COMPARING AND ASSESSING THE ENVIRONMENTAL IMPLICATIONS OF CONVENTIONAL, NUCLEAR, AND RENEWABLE ENERGY OPTIONS FOR ELECTRIC POWER PRODUCTION IN ONTARIO

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PREFACE

This paper is a follow-up to the document entitled "Electric Power Production and Transmission in Ontario from an Environmental Perspective", May 10, 1977, by Fisheries and Environment Canada. This latter document was prepared for submission to the Ontario Royal Commission on Electric Power Planning for the main hearings stage of the Commission's inquiry.

The development of this follow-up paper was assisted by contributions from a number of staff members within Fisheries and Environment Canada. Special acknowledgement goes to Mr. B. A. Emmett for his major contribution to Section 3 and for his role as critic of earlier draft versions, as well as to Mr. D. W. Brown, Mr. C. Cheng, Dr. R. Durham, Mr. R. Moulton, Mr. V. Shantora, and all others who assisted in preparing the Appendix to this paper.

The contents of this paper reflect the views of the author alone and not necessarily those of Fisheries and Environment Canada.

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INTRODUCTION

It is becoming recognized increasingly that technological applications give rise to effects which go far beyond the immediate implications of the particular application. Highly significant, but often less obvious, effects of a longer-term, cumulative, and broader economic, social, and environmental nature can result, in addition to the direct implications. Thus, a proper assessment of alternate technological applications to achieve particular social goals must be both systematic and comprehensive. In the case of alternate energy options, such an assessment has not been undertaken in this country at a general (vs. project) level. Major constraints are of an informational, methodological, and institutional nature.

This paper focuses on one particular component of what would constitute a comprehensive assessment of alternate energy supply options, namely, the environmental implications. The paper suggests what factors should be considered in comparing the environmental implications of options such as those dealt with in the Departmental document noted in the Preface. These options were: conventional (hydro, coal, oil and natural gas, and solid waste materials), renewable (solar, wind, and forest biomass), and nuclear sources for electric power production. A number of guidelines for conducting a comprehensive, comparative, environmental assessment of energy supply options are also defined. Although the paper is oriented to the particular case of Ontario, it also should have considerable relevancy to other regions of Canada.

In order to provide an environmental management context for this paper, three main approaches for minimizing environmental impacts from energy systems are outlined (Section 1). One of these approaches concerns the selection of the most environmentally appropriate energy option or group of options. This requires comparing and ranking the options in terms of environmental preferability. The information base for such a comparison and ranking of electric power production is discussed in Section 2 and supported by the Appendix to the paper. General guidelines for conducting more detailed and comprehensive environmental assessments of energy options are provided in Section 3.

It is hoped this paper will contribute to overcoming both informational and methodological constraints to the conducting of the environmental portion of a comprehensive, systematic assessment of alternate energy options.

SECTION 1: APPROACHES FOR MINIMIZING ADVERSE ENVIRONMENTAL EFFECTS OF ENERGY SUPPLY OPTIONS

There are three main approaches for reducing the adverse effects on the environment arising from energy supply systems:

1. Reduction of the production and consumption of energy (energy conservation).

2. Application of environmental controls and safeguards.

3. Adoption of the most environmentally appropriate energy supply option or group of options.

These approaches are discussed below.

1.1 ENERGY CONSERVATION

The results of the Department's submission entitled "Electric Power Production and Transmission in Ontario from an Environmental Perspective" (May 10, 1977) indicate that no electric power supply option is without significant environmental impacts and that these impacts are generally a function of the capacity of the electric power production system and the level of operation. The same is true of the production and consumption of energy in general. From an environmental point of view, the highest priority should be given to measures which will reduce overall energy demand, including projected growth rates, to levels which are as low as possible without causing undue hardship to society [1]. Conservation measures should concentrate on changing institutionalized patterns of

energy consumption which have become "locked in" from the recent era of relatively cheap and abundant energy availability [2], as well as on changing consumption patterns which are more immediately responsive to energy conservation policies.

1.2 ENVIRONMENTAL CONTROLS AND SAFEGUARDS

The development and application of any energy supply option should be contingent on the assurance of adequate environmental protection from either routine or nonroutine releases. The costs to achieve adequate levels of environmental protection should be internalized in the assessment of each particular option. Adequate controls and safeguards are extremely difficult to define in absolute or general terms. Even with extensive pollution controls, cumulative effects may still occur from large-scale developments which exceed environmental assimilative capacities or produce long-lasting toxic materials. Also, safeguards may be to the highest possible standards, but if the risk of an accident is still real and would entail significant irreversible or long-lived effects, only a virtually 100% assurance against such an accident might be considered adequate. It is society who eventually must make such decisions, but it is the role of the responsible public agencies to bring such matters to public attention.

New technologies, such as advanced CANDU cycles, will involve major changes in the nature of the real or perceived risk to human health and the environment posed by the generation of electric power. Environmental protection measures could become increasingly stringent in

the face of such changes. Anticipation of this likelihood in energy supply planning will be essential to help reduce prolonged disruption in power supply development.

Some new technologies of energy systems will require attendant, new pollution control measures or devices and perhaps new environmental protection concepts. In some cases, it may be more cost effective to develop cleaner or less risky processes or subprocesses for fuel production or power generation in order to meet existing or anticipated environmental regulations, rather than attempting to retrofit pollution control equipment to processes which are inherently "dirty" or risky.

Sufficient lead time should be allowed so that environmentally appropriate control technology and management systems are available well in advance of the deployment of a new system. Ideally, the energy technology and the environmental protection system should develop together. Environmental protection technology, if successfully applied in time, may significantly reduce the net social cost of energy supply in terms of damage to the environment and human health. As prevention of environmental damage is generally much cheaper than cleaning up after the fact, this approach is cost effective in social terms. This approach also can be cost effective in private terms by avoiding the need for expensive retrofitting or early phasing-out of processes rendered infeasible by changing environmental protection requirements and public attitudes.

1.3 ADOPTION OF THE MOST ENVIRONMENTALLY APPROPRIATE ENERGY SUPPLY OPTIONS

Some energy supply options are inherently more environmentally polluting than others. By selecting less polluting options wherever possible or practical, environmental impacts associated with the energy supply system can be reduced considerably.

In some (but not all) cases, the choice of a more environmentally appropriate option would require a premium to be paid, for example, in economic terms. The ultimate choice should be based on consideration of total costs and total benefits (see Section 3). However, from the environmental management point of view, emphasis should be given to encouraging environmentally appropriate options, even where a premium may have to be paid, in order to encourage research and development which will reduce the total costs (and increase the total benefits) of such options and, hence, increase their ultimate attractiveness.

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The above third approach for minimizing the adverse environmental effects of energy supply options is the focus of this paper. In the sections which follow, information requirements for assessing environmental implications of each option are discussed, followed by guidelines for conducting comparative environmental assessments of the various options.

SECTION 2: COMPARING ENERGY SUPPLY OPTIONS: ENVIRONMENTAL CONSIDERATIONS

In comparing and assessing the environmental implications of various energy supply options, it is important to consider both direct and indirect impacts. Figure 1 illustrates the concept of direct and indirect environmental impacts.

