactive material, and a thorough knowledge of hydraulic and hydrogeologic characteristics of the soil are necessary to prevent contamination of ground water.

High level wastes in the form of spent fuel are currently stored on an interim basis under water at the nuclear station. It is planned to have a central facility in operation by 1985 [9] to "manage" indefinitely the spent fuel from all Canadian nuclear stations, pending decisions regarding reprocessing and long-term waste management. If the reprocessing option is taken up sometime in the near future, this will be interim storage only. If not, the spent fuel must be disposed of in perpetuity because of the 24,390 year half-life of ^{239}Pu. Readily accessible storage under these circumstances is a burden on future generations and permanent disposal such as in isolated stable geologic strata is imperative. It is urgent and imperative that the geological and environmental criteria for disposal sites be determined and agreed upon, before a site is selected and a decision to store or dispose is made.

6.7 DECOMMISSIONING OF NUCLEAR INSTALLATIONS

(6-15) *Provision for decommissioning of the entire station, or for replacing or upgrading of any of its components without causing harm to the environment, should be an integral part of the design and operating procedures of each nuclear facility.*

Details of decommissioning procedures are uncertain. However, it is unlikely that a nuclear generating site will be abandoned unless it was a poor choice environmentally in the first place. More likely is an upgrading of the nuclear components as the thermal efficiency of reactors is improved through continuing engineering research and development. Disposal of large sections of highly radioactive reactor structures will be required, but experience at AECL in this area can be called upon to minimize radiation exposure to personnel during such operations. Transportation of large reactor components to a central disposal site is not feasible because of the large mass of shielding required. Long-term, on-site shielded storage will be needed until radioactivity levels have decayed sufficiently to allow off-site disposal. Storage could be required for a decade or so for neutron activation contaminants such as ^{60}Co. Provision for such storage or disposal, and for decommissioning operations, should be made in the design of each facility. The environmental (e.g., groundwater, soil contamination, etc.) aspects of decommissioning and disposal of contaminated equipment need careful attention.

If it should happen that, after a nuclear power station was built and in operation, the site was found to be quite unsuitable from an environmental point of view (e.g., foundation instability) and the facility had to be completely dismantled and removed, difficult problems of preventing contamination of the environment could arise. For this reason, allowance for decommissioning should be part of the design and operation of the plant.

6.8 FUTURE DEVELOPMENTS

6.8.1 Fuel Reprocessing

(6-16) *A full assessment of potential routine and nonroutine hazards to the natural environment must be made before any commitment is made to reprocess spent fuel in Canada.*

(6-17) *Reprocessing of fuel on an operational scale should not be approved until acceptable levels of discharge into the environment of all radioactive isotopes and materials produced by reprocessing have been established; and until technology has been developed to control radioactive discharges to the environment to those levels, especially volatile gaseous radionuclides released during processing.*

(6-18) *Safe disposal of vitrified high level wastes should be demonstrated satisfactorily before a commitment is made to reprocess spent fuel in Canada. The geophysical stability and hydrological characteristics of the formations under consideration are key factors for study.*

Spent fuel from CANDU reactors contains about 0.3% fissile plutonium, which can be recycled to produce further energy. In order to burn this plutonium, the irradiated fuel has to be reprocessed to extract the plutonium for incorporation into fresh fuel.

Experience with fuel reprocessing by other nations with nuclear programs has shown that both aqueous and atmospheric radioactive discharges from such plants are invariably present and frequently exceed regulatory criteria. For example, liquid wastes discharged to the Irish Sea from the United Kingdom's Windscale plant during 1973-4 included 1,800 curies of plutonium and 44,000 curies of ^{137}Cs [10]. Gaseous fission products with long half-lives liberated during dissolution of the fuel are ^{85}Kr, ^{129}I, and ^{3}H. The ^{85}Kr and ^{129}I can be trapped and stored, although no satisfactory method for disposal of ^{129}I with a half-life of 1.6×10^{7} years has yet been found [11]. In the U.S.A., no commercial fuel reprocessing plants are currently operating, partly for environmental reasons.

AECL has proposed to the Commission that reprocessing of CANDU fuel and disposal of highly radioactive waste can be incorporated into one site [12]. The wastes would be fixed in glass by the nepheline syenite process [13] and buried in a deep disposal well on site. This procedure carries with it inherent difficulties as a result of the volatility of some of the radionuclides in the dissolution of the spent fuel. Although those wastes that are concentrated in the glass would probably be as safe as burying unprocessed fuel, control and containment has not been demonstrated for volatile radionuclides such as ^{3}H, ^{129}I, ^{137}Cs, ^{106}Ru and ^{85}Kr which escape or are released during the reprocessing. This disposal problem faces every country with a nuclear program and no practical solution has yet been found. Careful consideration should be given to this problem in Canada before a waste disposal policy is approved.

6.8.2 Thorium Cycle

(6-19) *Thorium should not be used as a fuel until all environmental effects of fuel reprocessing can be controlled to established acceptable levels.*

One of the advantages of the high neutron economy of the CANDU reactor is the possibility of absorbing excess neutrons in the fertile element thorium to produce fissile ^{233}U. Once a sufficient ^{233}U inventory has been produced for a given electrical installation capacity, the thorium cycle is self-sufficient as an energy producer. This is an attractive fuel cycle because it decreases dependence on security of uranium supply without having to adopt fast breeder technology. It does, however, require fuel reprocessing to remove fission products which accumulate and reduce reactivity by parasitic neutron capture. The environmental aspects of controlling, or failing to control, the full range of products produced by reprocessing

CANDU fuels have, to date, received insufficient study. Particular attention must be given to the control of radionuclides in the gaseous and aqueous releases.

6.8.3 Fusion Power

(6-20) *Generation of electricity by nuclear fusion will inevitably produce radioactive and non-radioactive effluents, as well as waste heat. Environmental protection must play an integral role in the development of fusion technology and the design of fusion energy equipment, and also in the development and operation of the modified nuclear fission system that will likely accompany adoption of fusion power.*

Fusion power is unlikely to be a practical means of generating electricity for a considerable time; many estimates give the year 2000 at the earliest. The most likely technology involves the fusion of deuterium and tritium nuclei which produces ^{4}He and a neutron, with release of energy.

Early speculations suggest the potential environmental impacts of such a technology may be less severe than those associated with nuclear fission. There would be less impact from mining lithium ore than uranium as there are no radiological effects. However, D_2O production would still be required to provide deuterium feed. As in the CANDU reactor, there would be a high inventory of tritium in a fusion reactor, leading to the reasonable assumption that releases of this radionuclide to the environment may also be high. The primary coolant of this type of reactor would probably be a liquid metal because of the high power density. Impurities in the metal would become radioactive due to activation in the intense neutron flux, and thus, it would be necessary periodically to process the coolant and dispose of the radioactive wastes. The advantage that the fusion system has over fission is that the quantities of higher level wastes for ultimate disposal would be lower and their radioactive half-lives much shorter.

It is unlikely, however, that it would be economical to waste the intense neutron flux in the fusion reactor. In order to make fusion power competitive, it has been proposed that the flux be moderated by deuterium and absorbed by a fertile blanket of thorium to provide ^{233}U for fission reactor fuel. Thus, the indirect effects of fusion power could be the reprocessing of irradiated thorium and the production of further fission product wastes arising from use of the ^{233}U in the CANDU thorium cycle.

Like nuclear fission, nuclear fusion will inevitably produce nonradioactive effluents and waste heat as well as radioactive contaminants. Environmental considerations must play an important role in any development of nuclear fusion technology, from initial research and development to ultimate application.

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PART III

GENERAL ENVIRONMENTAL CONCERNS OF THERMAL POWER PRODUCTION

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SECTION 7: THERMAL PLANT COOLING SYSTEMS

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SECTION 7: THERMAL PLANT COOLING SYSTEMS

7.1 INTRODUCTION

The numerous environmental and laboratory studies that have been done in many countries in the past few years have illustrated that many, but not all, problems associated with the once-through cooling process tend to be site specific. What may be a serious problem at one plant may be inconsequential at another. In Ontario, however, with most of the cooling water coming from the Great Lakes, the variety of potential problems are fewer as the fauna and flora species associations are somewhat similar from Lake Superior to Lake Ontario. In addition, the ambient temperatures of the receiving waters of each lake differ from each other only in their summer maximums which, due to climate, are a few degrees lower in the upper lakes. However, there are potentially serious problems which could be site specific depending on the location in the Great Lakes.

