DOE/ET/20055--1 (App. J)

MASTER

Resource Policy Center

Thayer School of Engineering
Dartmouth College
Hanover, NH 03755

MASTER

Prepared by:
The Resource Policy Center
Thayer School of Engineering
Dartmouth College
Hanover, NH 03755

Under contract to:
The Rust Engineering Company
Birmingham, AL 35201
Biomass Project #21-1899

For:
The Biomass Energy Systems Branch
Division of Conservation and Solar Applications
U.S. Department of Energy
Washington, DC 20545

ENVIRONMENTAL REPORT

ADVANCED SYSTEM DEMONSTRATION FOR UTILIZATION OF BIOMASS AS AN ENERGY SOURCE

Technical Appendix J
Alternatives Studies

APPENDIX J: Alternatives Studies

PROJECT DIRECTORS:* Charles E. Hewett, MFS, Resource Policy Analyst
Colin High, PhD, Environmental Systems Scientist

LIST OF PREPARERS:* Karen Altman, BA, Engineer
Jane Difley, MS, Forester
William T. Glidden, Jr., MFS, Resource Policy Analyst
Andrew Heller, BA, Engineer
John Lohnes, BA, Environmental Scientist
Robert McGirr, MS, Environmental Systems Chemist
Dennis L. Meadows, PhD, Systems Analyst
Sally Thomae, PhD, Air Quality Analyst

EDITOR: Marion McCollom

*Alphabetical Order

PREFACE

This technical appendix is one of a series that reports studies undertaken during the preparation of the Department of Energy's Advanced System Demonstration for Utilization of Biomass as an Energy Source. This document is organized by major environmental topic and does not follow the format of the environmental report. It provides data and analyses to support the environmental report and allows all the material on this topic to be brought together in one report. Although this approach leads to some duplication of text, it allows the reader to understand the conclusions more fully and increases the value of the study for future environmental assessments of biomass facilities.

APPENDIX J: ALTERNATIVES

Table of Contents

Page No.

INTRODUCTION

This appendix is designed to provide a comprehensive review of a wide range of alternatives to the proposed action, the commercial demonstration of an industrial cogenerating facility fired with wood fuels. An extensive effort has been devoted to the evaluation of all reasonable alternatives to this project, including some not within the jurisdiction of the U.S. Department of Energy. A number of possible actions were also briefly considered, but, for various reasons, they were found not to be appropriate at present for a commercial-scale demonstration of an alternative energy source.

The critical, descriptive characteristics of the wood-fueled commercial demonstration project at Westbrook are considered to be:

- industrial cogeneration of power;
- the production of 510,000 pounds per hour of industrial process steam;
- the production of approximately twenty-five megawatts of electric generating capacity, some of which would be available to a public utility in southern Maine;
- the consumption of 2,000 tons of wood fuel per day.

Each of the alternatives examined in this appendix offers a different option for one or several of the characteristics of the project listed above. As a whole, the appendix describes the range of possible actions that the U.S. Department of Energy and its contractors have considered.

NO-ACTION ALTERNATIVE

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could decide to discontinue its support of this commercial demonstration of a wood energy system.

Description

The U.S. Department of Energy would terminate its support of this wood energy demonstration project at the end of the design and assessment phase. S.D. Warren would then have the option of continuing the project, or some modification of the project, on its own or of dropping the undertaking. In either case, the company will have to replace its boiler system in the near future. The present system will continue to operate, with an increasing need for maintenance, until it is replaced. The characteristics of the replacement facility in this case will depend on S.D. Warren Company's choice of energy system and fuel. The characteristics of alternative replacements for the existing boiler system are described elsewhere in this appendix.

Economics

If the Department of Energy withdrew from the project, federal funds presently committed to the planning and construction of the wood-fired facility would be reallocated within the Department of Energy. If the S.D. Warren Company decided to continue the project, the company would have to fund construction and licensing projects with internal or borrowed funds. If the company dropped the wood energy project, it would have other options for replacing its current boiler system, the economics of which are described later in this appendix.