2.1 DIRECT ENVIRONMENTAL IMPLICATIONS

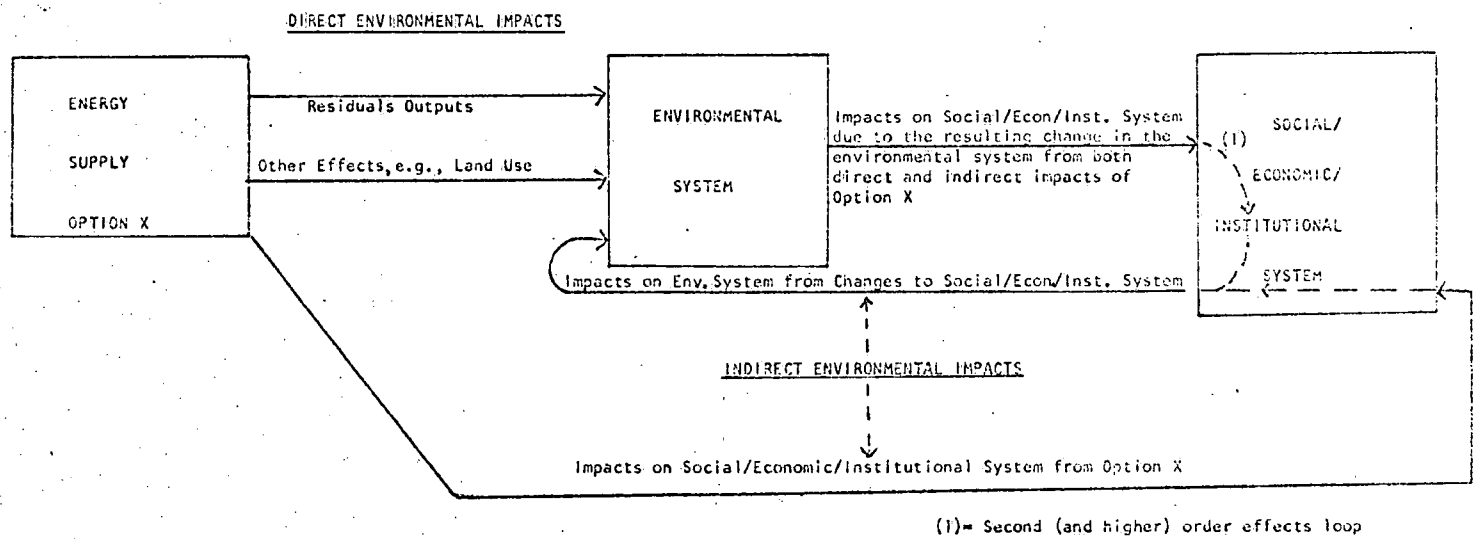
In the Department's submission entitled "Electric Power Production and Transmission from an Environmental Perspective" (May 10, 1977), a number of direct environmental impacts or possible impacts associated with each electric power production option were reviewed. Impacts throughout the total power production cycle were considered. A summary listing in comparative format of these impacts is provided in the appendix to this current paper.

2.2 INDIRECT ENVIRONMENTAL IMPLICATIONS

In addition to the more obvious or direct environmental implications, there are other less direct, but perhaps equally important, implications which should be considered in the environmental assessment of individual options. These may arise from, for example, the size and technological complexity of the current and planned electric power system. Several of the more important implications associated with the planned electric power system for Ontario are discussed below.

FIGURE 1

CONCEPTUAL ILLUSTRATION OF DIRECT AND INDIRECT ENVIRONMENTAL IMPACTS



2.2.1 Energy Research and Development

The choice of energy supply options toward which energy research and development resources are concentrated has substantial, indirect environmental implications.

The proposed reliance on nuclear energy (including future developments associated with nuclear technology) as the primary source of Ontario's future electric power requires a substantial research and development commitment in the form of scientists, technologists, and funds. Concentration on high cost technological options of this nature tends to lock the future into a technological fix which may not be appropriate in the context of changing future realities such as the possibility of evolving social values. For example, there are indications of a shift to values which seek expression in a more decentralized society based on a smaller-scale, renewable energy resource technology, which could have substantial environmental benefits in the long term.

The magnitude of the nuclear research and development effort required, particularly in a relatively small market such as Canada, creates pressure to seek investment recovery through export to countries where environmental or safety regulations may not be as stringent and where deliberate "diversion" is a real possibility, with attendant risks to the global (including Canadian) environment. This level of effort may also detract from seeing the potential (in social and environmental, as well as economic, terms) of less sophisticated or smaller-scale technologies and also in energy conservation, neither of which have enjoyed the benefits of

developing and implementing alternative energy sources and energy conservation programs, options which have a number of environmental advantages in many (but not all) cases. In effect, investments in planned energy systems will limit seriously the availability of funding necessary to raise more environmentally appropriate energy supply and conservation options to the level of feasibility and acceptance that conventional and nuclear options now enjoy. The environmental importance of a comprehensive and concerted energy conservation program in reducing large capital expenditures for energy supply systems is readily apparent.

Thus, in choosing among capital investment options for energy system expansion, consideration should be given to the broader implications of large capital expenditures such as their influence on the direction of future technology development, and the availability of resources for pollution control and for the development of more environmentally appropriate energy supply and conservation options.

2.2.3 Lead Time Requirements

The demand for electric power fluctuates considerably on a daily, weekly, seasonal, and sometimes annual basis. Ontario Hydro has developed various load management practices to deal with these short and medium-term fluctuations in load patterns. The long-term load following capability of the electric power system should also be given careful consideration. The next 25 years or so cannot be expected to see the relatively stable (growth) situation experienced over the preceding quarter-century. On the

supply side, the finite nature of nonrenewable energy resources and their availability at an endurable cost level (in social, economic, environmental, and political terms) is becoming increasingly apparent. On the demand side, long-term energy consumption patterns will see considerable fluctuation due to "externalities" such as climatic variability, changes in world and domestic economic development, changes in lifestyles relating to material consumption patterns (transition to "post-industrial" society?), more efficient use of all resources, and energy conservation programs. Factors such as these suggest the electric power system should be designed for long-term, as well as short-term, load following capability, with considerable inherent flexibility to expand or contract generating and transmission capacity as required.

High capital cost energy system components which require long lead times before power is actually produced, such as nuclear power generating plants with lead times which may range from 12 to 15 years, can reduce long-term system flexibility as compared to smaller components with shorter lead times. In the case of a nuclear power plant, once the decision is made to proceed (based on estimates of long-range load requirements), there is no power produced for 12-15 years and then, for example, 3,000 MW fixed capacity for 30 or more years. In the meantime, the demand situation may have either increased dramatically, stabilized at virtually no growth, or declined. Although "large lump", long lead-time effects can be smoothed in times of demand growth through phased implementation of a number of large plants, this approach can backfire if demand stabilizes or declines.

Effective long-term load following capability is important from an environmental as well as social and economic point of view. Long-term surplus system capacity weakens the resolve to promote energy conservation and creates an incentive to encourage increased consumption, including consumption through power export. The environmental impacts throughout the power production cycle arising from that increment of power which is produced in excess of what is needed could be substantial. On the other hand, a shortage of generating capacity, although giving an added boost to (or "forcing") energy conservation measures, may encourage the hasty substitution of energy supply alternatives which are less appropriate in social and environmental terms. Thus, there appears to be clear social and environmental benefits in developing energy supply systems which feature inherent flexibility and adaptability to changing energy consumption patterns. These system features should be utilized in conjunction with a concerted program of energy conservation which ensures the energy system responds to the real need for, not just demand for, energy.

The ideal situation may be an electric power system which has a relatively fixed long-term "core" or base load capacity, in combination with a substantial medium and long-term flexibility component which would permit fairly close load following capability during periods of substantial energy supply or demand fluctuation. Criteria for this flexibility component might include short implementation lead times, rapid response through add-on (or take-off) capacity, ease of recyclability of components and, possibly, a degree of system or component mobility to other load

centres where the need is greater and which are not connected to the transmission line network.

Certain applications of renewable energy resources, particularly those which offer shorter planning and implementation lead times and which lend themselves to smaller-scale applications, offer the potential to contribute substantially to more effective total electric power system flexibility and adaptibility. This could take the form of centralized generation directly into the grid system, decentralized or point-of-demand generation to dedicated users (e.g., photovoltaic cells on rooftops), or the direct (unconverted) contribution of energy for end uses such as space or water heating (e.g., solar panels on rooftops), as a substitute for electric power. Although economic barriers are currently significant, solar photovoltaic cells, aerogenerators, and biomass sources hold potential for increasing energy supply flexibility. If system flexibility were given an economic value, the economic barriers facing system components with more inherent flexibility would be reduced.

Regardless of the potential of alternate energy sources for contributing to energy system flexibility, full consideration should be given to developing energy systems for medium and long-term, as well as short-term, load following capability as an explicit design criteria.