7.2 ENVIRONMENTAL IMPACTS OF ONCE-THROUGH COOLING SYSTEMS

7.2.1 Entrainment and Impingement

(7-1) *Cooling water intakes should be designed and sited to avoid as much as possible the killing of larval fish and other aquatic life through entrainment or impingement.*

The results of studies at existing Ontario thermal generating plants have suggested that physical factors such as entrainment and impingement may be more important environmentally than temperature effects, and can lead to important reductions in the economic and recreational potential of fishing in the Great Lakes. Larger organisms such as fish are prevented from entering condenser cooling waters by large meshed screens. However, these screens do not prevent the entrainment of lower trophic organisms such as zooplankton, phytoplankton, and ichthyoplankton. During their trip through the cooling condensers, these organisms undergo sudden heat shocks and encounter increased pressures, as well as enduring considerable mechanical stress. This last factor is especially evident at some Ontario plants (for example, Lennox) where the discharge canal, being quite narrow, creates considerable turbulence. On-site activity studies (e.g., primary productivity using $^{14}CO_2$ and zooplankton feeding) used as an index of well-being have shown that the entrained pelagic (open water) community of phytoplankton and zooplankton as a whole apparently survive these experiences rather well. However, some reduced activity is measurable. The generally short regeneration time of phytoplankton and zooplankton suggests that the lake pelagic community, and especially the near-shore biota from where the intake water is obtained, are able to compensate for any losses which are occurring (providing, of course, the volume of water used remains small compared to the volume of the zone from which it is being removed). The entrained ichthyoplankton apparently are not as fortunate. Larval fishes suffer extreme mortality due to entrainment, perhaps as high as 100%. Furthermore, their regeneration time is long, in the order of years rather than days or weeks.

These same studies have also suggested, as expected, that some plankters (e.g., dinoflagellates) may be more susceptible to damage than others. A critical piece of information lacking at the moment is what the long-term effect of the loss of these more sensitive species will be on, for example, fish populations in the Great Lakes.

Some impacts on aquatic life can be avoided by reducing the velocity of intake water pumped into the condensers. If, however, this causes discharge water to become too warm, one cause of mortality is replaced by another. Compromises with respect to these negative effects seem inevitable if an acceptable level of thermal efficiency is to be maintained.

Impingement could pose problems to fish stocks if intake structures are situated in areas where there are high densities of preferred fish species, or where fish cruising along the shoreline encounter the intakes. As many fish species regularly migrate and hunt along considerable stretches of the lakeshore, a single fortuitously placed intake could affect a high proportion of fish over a wide area.

The forces of suction at intake pipes are severe enough that they regularly force fish onto screen barriers causing, in many cases, mortality. To prevent clogging, these animals are removed from "travelling screens" on a routine basis. Only about 2% of the fish mortality attributable to screen impingement involve currently valued (i.e., commercial or sport) fish species [1]. Preoperational environmental assessments at proposed sites should determine the best location(s) for intake structures. Such assessment must include consideration of the year-round behavioural characteristics of the fish. Final positioning should be determined on criteria which will minimize the destruction of biota, especially preferred fish species.

7.2.2 Supersaturated Water

(7-2) *If studies indicate "gas-bubble disease" in fish is a potential problem, steps should be taken to prevent fish from entering the cooling water discharge area.*

Another potential problem associated with once-through cooling is the supersaturation of water with atmospheric gases. Fish encountering these waters are susceptible to an affliction referred to as "gas-bubble disease" from which they can die [2]. The combination of pressure and temperature changes and turbulence near the discharge from a power plant can cause a supersaturation of the water with atmospheric gases, especially oxygen and nitrogen. Studies at four power plants have not identified this as a problem to date in Ontario. Preventing fish from entering the immediate discharge area would virtually eliminate this potential problem.

7.2.3 Temperature

(7-3) *To protect the organisms that get entrained in cooling water circulation and get carried through the plant, and also those immediately in contact with discharge waters, it is desirable that water exiting from the plant should not be more than 10-12°C warmer than that of the lake near the point of discharge. Regardless of the intake temperature, discharge water should rarely, if ever, exceed approximately 31°C. These guidelines should be modified to be more restrictive if the biota of a particular site prove to be more sensitive to temperature changes.*

There is little evidence that much damage to the aquatic environment is caused by the increased water temperature of the discharge effluent. Most species (both plant and animal) found in southern Ontario lakes seem to be able to survive, at least for short periods of time, in water temperatures slightly above 30°C. However, sustained periods at this temperature ultimately would kill many of the less hardy forms. Fish can and do avoid water that is too hot by swimming away; planktonic forms are not as fortunate. A water temperature even in the 20's could prove fatal if an organism, even a fish, were acclimatized to a much lower water temperature of perhaps 4°C. There exists a further possibility of increased incidence of parasites and disease caused by locally elevated temperatures, as may be the case during some parts of the year.

7.2.4 Biocides and Other Chemicals

(7-4) *The use of biocides as defouling agents should be kept to a minimum, while the use of cooling water for the discharge of station chemical wastes should be prohibited.*

Another potential problem could result from the practice of adding biocides, usually chlorine, to prevent fouling of the condensers. It is essential that the addition of any defouling agent not be done on a routine basis, but only selectively and when necessary. Only the minimum amount of biocide necessary to prevent fouling should be used. Quantities required will vary with the quality of the water being used for cooling.

It is desirable to explore and research alternate means of cleaning condensers. The use of mechanical alternatives such as the scouring balls at Nanticoke is environmentally preferable to chemical scrubbing. The ultimate goal should be to eliminate the use of biocides for cleaning condensers.

A variety of other chemicals are frequently used in, or associated with, the operation of the thermal power plants. Some of these are released regularly into the cooling water discharge. The flushing of substances of this nature into the aquatic environment can be toxic to fish and other aquatic organisms, and should not be permitted.

7.2.5 Plant Design and Siting

(7-5) *Design and siting of plant discharges and intakes should take into account the location of important spawning grounds, feeding areas, migration channels, or other biologically sensitive areas.*

Assessment of final designs for environmental suitability should be made by government environmental agencies (both provincial and federal) before construction begins. To avoid environmental problems, it is advisable for these agencies to be involved in the initial stages of site selection and plant design. There is a need for all-season hydrodynamic and biological information; it is not unlikely that the most important effect of a power plant on lake ecology may be in winter.

7.2.6 Large Energy Centres and the Collective Effects of Many Plants

(7-6) *The Great Lakes, although large, should be viewed as a limited sink for the disposal of thermal effluents from power plants and industrial operations. Alternate technologies for cooling must be actively pursued for incorporation into the proposed expansion programs of Ontario Hydro and others who use the lakes for cooling, in order to maintain future environmental impacts on the Great Lakes within acceptable levels.*

(7-7) *Future sitings of plants, if they are to be on the Great Lakes, should take into consideration the proximity of existing installations, as well as natural discharges and likely future industrial growth in the whole Great Lakes system.*

There is a distinct danger in assuming that because present large power plants apparently cause relatively few serious environmental problems, the Great Lakes can withstand more stress. It is not known how critical the present thermal balance is. It is clear that large energy centres located in areas of confined circulation could substantially increase adverse environmental effects, the magnitude of which could be very difficult to predict in advance. A series of stations located close together could conceivably have overlapping thermal plumes, the combined effect of which could be much greater than the sum of single effects. There may also be a snowball effect--a series of power plants on the lakeshore leading to a concentration of other industries which themselves are sources of thermal discharges. The development of thermal power plants and other industrial activity along the lakeshore may also disrupt natural discharges from land which help to keep the lake system healthy.

Related to this concern are the cumulative, whole-lake effects which might result from an excessive use of Great Lakes water for cooling by both the United States and Canada. Cumulative influences could lead to changes in gross limnological behaviour. For example, earlier springtime thermal stratification and a subsequent later overturn of the thermocline in the fall could create a prolonged period of oxygen depletion in deeper water. In addition, gross changes to the limnology of a localized area in the lake might lead to an overall higher mean water temperature which also might adversely affect local weather patterns.

7.3 ALTERNATE COOLING SYSTEMS

(7-8) *Long-range planning for expanding the electric power system in Ontario and other jurisdictions surrounding the Great Lakes should give serious consideration to alternate cooling systems as a means of reducing environmental damage to the Lakes.*

At present, all cooling water from Ontario Hydro stations on the Great Lakes is discharged at the surface from the shoreline, and uses the natural circulation of the lake to dissipate the introduced heat. In view of the planned increase of thermal power plants, both in Canada and the United States, on the shoreline of the same water bodies, the environmental impacts resulting from once-through plant cooling systems could become substantial. Costs due to the degraded environment of the lake--through reduced fishing, fouled beaches, loss of land value, etc.--could equal or exceed the savings in using once-through cooling as compared to alternate cooling systems. It is prudent to give serious consideration to alternate systems.