Environmental Impacts

The environmental impacts of the continued operation of the existing S.D. Warren Company energy system are discussed throughout this document as the background against which the impacts of the proposed new system are evaluated. The environmental impacts of other replacement systems that the S.D. Warren Company might choose in the absence of federal involvement in the project are discussed in other sections on alternatives to the proposed project. The discussion here will be limited to the implications of a Department of Energy decision not to support this wood-energy commercialization project.

The involvement of the federal government in this project is part of a larger effort to reduce the nation's dependence on petroleum and natural gas as sources of energy. As one effort to speed the transition from these sources to sustainable alternative sources, the Department of Energy is developing, evaluating, and demonstrating advanced systems for the use of biomass as an energy source. There are three major objectives. The Department of Energy seeks to make publicly available the information necessary to build and operate commercially viable, wood-fired, cogenerating facilities. This entails the development of technical designs, financial analyses, and environmental evaluations for wood-fired systems. A second major goal is to design, demonstrate, and monitor environmentally sound harvest systems that could provide wood fuel at a price suitable for energy production. The final major objective is to evaluate the socioeconomic effects of operating a wood-fired cogenerating facility and of procuring its fuel.

By failing to demonstrate the economic and environmental viability of biomass energy systems, the no-action alternative will effectively slow the nation's effort to reduce its dependence on petroleum-based energy systems. The no-action alternative, in effect, removes the opportunity to provide data and to resolve concerns that must be addressed in achieving widespread acceptance of biomass energy systems.

Designs for large, wood-fired boilers have been technically proven in the pulp and paper industry for many years. One factor limiting the construction rate of wood-fired boilers at the present time is incomplete knowledge on air emissions from wood combustion. Lack of appropriate emission factors for some criteria pollutants has required that wood-fired boilers be treated as if their emission characteristics resembled oil- or coalfired boilers. Theoretically, at least, the emissions of pollutants such as carbon monoxide and nitrogen oxides from a woodfired boiler should be substantially less than those from fossil-fuel-fired facilities. In supporting this proposed plant, the Department of Energy plans to monitor closely the emissions stream from the new boiler and to make available new information that is expected to streamline the regulatory process for the construction and operation of wood boilers.

Perhaps of greater importance is the need to demonstrate the commercial viability of harvesting and collecting wood for energy production purposes. Almost all wood-fired boilers operating at present fire millwood residues from primary and secondary wood products operations. Nationwide, the opportunities to use wood as a fuel will be increased multifold if low-quality trees in the forest can be procured in an environmentally sound manner at an acceptable price. Of concern is the constraint to wood availability posed by landowner attitudes and ownership patterns. Although some research on this subject has been undertaken (Kingsley & Birch 1977; Kingsley 1976; Hewett 1978), the results have not been definitive. The implementation of a successful, nationwide, wood-energy strategy requires an adequately publicized demonstration of an environmentally sound and economically reasonable collection system for low-quality wood. The no-action alternative would remove this opportunity for a carefully designed and monitored harvesting and collection system.

The long-term effects of whole-tree harvesting operations on forest nutrient budgets are not well-documented (High & Knight 1977; Hewett 1978). Whole-tree harvesting, which is the proposed harvesting technique to supply this plant (Rich 1978), may tend to deplete ecosystem nutrient reservoirs if harvests are repeated too frequently or are conducted without sufficient care. The degree to which this is a serious problem for wood-fired power plants is unknown at present. The no-action alternative removes an important opportunity to undertake the necessary research effort to resolve this issue.

The harvest region for the proposed facility hosts other wood-using industries and supports substantial recreational activity. Growing world and national demand for wood products and recent predictions that the domestic fiber demand will exceed net growth on commercial forest land by the late 1990s (USFS 1974) would suggest that New England's forests may be tapped in the near future to meet this demand. The proximity of these same forests to large concentrations of population also suggests that growing recreational pressures will coincide with the increased demand for forest products.

The addition of an energy market for low-grade forest material may increase the quality of forest management and the value of forest products in the region. This demand could also disrupt the existing situation and constitute a competitive rather than complementary market. The proposed project represents an opportunity to study the interaction of an energy market with other forest-based activities and to assist the complementary integration of this market with the existing market. This opportunity would be lost under the no-action alternative.