2.2.4 Centralization vs. Decentralization

Because of economies of scale, electric power is most economical in large centralized electrical generation facilities. Not only does this

result in centralized production of residuals and thermal effluent, the centralization of power production also affects the distribution of population and industrial activity. Both place demands upon the environment which are different than they would be if a similar amount of power were produced by smaller, dispersed facilities.

From an environmental standpoint, there are both advantages and disadvantages to decentralized power production. Although the land consumption factor associated with plant site and connecting transmission line corridors would likely be greater in the case of a series of smaller and dispersed thermal plants, there is more opportunity for the environmental assimilation of air and water pollutants (including waste heat) than in the case of a single equivalent energy centre where the environmental effects would be more concentrated. However, in the case of pollutants which do not readily assimilate and which have long residence times in the environment, decentralization of production facilities cannot be viewed as a solution to long-term cumulative effects. The long-range atmospheric transport problem and the cumulation of CO_2 levels in the atmosphere are examples of this. Only an absolute reduction in emission levels can be considered a viable solution in such cases. This reduction may be more economically achieved in the case of larger plants.

The environmental benefits from decentralization may be more significant when renewable technologies are considered which harness dispersed energy sources and match them to dispersed energy needs. Rooftop solar collectors, such as photovoltaic panels which serve as a substitute

for electric power from central power generating systems, can reduce the need for land required by central generating facilities and transmission line corridors. Local or backyard wind generators can also produce a reduction in land requirements of central systems, but the aggregated land requirements of a number of individual generators sufficient to meet an equivalent level of power demand could be substantial.

Decentralized, smaller-scale energy supply technologies enjoy a growing appeal in a society which is seeing signs of a desire to be more self-sufficient on an individual and community basis. Such technologies also are likely to be more appropriate to the needs of less industrialized nations, and their use could contribute to improved local and global environments.

SECTION 3: GENERAL GUIDELINES FOR ENVIRONMENTAL ASSESSMENTS OF ENERGY SUPPLY OPTIONS

In Section 3 of the Department's first submission to the Commission dated October 8, 1976 [3], the importance of considering the total costs and total benefits, including social, economic, and environmental implications, was discussed in assessing energy supply options. It was admitted that this is an appealing and relatively straightforward concept in theory, but represents a difficult task in practice, particularly where less tangible factors such as those relating to human and environmental health and aesthetics are involved. This current section suggests requirements for developing the information base for the environmental component of this comprehensive assessment. It should be noted that any change in the state or quality of the natural environment arising from, for example, the impacts of any stage of the power production process will have social and economic as well as broader ecological implications. Thus, the importance of a comprehensive environmental assessment is evident.

General guidelines for the collection, analysis, and assessment of information on the environmental implications of energy options are presented and summarized in this section. Implicit in any assessment is a valuation and comparison of sometimes diverse factors. Before reviewing these guidelines, a conceptual framework for approaching this difficult problem of placing a value on environmental impacts follows.

3.1 VALUE OF THE ENVIRONMENT TO SOCIETY

In economic and social terms, it is both constructive and appropriate to regard the environment as a scarce and valuable natural resource which contributes to society in two ways. Firstly, the natural environment contributes to the physical and psychological well-being, or quality of life, of individuals now and in the future through, for example, the provision of clean air to breathe, water to drink, opportunities for recreation, beauty to appreciate, and the intrinsic value of a healthy ecosystem. Secondly, the natural environment contributes to material standards of living (as measured, for example, by GNP per capita) by providing a variety of inputs to production and consumption activities. For example, the environment serves as a "factor of production" [4] by providing raw materials such as forest materials for paper, and fish and vegetables for food processing; by providing energy such as biomass and solar energy for process and space heat (fourth factor of production after materials, labour, and capital); and by serving as a receiving medium for the byproducts of industrial processes (fifth factor of production?).

The two above uses of the natural environment, while not entirely mutually exclusive, are often in conflict. In a large number of cases, for example, using the environment to support the production and consumption of energy will cause a deterioration in environmental quality and a reduction in the direct contribution the environment can make to the quality of life. Beyond a certain point, the misuse of the natural environment will affect permanently and inevitably the productive capacity of Canada and impair the

health of its citizens. The fact is often ignored that, even though nature may have been "tamed" or "conquered", the sustenance of all human life is totally dependent on maintaining a certain level of environmental quality.

While the natural environment may be appropriately viewed as a natural resource, it is unlike other natural resources in one important respect. It is not subject to individual ownership but is, in general, a common property resource shared collectively by society as a whole. Thus, the value to be attached to the preservation of a clean and healthy natural environment, as opposed to its increased use to support production and consumption activities, is a matter of collective or social choice. Environmental impacts are an inevitable consequence of energy production and use. The key to making appropriate social choices regarding either the protection or use of the natural environment with respect to an energy supply system is adequate and appropriate information regarding the total costs and benefits (environmental, economic, and social) of each energy supply option and also of energy conservation measures. Guidelines for developing this information base are outlined below.

3.2 GENERAL GUIDELINES

1) Assessment at Each Stage of the Energy Production Process

The approach taken to consideration of energy supply options should be comprehensive. Environmental impacts of each stage of the total energy production and consumption cycle (where applicable) from fuel

exploration through fuel extraction, upgrading, transportation, conversion (e.g., to electric power), waste disposal or waste management, transmission, and end use should be assessed. In addition, the environmental impacts arising from associated materials production, where these are significant relative to other impacts from the same options, such as in the case of solar panels and hydro power projects, should also be considered.

2) Routine and Nonroutine Impacts

Both routine environmental impacts associated with normal operations and the possibility of nonroutine environmental impacts associated with malfunction, accident, or deliberate diversion or damage should be carefully assessed.

3) Assessment Procedures for all Energy Options

The above guidelines should be followed consistently with respect to all energy options including renewable energy options and conservation measures. The environmental consequences of not having enough energy should also be assessed where applicable.

4) Impacts from Associated Developments

It is not sufficient to assess the environmental impacts of single energy facilities in isolation. Most energy facilities are part of integrated and cumulative energy and industrial systems. For example,

energy developments tend to attract secondary and tertiary developments in given industries which benefit from the established infrastructure. It is the cumulative effect on the environment of all developments or activities which is of concern, not an energy facility in isolation.

5) Indirect Environmental Impacts

Some energy options require extensive research and development resources, have large capital requirements, and involve long lead times before energy is actually produced or delivered. When such options are pursued with vigour, they give rise to less direct, as well as direct, environmental implications (see Section 2.2). Indirect implications include the availability of funds and R&D resources for developing and implementing more environmentally appropriate energy options such as certain renewable energy resources and energy conservation. Implications also arise from the capability of the energy system to "follow" changing longer-term energy needs patterns which, in turn, affects system size and energy production levels, factors which are determinants of environmental quality. These indirect environmental implications are just as real as the more direct impacts such as those arising from the production of residuals, and should be included in any comprehensive environmental assessment of energy options.