Alternate systems that could be employed at Ontario Hydro plants include: a) cooling towers; b) cooling ponds; and c) closed lake systems. As could be expected, each of these provides its own environmental concerns. None is as cheap as once-through cooling. However, on balance, all can be a good investment if they avoid destruction of the Great Lakes' ecosystem. As the number of power plants increases, these alternative methods can be expected to become relatively more attractive.

7.3.1 Cooling Towers

It may be necessary to use a closed-cycle cooling system, rather than overburden the local aquatic environment with an excessive amount of waste heat. Several European countries have experience in the use of cooling towers and their economic and environmental implications. Of concern, in connection with the techniques presently used, is the use of biocides and corrosion inhibitors (e.g., chromates) which could be released into the environment during blowdown procedures.

7.3.2 Cooling Ponds

Discharge of concentrated biocides and contaminants from cleaning operations and blowdowns would also be a problem for cooling ponds unless alternate means were found to clean the waste water. The additional land needed to operate cooling ponds, together with some local winter humidity and icing problems, are additional environmental factors to be considered in adopting this type of cooling in southern Ontario.

7.3.3 Closed Lake Systems

There may be environmental advantages in using closed lake systems rather than the Great Lakes for cooling water. Such systems could be designed to have beneficial applications such as a warm water park or for aquaculture. Careful pre-siting environmental assessments on an individual basis would be required. Such assessments should consider the ancillary industrial development in the area and its demand for cooling water. Development of a closed lake system should be integrated with regional land use planning. Although initial investments may be greater, this approach offers the potential of greater sustained total productivity and environmental quality if undertaken with full knowledge of environmental factors.

7.4 BENEFICIAL USES OF THERMAL DISCHARGES

(7-9) *Consideration should be given to incorporating the practical domestic or industrial use of thermal discharges as an integral component of future plant design, both to reduce environmental impacts and to conserve energy resources. A series of pilot projects should be initiated to demonstrate the technical feasibility and assess the economics and management problems of industrial and domestic use of thermal discharges in conjunction with electricity generation.*

Many studies have been made of the possible beneficial uses for heated effluent from power stations. In North America, few schemes to use heated discharge have been put into practice because high-grade energy has been relatively cheap, and because most large-scale schemes required dependable heat not related to the operational requirements of the power station and the schemes were expected to pay for themselves commercially [3]. Institutional problems also mitigate against optimum use of waste heat; e.g., Ontario Hydro's goal and mandate is to produce electricity as efficiently as possible, not to obtain the most energy benefit from the fuel consumed.

Despite the difficulties of establishing practical waste heat utilization schemes in Canada, it is clear that the enormous discharge of unwanted energy to the environment in the form of heated effluent is increasingly an unnecessary and profligate use of resources. Thermal discharges have been economically utilized in other countries, such as Sweden, with a climate similar to that of Ontario. In the near future, it may be too wasteful to discard such energy, when it could be used as a substitute for increasingly scarce nonrenewable resources. Any use of thermal effluent for practical purposes is environmentally beneficial, through lessening of direct discharge and avoiding the environmental costs of the high-grade energy that would otherwise have been used.

In the planning for the future electrical and energy system in Ontario, much more attention than was given in the past will have to be given to the optimum net use of total energy resources. In that context, practical use of the roughly two-thirds of produced energy, which is presently thrown away as unwanted, will figure prominently. It is appropriate, at this time, to consider designs and plans for making practical use of the low-grade heat from power stations, not as makeshift adjuncts to salvage discarded waste from existing plants, but as integral productive components of plants designed to obtain the maximum total use from the energy system compatible with efficient electrical generation. As part of the planning and design of future energy/electricity systems, a series of pilot projects should be initiated to demonstrate and assess the feasibility, economics, and management problems of using thermal discharges for space heat, industrial processes (e.g., drying), greenhouse maintenance, aquaculture or fish hatcheries, etc. The success of such projects should not, at least in the first instance, be judged on their market competibility alone, but should also consider the net environmental and net resource use factors.

A constraint to the use of low-grade heat for beneficial purposes is Ontario Hydro's policy of having relatively few, but very large, power plants. This policy restricts the potential applications where low-grade heat may be used economically. However, it should be noted that, in Europe, thermal effluent for heating purposes is piped in large volumes up to 60 kilometers and is still more economical than individual household furnaces. The effective use of thermal effluents requires some basic changes in utility responsibility and industrial and market structure, and is an example of the interdependence of energy technology, environmental constraints and costs, institutional practices, and social behaviour.

7.5 FUTURE ACTION

The Department of Fisheries and Environment maintains a strong interest in environmental problems arising from the cooling systems of thermal power plants. Of specific interest to this Commission is the International Joint Commission's continuing work in developing water quality objectives for the waters of the Great Lakes. At present, the Water Quality Board of the IJC is reviewing objectives for temperature and chlorine. In addition, it is anticipated that, in the near future, control requirements for both heated discharges and chemical pollutants will be defined by a joint Federal/Provincial/Industry task force.

Recent proposed amendments to the Federal Fisheries Act also confirm the concern for protecting the aquatic habitat. For example, one amendment recommends that "every water intake...in Canada... from any Canadian fisheries waters...for...power generation...shall if the Minister deems it necessary...be provided with a fish guard or a screen...so as to prevent the passage of fish...into such water intake...". Another amendment redefines the term "fish" to include "the eggs of fish". The new provisions will prohibit activities which have a serious effect on the support systems (e.g., food sources, spawning grounds, etc.) of fish, and will allow for the Minister to call for plans and specifications, to require modifications (of power plants) and, if necessary, to prohibit specific undertakings.

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SECTION 8: LONG-RANGE TRANSPORT OF AIR POLLUTANTS

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SECTION 8: LONG-RANGE TRANSPORT OF AIR POLLUTANTS

8.1 THE PROBLEM

Large quantities of gaseous products and particulate matter are produced by the combustion of fossil fuels for generation of electricity. Most of these products are vented to the atmosphere. All industrialized countries, including Canada, have enacted regulations controlling the maximum permissible concentration in the atmosphere of the major pollutants contained in products of fuel combustion. These levels are those at which, on the basis of best available information, identified damage to the environment or to human health can be avoided. Nevertheless, although the specific pollutant concentration at any one point may be kept below permissible limits by removal of pollutants at the source or by dilution in the atmosphere by dispersal from tall chimneys or stacks, the gaseous and particulate matter that does reach the atmosphere contributes to the total pollution load of the region. Many of the products of combustion remain in the atmosphere for a considerable length of time and are carried for considerable distances; and, together with the combustion products from other power stations and industrial activities, contribute to a cumulative change in the composition and quality of the atmospheric environment. Fossil fuel-fired electric power stations are thus agents in causing deterioration of regional environmental quality.

The significant substances involved in long-range and regional pollution from fossil fuel combustion are sulphur dioxide and nitrogen oxides, both of which are produced in the burning of oil and coal, and particulate matter (mostly silica, elemental carbon, and aluminous oxides) which result from coal combustion. Because sulphur is removed routinely from natural gas at the well-head, the chief pollutants from gas-fired plants are nitrogen oxides. These materials undergo various transformations and interactions with other atmospheric constituents and, in the case of inert or resistent particles, may act as catalysts or nuclei for other transformations. All of them eventually return to the surface of the earth, through gravitational settling, washing by rain and snow, or electrostatic precipitation. Most apparently settle within a few tens of kilometers of the source, but a significant fraction is dispersed over subcontinental areas, and a portion, mostly fine particulates and nitrogen oxides, reaches higher levels in the atmosphere and gets dispersed around the globe.

The emissions from the fossil fuel-fired power stations of Ontario Hydro contribute to the pollution load of the atmosphere over the industrialized region of the Great Lakes, upper Mississippi, northern Appalachians, Atlantic seaboard, and St. Lawrence valleys. The problem of regional air pollution must, therefore, be considered on a subcontinental scale. The sources are diverse and widespread and controlled by many jurisdictions; the effects are dependent, in large part, on patterns of atmospheric circulation and the geological composition of the soils in different areas. Over this large region, the cumulative, man-made pollution load has been sufficient to cause a measurable and progressive increase in acidity of rainfall. There is evidence that acidic rain and the resulting change in composition of surface waters and soil moisture can cause serious damage to fish stocks, forest regeneration, and agricultural productivity. Ontario is both a contributor to and a recipient of this regional pollution; but, because of the accidents of geography and geology, it probably "exports" more atmospheric pollution than it receives, and the sensitivity of its soils and waters to acid rain damage is slight in comparison with other areas downwind to the east and southeast.