6) Information Analysis - Cost/Benefit Analysis

As cost/benefit analysis is frequently employed in making economic evaluations of energy projects, it is convenient to be able to express environmental impacts in terms which fit into an economic cost/benefit framework. Theoretically and, in some cases, practically, it is possible to translate, using various techniques, impacts on the natural environment into costs or benefits measured in dollar forms for direct inclusion in a cost/benefit type of analysis. In these cases, trade-offs become relatively straightforward: $X worth of improvement in environmental quality can be obtained by foregoing economic activity which would have generated $Y in net economic benefits. However, in some important cases, this dollar cost/benefit framework is inadequate or does not apply. It may even be misleading or inappropriate to speak of environmental costs and benefits, terms which are often automatically given an economic interpretation. Some of the more significant limitations of traditional cost/benefit analysis are discusssed below, together with suggestions for other approaches to analysis. This topic was reviewed in Section 3.3 of the Department's submission dated October 1976 [3].

a) Environmental Risks from Accidents and Unknowns

Due to the great complexity of ecosystems, many environmental impacts are either completely unknown or known with considerable uncertainty. Some energy supply options involve risk of significant, nonroutine (e.g., due to accident or diversion)

damage to the environment. In these cases, cost/benefit analysis must be replaced by some form of risk/benefit analysis. Even risk/benefit analysis implies that, firstly, some widely accepted probability can be attached to the possibility of accidents which might threaten the environment and, secondly, that an assessment can be made in dollar terms of the environmental consequences of adverse outcomes, which again could be misleading or inappropriate.

b) Irreversibility of Impacts

Traditional cost/benefit analysis is not directly applicable where irreversibilities are important. These fall into two broad categories: firstly, the proposed use of irreplaceable natural environmental sites, with unique scenic and/or recreational attributes, for the production of energy; and, secondly, the release into the environment of substances for which the environment has no assimilative capacity. These substances persist essentially indefinitely and have adverse long-run impacts on ecosystems and human health (mercury, cadmium, PCBs, Mirex, etc.). Although ways have been suggested to modify cost/benefit analysis to take into account the value of unique, natural environments [5], there is essentially no satisfactory way, even theoretically, to apply cost/benefit analysis to the second case.

Where irreversibilities which threaten human health are involved, the trade-off concept implicit in cost/benefit analysis doesn't apply. Such analysis should be replaced by standards (effluent, emission, dumping, etc.) based on biological and epidemiological data, which would require output levels below those initially dictated by cost/benefit criteria [6].

c) Intangibles

There are also difficulties in incorporating intangible environmental effects (e.g., loss of scenic beauty, solitude, peace and quiet, etc.) into standard cost/benefit analysis. Despite a variety of techniques suggested, there is no universally accepted way to include such considerations [7]. Intangible effects can have social implications which are just as real as more tangible effects. Thus, regardless of their degree of intangibility, all impacts should be given explicit recognition in the analysis and decision-making process, in order that adequate weight is given to intangible as well as tangible factors.

d) Distribution of Impacts over Time and Space

Concern should not only be directed to the magnitude and nature of environmental impacts, but also to the distribution of the effects of these impacts among groups in society and across

generations. For example, just as there is concern about the adequacies of energy supplies left for future generations, so should there be concern equally about the quality and productivity of the natural environment left to future descendents. Both energy and environmental resources are crucial elements in determining the overall viability and productivity of society now and in the future [4, 8].

e) Economic Costs of Environmental Protection Measures

Despite serious reservations regarding the applicability of cost/benefit analysis in a variety of circumstances involving environmental impacts, environmental protection does involve the input of resources which have value in alternative uses in society. Therefore, where cost/benefit or risk/benefit analysis does not apply, some form of thorough economic analysis such as cost effectiveness analysis should be applied to determine the least cost way of attaining environmental standards set by political processes or on the basis of epidemiological or other data.

7) Full Public Disclosure

Full public disclosure of information on which major energy decisions may be based should be made well in advance of any commitments [9]. The public should be informed of all alternatives and their possible

implications in order to provide for active participation based on public awareness and understanding. It is particularly important that information on which judgemental decisions (made either explicitly or implicitly) will be required is clearly identified in order that such decisions reflect the concerns of younger generations and more vulnerable groups whose future livelihood and culture may be at stake.

8) Role of Public Participation in Environmental Assessment

The limitations of both the market system and traditional political and institutional decision-making processes in giving adequate consideration to social, environmental, and broader economic factors in certain situations has created the need to conduct special assessments or public inquiries on large programs and projects with significant impacts. In attempting to place valuations on both quantifiable and less tangible factors, the market system and techniques such as cost/benefit analysis (as discussed above), in many cases, inadequately reflect the numerous and sometimes conflicting social values affected. One solution is to short-circuit more traditional processes and go directly to source to seek the full participation of the interested and affected public in the decision-making process [10]. Effective public participation not only strengthens the democratic process, but also offers an alternative or supplement to analytic techniques such as modified cost/benefit analysis in evaluating and weighting the social, environmental, and economic implications of large projects such as expansion of the electric power system. Full public disclosure of information, as discussed above, is essential to develop an

informed public. This is an important prerequisite for effective public participation.

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The above general guidelines offer a framework for designing environmental assessments of energy supply options. More specific guidelines for conducting environmental assessments of particular aspects of the electric power system, such as hydro electric projects, thermal power plants, and transmission lines, have been developed for the Federal Government's Environmental Assessment and Review Process [11].

3.3 IMPORTANCE OF ON-GOING ENVIRONMENTAL ASSESSMENT OF ENERGY ALTERNATIVES

The submission papers to the Commission by the Department were not intended to provide a full and comprehensive assessment of each electric power production option based on the above guidelines. Rather, their purpose was to bring to the attention of the Commission, in highlight form, the more significant environmental implications of each option, based on currently available information, and what might be done to prevent or alleviate adverse impacts.

The importance of the first four guidelines above (assessment at each stage, routine and nonroutine impacts, consistent assessment procedures, and impacts from associated developments) has been noted and exemplified to some extent in the Department's submission papers where

possible or appropriate. Several examples pertaining to indirect impacts (Guideline 5 above) were reviewed in Section 2.2. Elements of the sixth guideline on cost/benefit analysis were mentioned from time to time, but no such analysis was conducted. The last two guidelines on public disclosure and participation pertain more to process than content.

It is clear the submissions by Fisheries and Environment Canada represent only an initial step toward an adequate assessment of the environmental (and resulting social and economic) implications of planned and possible electric power system developments in the province. If the most environmentally appropriate choices are to be made, choices which will have a profound effect on the quality of life and options available to future generations, a more sustained and on-going process is required at the strategic and policy level, as well as at the program and project level. The Federal Environmental Assessment and Review Process and the Ontario Environmental Assessment Act (1975) offer the potential to deal with the program and project levels. However, the inadequacy of established institutional arrangements to deal effectively with more fundamental energy questions such as the choice of energy supply technology, the cumulative effects of incremental developments, and energy demand/supply management, questions which have profound environmental implications, is apparent. This inadequacy has been recognized through the establishment of Ontario's Royal Commission on Electric Power Planning.

The most appropriate institutional arrangement to ensure adequate environmental assessments of long-range energy alternatives cannot be

decided from the environmental perspective alone. It may be more effective to constitute a public body whose primary mandate is to provide a focus for (e.g., coordinate, conduct, or integrate outside studies) social and economic as well as environmental assessments in the province, including primary, secondary, tertiary, and even quaternary effects, of energy alternatives. The experience of the U.S. Office of Technology Assessment and the Integrated Technology Assessment Program of the U.S. Environmental Protection Agency could be drawn on in establishing the structure, mandate, and activity framework for this body.

The analysis in this paper is not sufficiently comprehensive to recommend the establishment of any specific body. However, it is recommended that steps be taken to institutionalize a public capability to undertake comprehensive and in-depth environmental (as well as social and economic) assessments of energy alternatives, on an on-going, adequately sustained basis. This capability should extend into the future to include assessments of the total life cycle of the various energy alternatives, including their potential to determine the future quality of life and to determine what options will be available to future generations.

3.4 SUMMARY GUIDELINES FOR ENVIRONMENTAL ASSESSMENTS OF ENERGY SUPPLY OPTIONS

The general guidelines of this section may be summarized as follows:

1) In assessing and comparing energy supply options, consideration should be given to the total costs and total benefits of each option. This would include social, economic, and environmental implications.

2) Information for assessing the environmental implications of energy options should be comprehensive, including consideration of impacts at each stage of the total energy cycle, and both routine and nonroutine impacts. The environmental implications of (potential) associated developments in the vicinity of major power generation facilities should also be included. Comprehensive assessment procedures should be followed for all options including renewable energy sources and energy conservation measures.

3) Information analysis for environmental impact assessment, in addition to cost/benefit analysis where appropriate, should also include modifications to cost/benefit analysis such as risk/benefit analysis. Cost effectiveness analysis may also be appropriate in some instances. However, there are extremely important situations where prudence and judgement may have to substitute for hard analytic approaches. These include situations where impacts may be long-lasting and irreversible, where intangibles such as scenic beauty are involved, and where distributional effects across social groups and through future generations are involved. In such cases, it is vitally important

that information collection, analysis, and presentation be done as comprehensively and completely as is done for more tangible impacts. This is to ensure that the information base for decision making is not skewed by the more readily available or tangible factors, at the expense of equally real, but less definable, factors.