The total amount of pollutant added to the atmosphere, rather than its concentration at any one point, is important in estimating the cumulative environmental importance of long-range air pollution. The emission of pollutants is a direct function of the composition of the fuel (the sulphur content of typical coals burned in Ontario is from 1 to 3% and of typical fuel oils from 0.1 to 5%), the design and operating procedure of the furnaces (which determines the ratio of pollutant-type material in the ash or slag compared to that in the flue gases), and the methods used to reduce stack pollution (precipitators or scrubbers versus tall stacks). In the Great Lakes - northern Appalachian industrial area noted above, it has been estimated that about 20 million metric tons of SO_2 are released to the atmosphere each year. This release, even when spread over such a large area, produces a direct artificial modification of the environment. The contributions of Ontario Hydro plants to this total are relatively small, and less than the contribution from industrial activity in Ontario, but they are not negligible--the Lakeview generating station alone spreads 88 metric tons of sulphur dioxide into the air over Toronto per megawatt-year of electricity generated [1]. Electric power generation in Ontario is thus a factor in determining the long-term quality of the regional environment of Ontario.

8.2 REGIONAL ENVIRONMENTAL ASPECTS OF EMISSIONS FROM FOSSIL FUEL COMBUSTION

(8-1) *Emissions from point sources should not be considered in isolation, but rather in a cumulative, regional context. In the Great Lakes region, emissions from all major sources, on both the Canadian and U.S. sides, must be assessed to evaluate their collective impact on environmental quality.*

The long-range dispersal and transport of material in the atmosphere is independent of jurisdictional boundaries. Emissions from different point sources merge into regional masses of pollutant-bearing air and regional air masses interact to produce subcontinental scale atmospheric conditions. Consideration of the effects of emissions from fossil fuel power plants cannot, therefore, be restricted to the magnitude or character of any single source or of one jurisdictional region. The effects of point source emissions must be considered in the context of continental scale ambient concentrations which result from the integration of all sources interacting with the existing atmospheric transport and pollutant removal processes.

Sulphur from fuel combustion is emitted to the atmosphere as stack gas, mainly in the form of SO_2. The SO_2 is oxidized to SO_4 in the atmospheric transport phase and forms an airborne acid in the presence of atmospheric condensation processes. In the absence of neutralizing materials, the subsequent precipitation has a greater than normal acidity and contributes a strong hydrogen ion to the reactions within ecological systems. As certain types of particulates serve as neutralizing materials, the removal of particulates from stack emissions may actually accentuate the acid contribution [2].

The occurrence of precipitation increasingly more acid than normal is well documented over northeastern United States and eastern Canada [3, 4]. The influence of this widespread, but continuous, addition of excess hydrogen ions has increased the acidity of soft-water lakes to the extent that fish habitat has been damaged [5]. Evidence of the effects on forest growth and agricultural productivity in Canada is not as clear, but from the experience in other parts of the world, it is apparent that acid rains have an effect on fertility and seed germination, especially in lime-poor nonbuffered soils [6, 7].

A study by the U.S. National Academy of Sciences on Air Quality and Stationary Source Emission Control [8] has examined the magnitude and trends of pollutant emissions and their potential effects on atmospheric quality. Among the conclusions of this study are estimates that:

"10. Even if sulphur oxide emissions are held constant, a small increase in acidity of precipitation is likely by 1980, as a consequence of increased nitrogen oxide emission.

11. If sulphur oxide emissions are allowed to double between 1970 and 1980, the average acidity of precipitation in the northeastern United States and southeastern Canada is likely to increase by a factor of 2 - 3. The area affected may also be enlarged."

The increase in sulphate deposition and the associated increase in precipitation acidity has serious implications for the noncalcareous, soft-water regions of Ontario. The present trends toward soil and lake acidification would be accelerated and the time required to reach critical levels would be shortened. Deterioration and possible loss of fish production in the soft-water lakes can be expected, resulting in a severe impact on recreational sport fishing and the associated tourist industry. Studies conducted in Norway and Sweden [7, 9] indicate that a substantial curtailment in forest production could also be expected in the widespread nonbuffered soils of the Canadian Shield. Recent studies of the United States Environmental Protection Agency [10] have also shown concern for the long-term effects on human health of chronic exposure to increased levels of particulate sulphates.

Information available to date suggests that relatively low levels of deposition of sulphate and acidic salts cumulate to produce critical environmental conditions. By the time damage to biological systems is detected, a critical situation exists which is irreversible in natural terms except over long periods of time. It is not known whether there is, in effect, a "carrying capacity" or threshold of tolerance for acidity for the ecosystems of concern. Present research is devoted to determining the tolerance and sensitivity of important components of the ecosystem. Until it can be determined that natural factors will place a limit on increasing acidification, or the tolerance of the biological system for an acidic environment can be established, no environmentally "safe" limit of continued emission of combustion products can be assumed. All present evidence shows that the Great Lakes - northern Appalachian region has already passed the point at which environmental damage is caused, and that the problem is growing worse.

8.3 TECHNIQUES FOR CONTROL OF REGIONAL AIR POLLUTION

(8-2) *Where fossil fuels are used to produce electric power, the only acceptable means of protecting environmental quality and productivity is the reduction or control of sulphur and nitrogen oxides at source.*

The potentially serious concerns for present or increased deposition of combustion-related products due to long-range atmospheric transport will likely require increasingly stringent emission controls. This will have important implications for the fossil-fueled generation of electric power. Transport of combustion products from distant sources not only creates transboundary concerns, but also requires that any given generation site be considered as an integral part of a continental scale problem. It follows that the use of tall stacks to disperse pollutants over a wide area in order to reduce, through dilution in the atmosphere, the concentration of pollution near the ground close to the source is unsatisfactory and may be counter-productive in environmental terms. The only effective way of preventing pollution of the atmosphere, and its consequent damage to regional environmental quality and productivity, is to prevent pollutants from being discharged into the atmosphere.

8.4 INTERNATIONAL OR REGIONAL AGREEMENTS AND PLANNING

(8-3) *The planning for future electric power systems in Ontario should reflect the desirability that a regional or sub-continental plan or agreement should be drawn up in the near future to regulate fossil fuel burning activities in order to protect environmental quality.*

Because the problem of atmospheric quality modification through long-range transport of air pollution is continental in scale and independent of jurisdictional boundaries, it is essential that Canada-United States agreements be reached which will define permitted emission levels. Since both countries will be placing increased reliance on the use of coal for generation of power, and as the most economical and conveniently available supplies of coal have significant sulphur content, the need for these agreements is urgent. It is in the interests of the people of Ontario, who are subject to the effects not only of locally-produced pollution, but also of pollution originating to the south and west, for such an agreement or plan to be in place before either Ontario Hydro or utilities in neighbouring jurisdictions proceed independently with programs for expanding electricity generating capacity using fossil fuel power plants. Such agreements can be expected to have an influence on the technology and location of future Ontario Hydro facilities.

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SECTION 9: ENERGY AND CLIMATE

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SECTION 9: ENERGY AND CLIMATE

9.1 INTRODUCTION

(9-1) *The planning and development of the future electrical power system for Ontario should take into account the effects that variations in climate may have on the demands for energy and on the operation of the electric power system, and also the effects that energy production and use may have on the local, regional, or world climate.*

The climate has a significant influence on the demand for and supply of electrical energy. Variations in climate, on both short and long time scales, can have important effects on the cost and efficiency of energy systems and on the effectiveness with which energy supplied meets social and economic needs. Some of the available methods for generating power themselves may alter the existing climate regime. Man-caused alterations of climate, in turn, may have effects on the social and economic life of Ontario and these will influence the demand for energy. Thus, the mutual interrelationship between energy activities and needs, and climate, should be considered in assessing future energy and electricity requirements and in planning electrical supply systems.

A supplementary discussion and background paper, "Energy and Climate: An Assessment of Relationships between the Consumption and Production of Electricity in Ontario, and the Climate", has been prepared by the Atmospheric Environment Service of the Department of

Fisheries and Environment, and is being submitted to the Commission. This section presents some of the general points made in that paper. Reference should be made to the supporting paper for details on the points made below.

9.2 VARIABILITY OF CLIMATE IN ONTARIO

(9-2) *Year-to-year climatic conditions have become more variable in the last few years than they were in preceding decades. It is most important that electric utilies evaluate the impact that this increased variability, if continued, will have on their operations.*

Available records, plus common subjective experience, indicates that the climate of the 1950's and 1960's showed less year-to-year variation than was common during the preceding century. However, the frequency of apparently unusual climatic events has increased since about 1970, and suggests a return to a more typical condition of increased climate variability.

Variations in climate include the net short-term variations in weather, as well as changes in climatic trends. Changes in the mean daily, monthly, and annual temperature; in the range of temperature and rapidity of temperature change; in the amount, distribution, and intensity of precipitation; and in the frequency of storminess and the regularity of storm tracks all contribute to short-term, and eventually to long-term, variations in climate. All of these changes affect the demand for energy, either directly through the need for space heating, etc., or indirectly through agricultural and forest productivity, hydrological changes (low lake levels or floods, etc.), changes in urban pattern and architectural design, etc. As the energy systems in Canada and, particularly, the integrated electrical generation and distribution systems have a working life span longer than the time span of experienced climatic change in recent decades, it is a public responsibility, as well as good management and economics, for electric utilities to take into consideration, when planning for the future, the possibilities and reasonable range of climate variation and its effect on energy system operation.

The causes of climate variation on a global scale, and of changes in the broad latitudinal variations in atmospheric stability and instability, are not understood. In the absence of knowledge of causes and mechanisms, it is not possible to predict changes in climate. Prediction on the basis of observed past trends is risky at best; one characteristic of the recently experienced increase in short-term variability of climate is the increasing departure from past trends. Ontario, compared to many parts of the world, has experienced relatively uniform climatic trends. The accompanying background document provides evidence on this and states, for example, it may be reasonable to conclude that, on the basis of observed trends, the mean temperatures are likely to rise in northern Ontario and remain much the same in southern Ontario during the next decade. However, the variability of mean annual temperature is likely to increase in Toronto and decrease in northern Ontario during this period. It would not be justified to predict more than a decade ahead on the basis of past trends. More useful, perhaps, from an energy planning point of view, is a review of the character of individual trends to obtain an estimate of the likelihood of "climatic surprises".

There has been much discussion and a growing amount of research into the question of man-made influences on global or regional climate. Although a reasonable estimate can be made of the production of heat, carbon dioxide, etc., by man, the importance of these in affecting natural atmospheric processes is not known, and it likely will not be possible to separate clearly man-made influences from natural processes. Changes in global climate which may be induced by human activities or to which human activities may contribute, and which may change conditions in Ontario during the next 50 years, will most likely be due to increases in the content of CO_2, largely from the combustion of fossil fuels. This will lead to a net warming of the atmosphere. On the other hand, increases in particulate loading, largely from mechanical cultivation of land, deforestation, and over-grazing of arid areas, will probably tend to lead to planetary cooling, although the cooling effects are smaller and more difficult to assess than the warming that would be produced by an increase of CO_2. The net effect of these man-caused impacts has been considered likely to be a warming of 1 to 2^{o}C over the next 50 years. Such a warming trend, while possibly important and significant over time periods of several decades or a century, will almost certainly be masked by the year-to-year variations in climate. As a result, the year-to-year variations are the most important climatic factors to be considered in planning an electric power system.

An essential first step is to develop reliable methods of determining the sensitivity of peak electric power demands to year-to-year variations in climate. Because climate variations, rather than individual weather anomalies, have important behavioural feed-backs that affect energy (people turn up their thermostats during a single storm, but insulate their houses or move to Florida if the climate really changes), the energy/climate sensitivity is complex.

9.3 EFFECTS OF CLIMATE ON ELECTRIC POWER DEMAND

(9-3) *A variability or climatic contingency factor should be built into all estimates of electrical power demand.*

(9-4) *Consideration should be given to alternatives, other than system expansion, to maintain an adequate supply of power to cope with variations in climate.*

At present, Ontario Hydro estimates winter electricity demand on the basis of a forecasting model that allows for temperature, wind, and solar illumination. This excellent technique should be continued and refined, and its inputs related directly to the meteoro-logical forecast system. Such a system is of most use for short-term planning and guiding the day-to-day operation of the power system. For longer-term operations, and for planning to meet seasonal peak loads, etc., a more sophisticated assessment of the sensitivity of individual domestic or industrial electricity requirements to seasonal changes in temperature and persistent changes in precipitation and wind is warranted. Sensitivity of electrical energy use to seasonal or longer climate changes will become increasingly influenced by the price of energy, availability of other forms of energy and energy-sensitive technologies, and by the success of energy conservation programs. It should also be noted that subjective perception of climate change can have an influence on energy demand, aside from actual changes in temperature or storminess.

From the experience and research of Ontario Hydro and other utilities, and analysis of climate/energy demand relationships undertaken by the Department of Fisheries and the Environment (see supporting paper), it is possible to infer, although not to predict, the range of demand for electric power that would be associated with likely ranges in climate variation in Ontario.

Because of the complexities and uncertainties of climate/energy relationships, and because of the reasonable expectation that the climate will become more variable and possibly erratic in the next decade, it is not likely that energy demand forecasts can be made with as much certainty today as has been possible in the past. Therefore, to all the contingencies and allowances for economic and social variables that will affect future energy demand, it is prudent to add a contingency factor for energy changes caused by variations in climate.

The size and nature of a climatic contingency factor would have to be based on a careful study of climate/electrical demand relationships. It is not enough to say that where the climate of Ontario becomes more variable or follows a cooling trend, the annual peak demand during a number of winters would be larger than if there were not a cooling trend. The interactions of social and technological response and use or restriction of other forms of energy could moderate or greatly exaggerate the electrical demand effect of a given climate change.

There may well be a desire to plan an electrical supply system with sufficient reserve capacity to meet the maximum anticipated peak load during the most unfavourable likely change of climate foreseen during the life of the system. Such an approach would result in idle generating capacity during most, or perhaps all of the life of the power system, and would entail perhaps unnecessary capital and maintenance costs. Careful consideration should, therefore, be given to alternative supplementary power units, off-peak storage capacity, shut-down plans, and demand regulation practices which could be more flexible and responsive to climatic change without incurring the cost and energy penalties of system expansion to provide rarely-needed capacity.

9.4 CLIMATIC FACTORS AFFECTING THE PRODUCTION OF ELECTRICITY

9.4.1 Hydroelectric Power Generation

(9-5) *The electric power system for each region of Ontario should be sufficiently diversified to ensure that the capability of generating adequate electricity in a particular region is not jeopardized by a prolonged period of drought.*

Hydroelectric power generation is sensitive to variations in precipitation, temperature, and wind. If a prolonged dry spell occurs (e.g., for six months or longer, as has recently been the case in northwestern Ontario), hydroelectric generation decreases and more expensive methods of generation have to be used to meet the demand. Temperature affects hydraulic generation (other than the contribution of atmospheric temperature to the occurrence of precipitation) through the formation of ice on headponds and around power stations. Rough bases on the bottom of ice layers can reduce stream velocity and affect available power. Frazil ice can also add to these problems, by adhering to structures or channels and, in extreme cases, blocking water flow. Wind can have little direct effect on power station operation, but can influence snow drift location and ice breakup. Its main influence is on transmission lines.

9.4.2 Thermal Generation - Fossil Fuel Power

(9-6) *Bearing in mind the need to reduce the discharge of gaseous and particulate emissions from fossil fuel power plants to the lowest level possible, plants should be located in regions where natural ventilation coefficients are large and ambient sulphur pollutant levels from other sources are low.*

The effect on the environment of emissions from fossil fuel-fired power stations, and the efficacy of various control technologies, is discussed in Sections 2, 3, and 8 of this submission. Although dispersal of emissions in the atmosphere may not protect regional environmental quality (see Section 8), nevertheless, it is true that, other factors being equal, it is environmentally preferable for a fossil fuel plant to be situated in an area of vigorous atmospheric circulation. The ability of the atmosphere to disperse pollutants is, on the whole, greatest in southeastern Ontario.

A special problem of pollutant dispersal is, at times, encountered in subarctic regions, as along the Hudson Bay coast where, during periods of very low temperature and still air, a strong temperature inversion develops, trapping pollutants and exhaust moisture ice crystals into a dense ice-crystal fog. Some northern Ontario communities are subject to this phenomenon, which is most severe at temperatures below $-30^{\circ}C$. In such areas, it is important that the community power plant be sited in the area of most vigorous natural ventilation and cold weather air drainage.

9.4.3 Thermal Generation - Nuclear Power

Nuclear power generation is relatively insensitive to climatic variations. However, the climate does have an effect on the performance of the once-through cooling system, by influencing water temperature and water mixing characteristics. A prolonged dry spell could, of course, lower lake levels, and the design of intake and discharge structures should take into account the maximum reasonable range of levels that might be foreseen by change of climate.