4) Information and analyses on the nature and extent of environmental and social impacts of energy production and consumption, as well as on the implications of not having enough energy, should be fully disclosed well in advance in order to increase public awareness and understanding of alternatives and their full implications.

5) Effective public participation can greatly assist in valuing and weighting less tangible factors such as the social and environmental impacts of large energy projects, and should be encouraged.

6) Provision should be made to carry out comprehensive, in-depth, and future-oriented environmental assessments of energy alternatives in Ontario on an on-going, adequately sustained basis. This is particularly important to ensure the future quality of life and options available to future generations will not be jeopardized by a reduction in quality or productivity of the natural environment.

SECTION 4: CONCLUSION

In Section 1, three main approaches for reducing the adverse environmental effects of energy supply options were described, all of which are essential to the success of environmental quality objectives. This paper has discussed both the information base and guidelines for conducting a comprehensive environmental assessment which is essential for implementing the third approach, namely, the adoption of the most environmentally appropriate energy supply option or group of options.

The ever increasing scale and complexity of technological applications such as those associated with centralized electric power generation have profound implications which go far beyond the immediate effects of individual applications of the particular technology. These implications are of a social, economic, and environmental nature. A systematic, comprehensive assessment of alternate energy technology options is essential if overall social well-being is to be maintained and enhanced.

As pointed out in the Introduction, the major constraints to the implementation of comprehensive technology assessments are of an informational, methodological, and institutional nature. This paper contributes toward an informational and methodological framework for conducting the environmental component of comprehensive technology assessments as they relate to energy supply systems. It also notes the importance of creating the appropriate institutional arrangements for the conduct of such assessments.

If technology is to become the servant of society rather than its master, the full implications of technological applications must be understood well in advance of the implementation stage, when options are at their greatest; not part way through implementation when alternatives are progressively reduced or effectively displaced. In addition, the full implications must be understood, not on a piecemeal or fragmented basis by particular segments of society, but through a comprehensive, "total systems" perspective by all concerned members of the general public. An informed public which is given adequate opportunities for participation in decision-making processes is the most effective approach for ensuring the development of an energy system which will truly serve, rather than determine, society.

SECTION 5: REFERENCES AND NOTES

1. Fisheries and Environment Canada, "Energy Conservation from an Environmental Perspective: A Discussion 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", April 20, 1977.

   - In this submission paper, the Department states the following position:

     "Energy conservation, where it is taken to mean a reduction in energy use without substituting more environmentally polluting resources, or where it is taken to mean more efficient matching of energy source to end use, should be given the highest priority as a means to both responding to energy shortages and reducing environmental degradation."

2. Robinson, D. L., "Energy Conservation and Environmental Management: A Synergistic Partnership toward a Sustainable Society", October 1977.

   - This paper reviews a number of areas of institutionalized energy consumption such as industrial processes, building and urban design, transportation, food production, and pollution control, and proposes solutions compatible with energy conservation and environmental objectives.

3. Fisheries and Environment Canada, "Submission to the Ontario Royal Commission on Electric Power Planning", October 1976.

4. Freeman, A. M., "Distribution of Environmental Quality", in A. V. Kneese, B. T. Bower, Environmental Quality Analysis: Theory and Method in the Social Sciences, Baltimore, Johns Hopkins University Press for Resources for the Future, 1972.

5. Smith, V. K., "Relative Prices, Technical Change and Environmental Preservation", Natural Resources Journal, Vol. 15, April 1975, pp. 283-295.

6. Pearce, D., "The Limits of Cost/Benefit Analysis as a Guide to Environmental Policy", Kyklos, Vol. 29, 1976, pp. 97-112.

7. Emmett, B. A., Evaluation of Intangibles: State of the Art, unpublished mimeo, Environment Canada, 1974.

8. Ricci, P. F., Perron, L. E. and Emmett, B. A., "Environmental Quality, Expenditure Patterns and Urban Location: Effects on Income Groups", Socio-Economic Planning Sciences, forthcoming.

9. Williams, R. and Bates, D. Y., "Technical Decisions and Public Accountability", Canadian Public Administration, 1976, pp. 603-632.

10. Ackoff, Russell L., "Does Quality of Life Have to be Quantified?", in General Systems Yearbook (Society for General Systems Research), Vol. XX, 1975.

    - The author argues that measurement of quality of life for decision-making purposes may be possible in principal, but not in practice, since quality of life involves satisfactions derived from intrinsic values immediately experienced and also from the process (not just the end result) of working toward ideals. He then proposes an alternative in the form of developing social systems in which each member of the system can participate effectively and thus bring more of one's own future under control. Involvement in such a future-creating process itself is a source of satisfaction and, hence, an improvement in the quality of life.

11. The Chairman: Environmental Assessment Panel, "Guidelines for Preparing Initial Environmental Evaluations", Fisheries and Environment Canada, October 1976.

APPENDIX

SUMMARY COMPARISON OF ELECTRIC POWER PRODUCTION OPTIONS

SUMMARY COMPARISON OF ELECTRIC POWER PRODUCTION OPTIONS

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SUMMARY COMPARISON OF ELECTRIC POWER PRODUCTION OPTIONS

INTRODUCTION

In the Department's submission paper entitled "Electric Power Production and Transmission from an Environmental Perspective", the environmental implications of each major electric power production option were reviewed on an individual basis. This section brings together in a comparative format some of the more important environmental concerns of the various options which apply to each stage of the power production and transmission process.

Several points should be noted before beginning the comparison. In the case of nuclear power, heavy water is not a fuel option, but it has been included as a separate item for completeness. Since heavy water production or recycling would be required for all nuclear options reviewed here, both initially before plant start up and to a lesser degree during plant operations, its impacts should be considered common to these options.

The use of the word "option" is not intended to suggest that any of the electric power supply alternatives discussed could or should substitute for all others. Obviously, realities of availability, economics, timing, etc. will have a bearing on the package of electric power supply options utilized for the foreseeable future. The makeup of this energy supply package will have substantial environmental implications. The purpose of comparing the various possible option components is to determine which options or groups of options are more environmentally appropriate and, hence, which should have their development encouraged where the potential permits.

A.1 POWER PRODUCTION CYCLE

A.1.1 Fuel Exploration and Extraction

Hydro

N/A (not applicable)

Natural Gas and Oil

- Damage to ground cover in permafrost regions and to Arctic ecosystems in general can occur from seismic lines, from the movement of equipment, from drilling activities, and from the disposal of waste drilling fluids.
- Blowouts on Arctic waters, if not rapidly sealed, could have devastating effects on the Arctic environment.
- Construction of access roads may affect surface water hydrology and cause serious erosion problems, unless substantial care is taken through proper culverting, routing, etc.
- Extraction of tar sands materials may cause substantial pollution of surface and ground water regimes and seriously disrupt land-based ecosystems.

Coal

- Coal extraction may result in the loss of land for farming or recreational activities and the destruction or disruption of wildlife habitats.
- Watershed areas, drainage patterns, and ground water flow regimes will be disrupted and there will be a greater disturbance of the natural environment due to the increase in local activity.
- Particulate fallout will affect land and water environments in the vicinity.

Solid Waste Materials

N/A

Heavy Water Production (not an option as noted in introduction)

N/A

Uranium (once through)

- Direct effect of mining is inhalation of radon and thoron daughter products by miners and deposition in their lungs, thereby inducing the probability of future lung cancer. Decreasing the radon concentration in mine air by increasing ventilation could diminish this impact.
- Leaching of ^{226}Ra, ^{230}Th, and ^{210}Pb from mine tailings by surface runoff contaminates surface water supplies with these radionuclides. Biological oxidation of sulphides in ores produces acid drainage which in turn enhances the leaching. New technology is required to fix the radium and thorium in the tailings.

Thorium/^{233}U

- As for Uranium.

Plutonium Recycle

- As for Uranium.

Solar

N/A

Wind

N/A

Forest Biomass (Thermal Power Generation)

- Environmental damage and depletion of forest reserves may occur unless proper resource management practices are followed.

TABLE A-1

Summary Table For Section A.1.1.

Stage of Power Production Process:

FUEL EXPLORATION AND EXTRACTION

Alternative	Environmental Impact Components			Environmental (or Health) Significance
	Air	Water	Land	
HYDRO	N/A *	N/A	N/A	
NATURAL GAS	-	-	- Permafrost Damage - Seismic Lines	Drilling accidents in Arctic waters risk substantial long term and possibly irreversible damage on a wide scale to fragile Arctic ecosystem. Permafrost damage could result in long-term or irreversible scarring of land with significant effects to land-based ecosystems such as caribou herds.
OIL	- Fuel Combustion Products	- Drilling Accidents - Brine Disposal - Runoff from Tar Sands Extraction	- Permafrost Damage - Seismic Lines - Surface Mining of Tar Sands	
COAL	- Fuel Combustion Products - Waste Pile Fire Particulates	- Acid Mine Drainage - Leaching of Waste Piles - Erosion & Silting of Watercourses - Fallout of Particulates	- Strip Mining Effects - Land Subsidence - Land Consumption by Mine Area - Fallout of Particulates	Strip mining results in loss of habitats, scarring of land and erosion. Control of acid mine drainage and leaching of waste piles is required.
SOLID WASTE MATERIALS	N/A	N/A	N/A	
HEAVY WATER PRODUCTION	N/A	N/A	N/A	
URANIUM (ONCE THROUGH)	- Radon release	- Radium, thorium and daughter products leaching from tailings ponds - also acid drainage.	- Mine tailings cover large areas	Lung cancer hazard to mine workers; bone cancer hazard from using polluted water supplies for drinking water; low pH in rivers kill fish.
THORIUM/233_U	ditto (reduced uranium requirements)	ditto (reduced)	ditto (reduced)	ditto (reduced)
PLUTONIUM RECYCLE	ditto (reduced)	ditto (reduced)	ditto (reduced)	ditto (reduced)
SOLAR	N/A	N/A	N/A	
WIND	N/A	N/A	N/A	
FOREST BIOMASS	-	-	-	Proper forest resource management practices should keep environmental effects to reasonable levels.

* N/A - Not Applicable

A.1.2 Fuel Upgrading and Refining

Hydro

N/A

Natural Gas and Oil

- The upgrading and refining of natural gas and oil is responsible for a number of pollution effects including air and water emissions. These emissions would typically include the discharge of oily and toxic wastes into waterways and of SO_2, NO_x, and hydrocarbons into the natural environment. These emissions must be strictly controlled to ensure a minimal environmental impact.
- Refining of tar sands requires vast quantities of water, thus risking serious environmental effects from disruption of the hydrologic cycle and pollution of ground and surface water regimes.

Coal

- Coal gasification requires large quantities of process water. Substantial water diversion schemes may be required to meet these requirements in western Canada.

Solid Waste Materials

- Environmental effects of garbage upgrading plants are localized, if any.

Heavy Water

- Hydrogen sulphide gas used in D_2O production is highly toxic. Continuous discharges to lakes can harm fish if not carefully controlled. Accidental releases to the local areas would be detrimental to human health. Continuous atmospheric releases are burned to produce sulphur oxides which add to air pollution problems.

Uranium (once through)

- The refining of uranium produces some radioactive waste, but mainly nitrates, ammonia, and some toxic metals such as arsenic. Disposal of these wastes has lead to problems of contamination of surface waters in the past (Port Hope). No permanent solution has yet been found.

Thorium/^{233}U

- ^{233}U is a very highly radiotoxic substance. This requires that all fuel fabrication be done remotely (remote from plant staff). Releases must be kept to virtually zero, which requires that air cleaning equipment must approach 100% efficiency.

Plutonium Recycle

- Due to the very high radiotoxicity of ^{239}Pu, all fuel fabrication must be done remotely. Air cleaning equipment must approach 100% efficiency to meet release standards.

Solar

N/A

Wind

N/A

Forest Biomass

--

TABLE A-2

Summary Table For Section A.1.2

Stage of Power Production Process:

FUEL UPGRADING AND REFINING

Alternative	Environmental Impact Components			Environmental (or Health) Significance
	Air	Water	Land	
HYDRO	N/A*	N/A	N/A	
NATURAL GAS	- Sulphur Oxides - Nitrogen Oxides	-	- Stockpiling of Sulphur	Discharge of sulphur and nitrogen oxides into the atmosphere can cause local and long-range effects.
OIL	- Sulphur Oxides - Nitrogen Oxides - Carbon Monoxides	- Thermal Discharge - Sulphuric Acid - Spent Caustic - Water Requirements for Tar Sands Refining	- Spent Clay - Spent Phosphoric Acid Catalyst	As for Natural Gas. Discharge of oily and toxic wastes into waterways must be controlled to the limits of the best practicable technology.
COAL	- Particulates from Coal Processing and Wastes - Waste Bank Fires	- Plant Effluents - Leaching of Waste Piles - Fallout of Particulates	- Coal Cleaning Waste - Sulphur Waste - Fallout of Particulates	Contribution to particulates problem. Water diversions to meet coal gasification or liquifaction requirements may be required.
SOLID WASTE MATERIALS	-	-	-	
HEAVY WATER PRODUCTION	H_2S Combustion Products - SO_2	- H_2S Releases	- H_2S Releases	SO_2 adds to long-range transport problem. H_2S accidental releases have local toxic effects, H_2S in water toxic to fish.
URANIUM (ONCE THROUGH)	- HF Discharges	- Radioactivity, Nitrates, Ammonia, Arsenic	- Radioactivity, Nitrates, Ammonia, Arsenic	Leaching of pollutants from landfill disposal sites to ground and surface water is a health hazard.
THORIUM/233_U	233_U	233_U	233_U	Fuel fabrication requires remote operation and 100% air cleaning capability due to radio toxicity of 233_U.
PLUTONIUM RECYCLE	239_{Pu}	239_{Pu}	239_{Pu}	Similar to above due to 239_{Pu} radiotoxicity.
SOLAR	N/A	N/A	N/A	
WIND	N/A	N/A	N/A	
FOREST BIOMASS	-	-	-	

* N/A - Not Applicable

A.1.3 Fuel Transportation, Storage and Handling

Hydro

N/A

Natural Gas

- Pipelines may disrupt migration and nesting patterns and spawning grounds for fish and wildlife species in the area.
- There will necessarily be an influx of people into the area to carry out the construction and operation of these facilities. This will disrupt and destroy wildlife habitats and cause a general movement of wildlife away from these sites.
- Construction of access roads may affect surface water hydrology and cause serious erosion problems.

Oil

- As for Natural Gas.
- Pipelining of oil may cause eventual melting of permafrost base, thus risking pipeline rupture and extensive ecological damage in the area.
- The bulk transport of oil from the Arctic by sea will require that strict preventative measures are taken against spills and that appropriate research takes place on which may be based appropriate contingency plans for spill cleanup.

Coal

- The environmental effects of the transportation, storage and handling of coal relate primarily to wind-blown dust. The use of sprays to bind the coal can minimize this effect.
- Coal transportation and handling systems have substantial land requirements.

Solid Waste Materials

- Environmental effects of transporting processed garbage is probably no more significant than for transporting garbage to land disposal site.

Heavy Water Production

- No significant environmental impacts.

Uranium (once through)

- No significant environmental impacts.

Thorium/^{233}U

- Any damage to fuel bundle during transportation could cause loss of highly toxic ^{233}U to the environment.
- Improper handling or storage of ^{233}U could cause criticality accident with resultant high neutron flux.

Plutonium Recycle

- Similar to Thorium/^{233}U except toxic element is ^{239}Pu.