9.4.4 Renewable Energy Resources

(9-7) *The design of solar and wind energy systems should be based on the spatial and temporal distributions of short-wave radiation and wind energy respectively.*

The renewable energy resources of potential use to Ontario in the near future (see Section 5) are direct products of, or components of, the present climate. The energy available is limited by the characteristics of the climatic regime. The output from a solar power source is controlled by the availability of insolation received at the ground; the power produced by a wind generator is dependent on the frequency distribution of wind velocities; and the production of biomass in a forest varies according to the temperature and precipitation regimes.

Both the spatial variations in the average value of each of these parameters throughout the province and probable increase in climatic variability will affect the energy potential of each source. A considerable amount of data is available on the average energy available from sun and wind in various parts of Ontario, although more detailed site-specific information, especially concerning small-scale variations in surface wind velocity distribution, would be useful to aid in selecting optimum power sites. In general, the data confirm, not surprisingly, that the use of solar collectors should be encouraged in southern Ontario, where the availability of solar energy is relatively large, and also in west-central Ontario where the potential for wind energy is comparatively small. Areas most promising for year-round utilization of wind energy are the regions just north of Lake Huron, Lake Erie, and Lake Ontario. From the available data, the Sudbury region has the highest annual potential.

The potential production of biomass, in terms of tons of combustible or decomposable cellulose production per hectare per year, clearly depends upon climatic factors. Although there are many complexities and many factors are insufficiently known, available data suggest that the primary productivity of temperate forests of southern Ontario is about twice that of the boreal forests of the Hudson Bay slope. On this basis, intensively-managed "energy forests" (see Section 5.3.2) would appear to have a greater chance of being successful in southern Ontario, despite higher land values.

9.5 EFFECTS OF ENERGY PRODUCTION SYSTEMS ON CLIMATE

9.5.1 Hydroelectric Power Generation

The generation of electric power by hydraulic methods can result in a modification of the local climate through the creation of a headpond reservoir. If the surface area of the headpond or reservoir is large, there could be a significant effect on local temperature and humidity, and on surface winds. Increases in evaporation from the reservoir surface, over and above the evaporation that would have occurred from the unflooded area, range from about 10% in northern Ontario to as much as 20% in the southern part of the province. Most of the water evaporated would not fall near the reservoir, but would be advected into other regions.

9.5.2 Fossil Fuel Generating Stations - Emissions to the Atmosphere

(9-8) *The contribution that fossil fuel-fired generating stations make to the alteration of the composition of the regional or global atmosphere and to the planetary heat balance should be considered in long-term planning for electrical power systems.*

The effect on the environment of the combustion of fossil fuels to generate electricity has been discussed in Sections 2, 3, and 8. It has been noted that every effort should be made to prevent the main pollutants, SO_2, NO_x, and particulate matter, from entering the atmosphere. In addition, large amounts of carbon dioxide (CO_2) and waste heat are vented. Carbon dioxide and particulates can alter the composition, the reflectivity, and the net albedo of the atmosphere. If present trends of increased emission continue, it appears likely that they may cause a small increase in global mean annual temperature in the next half-century (see Section 9.2).

The local climate can also be affected by the emissions of sensible and latent heat into the atmosphere. In cases where the atmosphere is unstable, the heat injected into the atmosphere could lead to the formation of convective clouds and possible thunderstorms. It should be noted that the increases in global temperature resulting from such heat emissions are likely to be much smaller than the warming trend associated with CO_2 emissions. On the other hand, the emission of water vapour into a very stable atmosphere could increase the frequency of fog in the immediate vicinity of the plant. This is a particular problem for communities along the Hudson Bay and James Bay coasts during winter periods of calm weather and low temperature.

9.5.3 Thermal Power Stations - Heat Dissipation through Cooling Waters

Both fossil fuel and thermal nuclear power stations discharge large amounts of heat through cooling waters. The amount of energy discharged to the environment is about twice the amount of energy produced as electricity. In Ontario, almost all of this energy is rejected into the waters of the Great Lakes system. Studies are underway to measure the influence of this added heat on the hydrodynamic and biological behaviour of the lakes. It appears that, if present trends of heat discharge were to continue, and the projected future thermal power stations were to continue to use the lakes as a heat sink, by the year 2000 the increased lake temperature and resulting increased evaporation would have an important and, not as at present, a minor local effect on the environment. The net effect on climate is more difficult to predict, but the influence on humidity and cloudiness and changes in ice/open water conditions, which might influence snowfall patterns, could be expected.

9.5.4 Renewable Energy Resources

The utilization of renewable energy resources would have a negligible influence on climate. In fact, it is the absence of the addition to the heat load and the lack of influence on atmospheric conditions that make solar and wind energy such attractive candidates for supplying future energy needs.

Solar energy collectors, if used in mass over large areas, could cause local changes of surface albedo and thus affect radiation balances and, perhaps, surface winds. However, the effect would appear to be negligible. Wind generators, at most, could interfere with air flow and temperature distribution to about the same degree as a grove of trees. Poor management practices accompanying biomass harvesting could lead to either increased or decreased surface runoff, increased snowmelt, or decreased evaporation, and thus affect the local water balance; and this, in turn, could have a local climatic effect. However, such effects would not appear to be compatible with good management of the energy resource.

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SECTION 10: LAND USE AND WILDLIFE CONSIDERATIONS OF THERMAL POWER PRODUCTION

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SECTION 10: LAND USE AND WILDLIFE CONSIDERATIONS OF THERMAL POWER PRODUCTION

10.1 LAND USE SIGNIFICANCE OF SYSTEM EXPANSION

(10-1) *An electrical energy development plan for Ontario should be assessed against, and related to, a comprehensive land use plan for Ontario.*

Section 4.1 of the first submission from this Department presented a summary of the land use implications associated with expansion of the Ontario electric power production system. Considerable amounts of land can be withdrawn from other uses by expansion of the hydroelectric system. Additional land will be withdrawn from other uses by new reservoirs in northern Ontario and, to a lesser degree, by pumped storage facilities in southern Ontario. Land consumption by thermal power plants is normally substantially less than by equivalent hydropower facilities. However, their land use problems may be severe where power plants or grid terminals are located in densely settled, highly industrialized, or intensively farmed regions in southern parts of the province.

Electric power plants are a determining factor in regional development. The infrastructure associated with the construction and operation of a generating plant, such as road, rail and harbour facilities, residences, services and social amenities catering to an established or developing labour force, all use land. Despite the "averaging" effect of a province-wide electrical grid, other industry may be expected to be attracted to a new or expanding power centre, either to use the readily available power or to take advantage of a developed, secure, and expanding infrastructure. This new industry and population may be incompatible with the established land use--perhaps agricultural, forestry, or suburbia--and, thus, land use conflicts and land value injustices may result. Conflicts of this nature may place severe strains on environmental quality and make responsible environmental management very difficult.

While the land use implications of the location and operation of one power plant may be acceptable, a quite different net influence on land use may become apparent when the total power production system is assessed. An integrated power generation system may, in effect, severely restrict the options for alternate use of land in southern Ontario although, if each site were viewed on its own, it might appear that the best local choice was made. An energy development plan for Ontario should be related to a comprehensive land use plan for Ontario.

Fuel requirements for thermal generating plants can be expected to give rise to additional consumption of land for the extraction of coal in western Canada and for the mining of uranium in Ontario or western Canada; for the transport, storage, and handling of coal from western Canada to Thunder Bay; and for transport by pipeline of Arctic gas and oil to southern sites. Transportation routes, such as railways and pipelines, have much wider implications than simple consumption of land. They form boundaries or routes which can (i) restrict other movements and land use; (ii) serve as a focus for more movement of other goods and development of other industry; and (iii) strongly control nearby land values and thus land use in the adjacent areas.

Thus, the analysis of options for expansion of electric power generation systems in Ontario should be accompanied by a comprehensive assessment of the total land use implications of this expansion, in Ontario and elsewhere. Such assessment should include the long-term land use requirements, and their economic and social implications, throughout the total energy production process. It should also consider the secondary developments arising from or encouraged by different options or schedules for expansion of energy production facilities.

The electricity transmission system used in Ontario has considerable environmental and land use implications. These are discussed in Section 11.