Solar

N/A

Wind

N/A

Forest Biomass

- Use of heavy equipment to transport logs in the bush can scar protective vegetation cover in fragile areas.

TABLE A-3

Summary Table for Section A.1.3

Stage of Power Production Process:

FUEL TRANSPORTATION

Alternative	Environmental Impact Components			Environmental (or Health) Significance
	Air	Water	Land	
HYDRO	N/A *	N/A	N/A	
NATURAL GAS	- Nitrogen Oxides at Compressor Stations		- Land Consumption by Pipeline and Access Roads	Potential for irreversible damage to land and watercourses during pipeline construction. Possible disruption of migration patterns.
OIL	- Power Source Emissions	- Tanker Spills and Flushing	- Pipeline Spills - Permafrost Damage - Land Consumption by Pipeline	Since there is the potential for long-term or irreversible effects from oil spills, contingency plans must be developed to provide fast and effective response for containment and clean-up.
COAL	- Particulate Blowoff (windage losses)	- Fallout of Particulates	- Fallout of Particulates - Land Consumption by Rail or Pipeline and Related Facilities	Nuisance effect of wind blown particulates from coal shipment. Effects of railway noise.
SOLID WASTE MATERIALS	-	-	-	Insignificant
HEAVY WATER PRODUCTION	-	-	-	Insignificant
URANIUM (ONCE THROUGH)	-	-	-	Insignificant
THORIUM/233_U	233_U	233_U	233_U	Risk of 233_U release if accident
PLUTONIUM RECYCLE	239_{Pu}	239_{Pu}	239_{Pu}	Risk of 239_{Pu} release if accident
SOLAR	N/A	N/A	N/A	
WIND	N/A	N/A	N/A	
FOREST BIOMASS	-	-	- Possible damage from heavy equipment	- May be significant in fragile areas

* N/A - Not Applicable

TABLE A-4

Summary Table for Section A.1.3

Stage of Power Production Process:

FUEL STORAGE AND HANDLING

Alternative	Environmental Impact Components			Environmental (or Health) Significance
	Air	Water	Land	
HYDRO	N/A*	N/A	N/A	
NATURAL GAS	-	-	-	
OIL	- Hydrocarbons	- Spill Runoff	- Land Consumption by Storage and by Containment Facilities - Tank Spills	Potential for spills requires that contingency plans be drawn up. Hydrocarbon emissions promote reactions with NO_x in urban atmospheres creating smog conditions with possible vegetation damage.
COAL	- Particulate Blowoff (windage losses)	- Fallout of Particulates - Coal Pile Runoff	- Fallout of Particulates	Nuisance effects are caused by wind blown coal dust. Leachates from coal piles must be contained and treated.
SOLID WASTE MATERIALS	-	-	-	
HEAVY WATER PRODUCTION	-	-	-	Insignificant
URANIUM (ONCE THROUGH)	-	-	-	Insignificant
THORIUM/^{233}U	-	-	-	Risk of criticality accident
PLUTONIUM RECYCLE	-	-	-	Risk of criticality accident
SOLAR	N/A	N/A	N/A	
WIND	N/A	N/A	N/A	
FOREST BIOMASS	-	-	-	

* N/A - Not Applicable

A.1.4 Power Generation

Hydro

- Environmental effects may occur due to changes in the hydrologic cycle. These effects include the creation of artificial reservoirs, fluctuations in water levels, stratification of waters, and changes in the downstream flows, sediment loads, and temperatures. The degree of these effects is very site specific varying from relatively small effects for run-of-the-river type installations (e.g., Niagara River) to very large effects where sizeable reservoirs and diversions are involved (e.g., James Bay Project).

Natural Gas

- Nitrogen oxide emissions are of some concern.
- Impact of cooling water system on local aquatic ecosystem of receiving water body may be significant.

Oil

- Sulphur dioxide is the emission pollutant of primary concern. Fallout of sulphur oxides from the atmosphere contributes to vegetation damage and acidification of surface water. The utilization of flue gas desulphurization units would substantially reduce this environmental concern.
- Impact of cooling water system - as for Natural Gas.

Coal

- Sulphur dioxide emissions - as for Oil.
- The relative significance of air emission quantities for thermal fossil fueled plants generally becomes progressively worse from natural gas to oil to coal.
- Impact of cooling water system - as for Natural Gas.

Solid Waste Materials

- Sulphur dioxide emissions are considerably less than those from coal.
- Other air emissions (e.g., NO_x, particulates) may be comparable to those from coal depending on boiler design, efficiency of control equipment, etc.
- Impact of cooling water system - as for Natural Gas.

Heavy Water Production

N/A

Uranium (once through)

- Tritium releases are the main concern from CANDU reactors in the long term, as levels will build up in the Great Lakes. Other radionuclides released are at very low levels, but may build up in the vicinity of reactor outfalls.
- Low probability of major accident, but consequences would be catastrophic.
- Waste heat discharges may cause some local adverse environmental effects. Due to lower thermal (conversion) efficiency of CANDU reactors relative to thermal fossil fuel plants, more heat per unit of power generated will be released.

Thorium/^{233}U

- Similar to Uranium.

Plutonium Recycle

- Similar to Uranium.

Solar

- There may be some local climatic changes due to a large array of solar collectors, but the effects are likely minimal.
- Thermal discharges from central solar thermal plants could be greater than for conventional thermal plants. No thermal discharges would occur from photovoltaic options.

Wind

- Some local change in wind regime may occur downstream from the wind generator, but the effects are likely minimal.

Forest Biomass

- Air emissions can be controlled relatively easily and should not cause significant adverse environmental effects. Some SO_2 and phosphate emissions will occur, as well as thermal discharges.

TABLE A-5

Stage of Power Production Process: POWER GENERATION

Summary Table for Section A.1.4

Alternative	Environmental Impact Components			Environmental (or Health) Significance
	Air	Water	Land	
HYDRO	-	- Disruption to hydrologic cycle	- Shoreline effects due to fluctuating reservoir levels	Reservoir shoreline and downstream effects may be significant unless "run-of-the-river" site.
NATURAL GAS	- Nitrogen Oxides - Thermal Discharges	- Thermal Discharges		NO_x emissions result in photochemical reactions in the atmosphere with possible resultant human and vegetation effects.
OIL	- Sulphur Oxides - Nitrogen Oxides - Particulates - Thermal Discharges	- Thermal Discharges - Fallout from Atmospheric Emissions	- Fallout from Atmospheric Emissions	As above plus: SO_2 emissions in combination with particulates can cause human health effects under adverse weather conditions. Effects can be local or also contribute to growing problem of long-range transport of pollutants and fallout into the Great Lakes. This can cause increase in phosphorus leves, pH depression, etc.
COAL	- Sulphur Oxides - Nitrogen Oxides - Particulates - Thermal Discharges	- Thermal Discharges - Fallout from Atmospheric Emissions	- Fallout from Atmospheric Emissions	
SOLID WASTE MATERIALS	- Particulates	- Thermal Discharges - Fallout	- Fallout	
HEAVY WATER PRODUCTION	N/A*	N/A	N/A	
URANIUM (ONCE THROUGH)	- ^{3}H, ^{133}Xe, ^{131}I	- ^{3}H, ^{137}Cs - Thermal Discharges	- ^{3}H, ^{131}I	Health significance only in long term, possibility of increased cancer rate due to build-up in lake sediments, biota and water.
THORIUM/^{233}U	Ditto	Ditto	Ditto	Ditto
PLUTONIUM RECYCLE	Ditto	Ditto	Ditto	Ditto
SOLAR	- Possible minimal climatic effects	- Thermal Discharges	-	Climatic effects minimal. Thermal discharges (excluding photo voltaic) more significant than for other thermal plant options.
WIND	-	-	-	
FOREST BIOMASS	- SO_2 and Phosphate Emissions	- Fallout from atmospheric Emissions - Thermal Discharges	- Fallout from atmospheric Emissions	Effects relatively insignificant

*N/A - Not Applicable

A.1.5 Waste Disposal (including Nuclear Fuel Reprocessing)

Hydro

N/A

Natural Gas

- Not a particularly significant problem, relative to coal.