10.2 ENVIRONMENTAL IMPLICATIONS FOR WILDLIFE OF SYSTEM EXPANSION IN SOUTHERN ONTARIO

(10-2) *The critical requirements of all natural species in the area of proposed energy production and distribution sites should be determined and considered fully before a decision is made to establish an electricity generating or transmission facility. Energy development or power plant construction should not take place in areas where unique or important habitats and natural areas may be severely disrupted or destroyed, unless all alternatives, and the cost to the ecosystem in relation to the benefits from the energy, are carefully weighed. Final location and construction decisions should not be made by energy and economic authorities alone, but by those concerned with total resource use and social well-being.*

(10-3) *The public should be made fully aware of the short- and long-term consequences, on natural plant and animal communities, of energy development at specific sites. The public should have an opportunity for taking part in the value decisions that must be made between the availability of energy as part of urban and industrial development and the maintenance of natural environmental quality and diversity.*

(10-4) *Utilities involved in plant construction and site development should be responsible for ensuring that disturbance to natural areas is minimized. Rehabilitation of natural areas should be an integral part of site development, and management procedures to preserve environmental quality should be an integral part of the operation at electric facilities.*

(10-5) *In anticipation of future power plant developments on Great Lakes shorelines in southern Ontario, a program should be instituted to assess and map areas critical for wildlife. Information resulting from this assessment should be made public and disseminated before further energy development decisions are made.*

The construction of additional thermal power plants in southern Ontario will add to the already extensive alteration of the natural environment in this region. Most of the original hardwood forests have been cleared. Over 50% of the wetlands have been drained [1]. Habitat destruction has endangered the survival of a number of species in southern Ontario which are not found elsewhere in Canada. Five species of fish from Lakes Erie and Ontario and their tributaries, four species of amphibians, and eleven species of turtles and snakes from southern Ontario are also on the list of endangered species [2, 3]. Most of the above species have a small range in Canada and very specific habitat requirements. Consequently, even slight changes in their environment can constitute a serious threat to their survival. Wetlands are probably the most critically limited habitat in southern Ontario because most of the endangered species live in water for all or part of their life-cycles. Furthermore, the wetlands of the Lake Erie and Lake St. Clair shorelines are essential for the survival of a major portion of migratory waterfowl and other birds of the Atlantic and midcontinent flyway. These habitats, and the species which inhabit them, could be particularly threatened by Ontario Hydro's expansion plans.

Because thermal power plants are most economical if located near consumers, and present designs must be located near large water bodies, future plants will likely be located largely on the shorelines of the Great Lakes. Natural habitats will be disrupted or eliminated by the plant site, service roads, transmission lines, and associated developments. In addition, certain activities at the plant site may have widespread effects on surrounding habitats. Using large amounts of water for cooling may upset the basic energy and nutrient pathways of ecosystems. Shorelines will be altered by artificial "protection" or by creating or changing the direction of currents to cause erosion or deposition. All these factors are apt, deliberately or inadvertently, to destroy coastal wetlands. Creating warm or ice-free areas may concentrate waterfowl, fish, or other animals at abnormal periods when disease or exposure could result.

In anticipation of future power developments in southern Ontario, information on areas critical for wildlife, and on the population dynamics of species believed to be endangered or threatened, is badly needed. Responsible and economically feasible energy development plans can be made in harmony with responsible environment protection and management only if the status and habitat requirements of species in a given area are clearly known and appraised before energy or associated industrial developments are evaluated and decided upon. A cooperative program to obtain and disseminate this information would be most useful, and could encompass the concerns of provincial and federal agencies, utilities, university researchers, and citizens' groups.

It will be difficult to prove the outright destruction of a species by single site development, since the main effect on wildlife is indirect through the destruction of habitat. The impact of a single plant site and natural habitat may seem small, but the incremental effect of a series of plants is easily seen to be serious. These factors make it extremely difficult to assess and appreciate fully the longer-term implications of expanding human activity such as power system developments, which are undertaken on a one-by-one basis, or to make wildlife-cost/energy-benefit calculations.

It is not a trivial matter to balance the worth of a dead turtle against the value of a megawatt of power available at the flick of a switch. The people of Ontario must be encouraged to think carefully and seriously about the irreversible tradeoffs they may be making, step by step, between convenient power now and a permanently impoverished natural world. At some point, an impoverished natural world leads inexorably to an impoverished human society and an endangered human race. We have a responsibility to assess the importance of the effect on wildlife in terms more basic than short-term economic profitability and practical convenience.

The Ontario Environmental Assessment Act and, where applicable, the federal Environmental Assessment and Review Process will help to ensure that natural environmental values are considered. However, neither covers the whole range of concerns, and such procedures are not able, in themselves, to place individual activities in the context of the health of the regional ecosystem. The ultimate protection of the natural environment must rest on the value that the human population at large places on the natural environment.

Several Acts (Canada Wildlife Act, Migratory Bird Convention Act) empower DFE to purchase and manage lands for the conservation of species. The full responsibility for the welfare of migratory birds lies with the federal government under the terms of the Migratory Bird Convention Act. Based on this Departmental mandate, a direct concern for DFE is the preservation of habitat identified as being critical for migratory birds. Only a portion of that habitat is contained in the National Wildlife Areas owned by the federal government. The Fisheries Act provides the authority to DFE to protect the habitat of fish; accordingly,the federal government has a continuing interest in the management and use of aquatic habitat from the point of view of fish production. The Department also places considerable importance on the preservation of habitat critical to the survival of endangered species which, though directly under the provinces's jurisdiction (except migratory birds), is a national concern.

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PART IV

ELECTRIC POWER TRANSMISSION

SECTION 11: ELECTRIC POWER TRANSMISSION

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SECTION 11: ELECTRIC POWER TRANSMISSION

A discussion of some of the more significant environmental effects associated with the transmission and distribution of power was presented in Sections 4.2 and 5.5. of the first Departmental submission to the Commission. Statements arising from these sections are presented below, with further discussion.

11.1 AESTHETIC ASPECTS OF TRANSMISSION LINE CORRIDORS

(11-1) *The aesthetics of transmission lines should be considered in route selection, structural design, and corridor maintenance. Consideration of aesthetic factors should include the effect of aesthetics on land values, social acceptability, and the consequent influence on energy costs and overall resource use.*

Transmission lines and the swath created for them present an unpleasant visual impact on many people [1]. This visual impact can have a strong influence on land values and on the social acceptability of living, working, or engaging in recreation near transmission lines. In turn, these factors affect the use of the environment and resources in the vicinity and, hence, the costs of environmental management and the net costs of energy. Thus, attention to aesthetics is not a luxury or a frill, but a sound investment. In many cases, the ultimate solution to undesired transmission lines is underground transmission, but there is still considerable scope in minimizing the aesthetically negative aspects of overhead transmission. This can be achieved by careful planning to avoid visually sensitive areas, designing routes that enhance pleasing topography rather than disrupting the scenery, using attractively designed structures, placing structures where they blend into background, and screening with vegetation. Sophisticated methods of selecting the least obtrusive route have received considerable attention and research by planners and landscape architects in recent years [2, 3]. Ontario Hydro is encouraged to take advantage of worldwide developments in this area.

11.2 MULTIPLE USE OF TRANSMISSION RIGHT-OF-WAY

(11-2) *The land within the transmission line corridor should, wherever possible, be made available and managed for other uses compatible with the protection of natural biological systems. However, where important or unique plant or animal life in the region is threatened, advantage should be taken of the opportunity that transmission line rights-of-way offer to provide natural refuges with strictly controlled access.*

(11-3) *Planning for the future expansion of the electric power transmission system should consider options based on the utilization of existing corridors and on multiple-use corridors. Such considerations should include the range of transportation systems and the social and environmental costs and benefits of corridor options.*

Given the increasing value of land for food growing, recreation, and ecological preservation, particularly in the more urbanized areas of the province, it would seem to be highly desirable that single purpose or restrictive land use by transmission line corridors be minimized wherever possible. With proper planning, rights-of-way can be used for wildlife habitat and recreation, in addition to their primary use [4, 5, 6].

Because transmission line corridors in Ontario traverse a wide range of geographical and environmental conditions, often within relatively short distances, there are admirable opportunities for a diversity of uses that are compatible with their main purpose of protecting the carriage of electricity. Food growing, cross-country skiing and hiking, silviculture and fish rearing all can be successful, with due consideration of the needs of the utility, and of human safety and adjacent property rights. If the biological aspects of corridors are to be preserved, it may be necessary to prohibit insensitive uses such as by snowmobiles and all-terrain vehicles. Some rights-of-way are admirably suited for management as "linear parks" or ecological preserves where the diversity of natural plant species can be maintained and encouraged in otherwise fully developed areas.

Linear land consumption by road, rail, pipeline, transmission, and communication systems not only restricts or eliminates land use options in the right-of-way, but also is a determining factor in the evolution of adjacent and regional land use patterns. Multiple-use corridors are one way to reduce such effects [7].