Oil

- Not a particularly significant problem, relative to coal.

Coal

- Ash collected as a waste product of the combustion process can seriously pollute ground and surface water in the vicinity of the disposal site unless proper disposal measures are followed.

Solid Waste Materials

- Similar to coal.

Heavy Water

- No significant waste disposal problems.

Uranium (once through)

- Permanent disposal of irradiated fuel bundles has not yet been demonstrated nor have criteria been established for protection of the environment in event of radionuclide release during storage.

Thorium/^{233}U

- No fuel reprocessing plant has yet operated anywhere in the world without high releases of radionuclides. Radionuclides released in large amounts are ^{3}H, ^{85}Kr, ^{137}Cs, ^{106}Ru, ^{129}I and ^{233}U with half-lives of from 12 to 159,000 years. Biomagnification of radionuclides released in fish, benthos, and plants cause increasing radiation dose to man through the food chain, resulting in somatic and genetic effects.
- The risk of high releases of radionuclides from fuel reprocessing is regarded with the highest concern, both from the perspective of environmental quality and the accompanying implications for human health. The extremely long-term persistence of such materials in the environment, once their release occurs, should prompt the most thorough and comprehensive consideration of any fuel reprocessing option.

Plutonium Recycle

- As for Thorium/^{233}U except that ^{239}Pu replaces ^{233}U, with a half-life of 24,000 (versus 159,000) years.

Solar

N/A

Wind

N/A

Forest Biomass

- Disposal of combustion products probably not a problem to the environment.

TABLE A-6

Summary Table for Section A.1.5

Stage of Power Production Process:

WASTE DISPOSAL (INCLUDING FUEL REPROCESSING)

Alternative	Environmental Impact Components			Environmental (or Health) Significance
	Air	Water	Land	
HYDRO	N/A *	N/A	N/A	
NATURAL GAS	-	-	-	
OIL	-	-	-	
COAL	-	- Contamination of ground and surface water.	- Land requirements for fly ash and slag disposal.	- Land requirements and potential for leaching are major concerns. - Development of other uses for solid wastes will reduce environmental impacts.
SOLID WASTE MATERIALS	-	- As for coal	- As for coal	
HEAVY WATER PRODUCTION	-	-	-	
URANIUM (ONCE THROUGH)	^{90}Sr, actinides	^{90}Sr, actinides	^{90}Sr, actinides	Requirement for permanent disposal. Releases possible due to container failure and ground water action.
THORIUM/^{233}U	^{3}H, ^{85}Kr, ^{129}I, ^{106}Ru.	^{3}H, ^{137}Cs, ^{106}Ru, ^{233}U.	^{3}H, ^{129}I, ^{106}Ru.	Much greater probability of health effects due to demonstrated high releases of radionuclides by all operating reprocessing plants in the world.
PLUTONIUM RECYCLE	Ditto	^{3}H, ^{137}Cs, ^{106}Ru, ^{239}Pu	Ditto	Ditto
SOLAR	N/A	N/A	N/A	
WIND	N/A	N/A	N/A	
FOREST BIOMASS	-	-	-	

* N/A - Not Applicable

A.2 CONSTRUCTION/SITE DEVELOPMENT/MANUFACTURING OF POWER GENERATION CAPABILITY

Hydro

- The major impact is the loss of land used for reservoirs, impoundments, or diversion channels. The effects include loss of important habitats, forest resources and hunting potential, and disruption to the lives of native peoples in the region. This loss of land can be considerable for developments involving the creation of new reservoirs or a significant rise in the levels of natural lakes. On the other hand, run-of-the-river type developments utilize relatively little land.
- Construction impacts may also be significant and include those arising from access roads and materials extraction in the region.

Fossil Fuels (Natural Gas, Oil and Coal) and Solid Waste Materials

- The major impact from thermal power plant siting and construction concerns land use. Loss of land or restriction of land uses, either on site or in the vicinity of the site, can adversely affect important natural habitat areas, as well as remove farmland from production.
- Plant construction activities may also disrupt the local environment and communities in the area.
- Production of materials for plant construction will also have significant environmental impacts throughout the exploration, extraction, upgrading, transportation, refining, and fabrication process, but the cumulated impacts are probably not too significant relative to the on-going impacts of the total power production process.

Heavy Water

- Effects are generally as for fossil fuel plants, but the five-mile exclusion radius causes additional restrictions on land use.

Uranium (once through), Thorium/^{233}U, and Plutonium Recycle

- Effects are generally as for fossil fuel plants.

Solar

- Centralized solar thermal power or photovoltaic plants would require considerable land, but the effects could be reduced through multi-use approaches such as combined agriculture and solar collection.
- Materials requirements to produce solar collectors are substantial and considerable environmental pollution from materials extraction, upgrading, and refining could result. However, such effects would be "once-in-a-lifetime" for each collector.

Wind

- Effects for centralized wind generation would be generally as for solar power generation except land use requirements for spacing of wind generators would be considerably greater.

Forest Biomass

- Land use, plant construction, and materials impacts are probably similar to those for fossil fuels except a more remote site location could reduce the land use and construction impacts.

TABLE A-7

Summary Table for Section A.2

CONSTRUCTION/SITE DEVELOPMENT/MANUFACTURING OF POWER GENERATION CAPABILITY

Alternative	Environmental Impact Components			Environmental (or Health) Significance
	Air	Water	Land	
HYDRO	-	-	- Loss of land due to reservoir etc. - Construction impacts	- Impacts to natural habitats, forests, and native people can be substantial, unless it is a "run-of-the-river" type site.
NATURAL GAS	-	-	- Land use impacts - Construction impacts	- Loss of natural habitats and prime agricultural land are significant impacts in Southern Ontario.
OIL	-	-	ditto	ditto
COAL	-	-	ditto	ditto
SOLID WASTE MATERIALS	-	-	ditto	ditto
HEAVY WATER PRODUCTION	-	-	ditto plus 5 mile exclusion radius	ditto - Land use effects greater due to exclusion radius.
URANIUM (ONCE THROUGH)	-	-	ditto	ditto
THORIUM/233_U	-	-	ditto	ditto
PLUTONIUM RECYCLE	-	-	ditto	ditto
SOLAR	- Emissions from materials production	- Emissions from materials production	- Land use impacts	- Land use requirements can be considerable for centralized generation but minimal for point-of-demand generation. - Impacts from materials production are likely substantial.
WIND	ditto	ditto	- Land use impacts	- Similar to solar but greater land requirements and less materials production impacts.
FOREST BIOMASS	-	-	- Land use impacts	- More remote locations for plant may reduce land use impacts relative to other thermal options.

NOTE: Emissions and effluents from materials production for hydro, fossil fuel, nuclear, and forest biomass options are significant, but are probably small relative to impacts from fuel cycle.

A.3 TRANSMISSION AND DISTRIBUTION OF POWER

Hydro

- Long distance transmission corridors may be required to link the hydro plant to the grid.

Fossil Fuel and Nuclear Options

- All options require transmission line links. The more significant environmental concerns of the transmission line system include aesthetics, loss of valuable farmland, construction impacts, herbicide use for vegetation control, and the risk of PCB leakages from transformers and other equipment.

Solar

- As for fossil fuels for centralized solar power generation.
- Point-of-demand or local power generation eliminates the need for transmission and distribution systems.

Wind

- As for solar.

Forest Biomass

- As for fossil fuels except more remote locations would require longer transmission line links to the grid system.

A.4 CONCLUSION

The above summary comparison of the various electric power supply options reveals the difficulties in making any general assessment of the relative environmental impacts of each option. Obviously, not only the type of impact must be considered, but also factors such as the location of impact (e.g., Arctic or Southern Ontario), the scale and concentration of pollution releases, the risks of accident, the implications if any accident does occur irrespective of the probability of its occurrence, the possibility of remedial or clean-up measures being instituted and their likely degree of success, the extent to which pollution control measures will be implemented, and the implications of less direct and broader, socio-economic and environmental effects.

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