11.3 CONSTRUCTION

(11-4) *Transmission line routing through forested or other natural areas should avoid sensitive environmental areas and give due consideration to relative environmental values affected, such as wildlife habitats and habits, and the effects of removal or constriction of productive forest areas.*

(11-5) *Rehabilitation or restoration of damaged natural areas should be an integral part of transmission line construction.*

The most obvious environmental impact of a transmission line is the cleared corridor which accompanies it. For every 100-200 feet of transmission line, depending on width, one acre of land is required. The removal of forest and bush can adversely affect nearby water quality and water flows. Clearing of land in forested areas removes from production a valuable natural and renewable resource. Forest, wetland, and other wildlife habitats would be altered, or could be irreversibly damaged, by the creation and maintenance of the open corridors in forests and the construction of access roads. The linear band of cleared land may make more difficult the management of a forest and increase the cost of harvesting. On the other hand, the associated access roads may increase the efficiency of management or lead to overexploitation and overuse.

The effects of transmission corridors on natural habitats are mainly incremental. However, the seminatural communities which develop in transmission rights-of-way may be attractive for some native species of wildlife and plants, and apparent increase in bird-nesting is frequently noted. Routes which are chosen to avoid undisturbed areas and to follow existing corridors can minimize loss of habitats. When accompanied by rehabilitation or restoration programs, a return to productive, altered but still natural, conditions can be accelerated appreciably. If properly planned and managed, transmission corridors can be environmental assets rather than problems.

11.4 CORRIDOR MAINTENANCE - USE OF HERBICIDES FOR VEGETATION CONTROL

(11-6) *Environmental effects on various ecosystems arising from herbicide application in transmission line corridors should be closely monitored to ensure environmental problems do not result. Special consideration should be given to the question of herbicide persistence and to the possibility of cumulative or synergistic effects.*

(11-7) *Consideration should be given to alternatives to herbicides for the management of vegetation in transmission line corridors.*

Common procedures for maintenance of rights-of-way in Ontario include the use of herbicides for controlling vegetation. The justification for this practice is that herbicides are cheaper than manual methods of vegetation control. If the corridor has no other use or value and its maintenance cost is charged solely to the cost of providing energy, then the cheapest effective method will continue to be used. To date, the use of herbicides by Ontario Hydro does not appear to have resulted in important identified environmental problems. However, the continued application of such toxic substances to natural areas can cause significant long-lasting environmental effects unless great care, based on knowledge of the effects on the ecosystem, is taken in their selection and use. Knowledge in this area is still incomplete. A process of pre- and post-registration review of herbicide use has been established, which aids in the assessment of the potential environmental effects of the use of toxic substances to control vegetation.

Alternatives to herbicide use may provide satisfactory vegetation control with minimal adverse environmental risk. In some regions, a stable low-growing vegetative cover can be established without resort to chemical control [8, 9] or by the use of growth inhibitors that have low toxicity [10]. The main alternative to the use of herbicides is managed multiple use of the land of the corridor, so that it is valuable for more than providing a clear place beneath overhead wires. If there are concurrent valuable uses, management of the land can include care and management of the vegetation, and the costs can be justified for purposes other than energy transmission. For example, in British Columbia, a program of using the corridors as forest seedling nurseries managed by Junior Forest Rangers and other youth groups has been successful from the point of view of both youth training and management of the vegetation in the corridor.

Special precautions should be taken in the use of herbicides in especially sensitive areas, such as the muskeg tracts south of the Albany River. In general, the Hudson Bay slope contains large portions of organic terrain with more sensitive and fragile ecosystems than would be found farther south, and chemical control methods should be avoided if at all possible.

11.5 CHEMICAL POLLUTANTS

11.5.1 Sulphur Hexafluoride Gas in Switchgear

(11-8) *Measures to contain and prevent the escape of sulphur hexafluoride to the environment should be strictly adhered to in order to avoid any unnecessary buildup in the atmosphere.*

The potential problem of sulphur hexafluoride, which may be released from some electrical switching equipment, was briefly discussed in Section 5.5.4.1 of the first submission. SF_6, in itself, is considered to be harmless to man. However, it may lead to conditions conducive to asphyxiation, due to exclusion of air from the atmosphere. The sensitivity of other forms of life, particularly during winter dormancy, is not known. In view of the current concern regarding the effects of aerosols on the atmosphere, precautionary measures to contain this gas should continue.

11.5.2 Polychlorinated Biphenyl Compounds

(11-9) *During the mandatory phase-out of polychlorinated biphenyl compounds from industrial and domestic use, extreme care should be taken to ensure that these materials do not enter into the environment unknowingly or through inappropriate disposal methods.*

PCBs have been shown to affect the health of, and inhibit reproduction in, most fauna and human beings. Recent discoveries of the very persistent nature and the widespread presence of PCBs have created much concern.

A federal regulation to control the use of polychlorinated biphenyl compounds was published in the Canada Gazette on February 26, 1977. This regulation will eliminate the use of PCBs in any new goods other than electrical capacitors and transformers, effective June 1, 1977. It has been promulgated as the first step towards a planned complete elimination of PCBs from all uses in Canada.

Some heat transfer and hydraulic equipment and vapour diffusion pumps still use PCBs. The proposed regulation is intended to permit those uses only for a period sufficient to allow an orderly change-over to alternative materials or techniques. The elimination of the use of PCBs in new electrical equipment and, eventually, the replacement of existing electrical equipment containing it is necessary in order to complete the total phase-out of the use of PCBs.

A notice in the January 8, 1977 issue of the Canada Gazette requires anyone engaged in activities involving PCBs to notify the Department of Fisheries and Environment. The Department is now compiling information on the quantities of PCBs in various inventories and waste streams, and is identifying likely sources of future losses of PCBs into the environment so that preventative action can be taken. The Department considers it most important that surplus PCB material or equipment that contains PCBs not be disposed of along with ordinary waste materials. Normal incineration, for example, may disperse, not destroy PCB compounds.

Fisheries and Environment Canada regards the PCB problem as one of high priority. PCBs will be one of the first toxic substances to be subject to regulation under the new Environmental Contaminants Act.

11.6 OPERATIONAL IMPACTS

11.6.1 Ozone

Two areas of possible environmental impact from the transmission of power were reviewed in the first submission, namely, ozone from high voltage transmission lines and electromagnetic radiation association with the transmission system. In the case of artificially produced ozone, no significant environmental effects have been identified.

11.6.2 Electromagnetic Radiation

(11-10) *Ontario Hydro should continue its research [11] and its monitoring of the results of research elsewhere on the possible human health effects arising from high voltage electric fields and ambient microwave radiation. Consideration should be given to the possible effects on other forms of life and the identification of long-term or cumulative effects on humans.*

Section 5.5.3.2 of the first submission pointed out the rudimentary state of knowledge of the biological effects of electromagnetic radiation in the environment. Research is still in the exploratory stage. Evidence to date on the biological or environmental importance of ambient electromagnetic fields varies widely and is, in part, contradictory. There is no consensus on whether further reseach in this area is justified. It would appear, however, there is reason to suspect that chronic exposure of humans to low level, nonthermal, microwave energy can produce or influence biological and psychological changes. Suspected effects include damage to the central nervous system, increased incidence of heart attacks and cataracts, cell growth abnormalities (cancer), and erratic behavioural patterns.

Although unequivocal evidence for direct physiological damage from electromagnetic fields is lacking, it is clear that, for the first time in his evolutionary history, man has been subjecting himself for a full generation to ambient levels of microwave and radiofrequency energy millions of times stronger than those occurring naturally. His maximum doses, obtained from proximity to high voltage electrical equipment, are also a new biological experience except for organisms that happen to be in the path of lightning bolts. The effects of these electromagnetic experiences are not known, nor is it known whether they can be dismissed as negligible.

Because of the unproved nature of electromagnetic risk, few standards of safety have been proposed. The Soviet Union has set an exposure level for electrical workers that is 1,000 times lower than that allowed in the United States for prolonged exposure, and ten times lower for short exposure. No standards have been set in Canada.

In view of the planned development of a high-tension electrical transmission grid and the extensive microwave communications system employed by Ontario Hydro, and because of the increasing public use of electric power for radiation emitting devices such as household microwave ovens, the potential effects of electromagnetic energy on humans and other organisms should be better known. Ontario Hydro has undertaken some research in this area. It is recommended that these studies be continued, with the collaboration of environmental and health agencies, and that advances in knowledge in other countries in this little known but potentially vital field be monitored.

11.7 REFERENCES TO SECTION 11

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