Relationship to National, State, or Local Plans and Policies

The no-action alternative conflicts with policies established by the U.S. Department of Energy and the Maine Office of Energy Resources (MOER 1976). Both agencies are committed to investigating and demonstrating alternative energy sources appropriate for various end uses. A recent review of domestic policy for solar energy recommended that the federal government "encourage research and development of medium and high temperature applications, systems development, and performance of market analyses" for solar technologies including biomass (DPR 1978, p.vi-8). Maine Office of Energy Resources policies regarding the use of wood are outlined in Table 1.

TABLE 1: MAINE OFFICE OF ENERGY RESOURCES POLICY REGARDING DEVELOPMENT OF WOOD ENERGY

- Thorough analysis should be undertaken to evaluate the overall availability and environmental impact of greatly increased use of wood for energy. Such analysis should include determination of the production capability of Maine's forest with proper management, and any potential price impacts on the wood resource that may result.

- Efforts should be increased to improve woodlot management practices, particularly by small woodlot owners. Successful pilot programs for coordinating fuelwood buyers with fuelwood sellers should be expanded statewide.

- Consideration should be given to allowing a higher rate of return (or exemption entirely from public utility status) for an experimental (up to 60-Mw) wood-fired electric generating station whose electricity is to be distributed through an existing utility.

Source: MOER 1976, p.5-30.

Summary of Long-Term Effects

The primary impacts of the no-action alternative are foregone opportunities to resolve the questions and issues central to the successful introduction of wood as an important transitional energy source. Escalating pressures for alternative energy sources could generate unwise decisions regarding wood energy if a sufficient body of knowledge and experience is not publicly available. The no-action alternative hinders the gathering of this information.

ALTERNATIVES TO PROPOSED COGENERATING FACILITY

The alternatives described in this chapter are intended to describe methods of generating or conserving steam and electricity in a cogenerating facility at the S.D. Warren mill site. The principal characteristic of the proposed facility used in the evaluation of these alternatives is its capacity to produce 510,000 pounds of process steam per hour and twenty-five megawatts of electricity.

No New Capacity

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could decide not to support the installation of any new generating capacity at the Westbrook mill and the S.D. Warren Company could decide not to replace its existing boiler facilities on its own.

Description

In the event that the S.D. Warren Company decided to rely on its existing cogenerating capacity, the operational characteristics of that facility would remain essentially the same as they are at present. The only significant difference would be the need for additional maintenance of the generating facility as it aged. Also, the necessary supplies of residual oil, currently the plant's primary fuel, could become difficult to obtain in the future. It is expected that a combination of these factors would ultimately require shutdown of the entire Westbrook pulp and paper-making operation.

The severe socioeconomic dislocations resulting from the elimination of the 2,176 jobs at the mill and the additional 8,704 indirect jobs in the community (Finn 1979a), plus the substantial loss of local income from plant taxes, payroll, and purchases, would result in substantial hardship in the region. The Scott Paper Company and its subsidiary, the S.D. Warren Company, intend to continue operation of the Westbrook mill for the indefinite future (Rolfe 1978). For these reasons, the no new capacity option is not considered a feasible alternative.

Conservation

Policy Statement

As a partial alternative to the proposed action, the U.S. Department of Energy could assist the S.D. Warren Company to implement a major energy conservation effort within the mill complex. Under this alternative, S.D. Warren Company would still need to replace its energy system, but this system could be reduced in size in proportion to the energy savings resulting from the conservation program.

Description

By reducing the amount of energy consumed in the production of paper, S.D. Warren could conserve fuel and reduce the capacity and cost of its replacement boiler system. Energy savings could be achieved through a variety of methods ranging from simple "housekeeping" activities to the implementation of new energy-efficient processes. Because of the complexity of the pulp and paper-making process, the specific energy-use characteristics of a given mill are unique. To assess accurately the potential energy savings at any mill, a full-scale audit of all energy-consuming processes must be undertaken. The effort necessary for such a study is beyond the scope of this analysis; a general discussion will be presented, however.

Nationwide, pulp and paper-making consumed 2.18×10^{15} Btu in 1977 (API 1978a), or 31.2×10^{6} Btu per ton of production; it is thus one of the country's most energy-intensive industries. A current industry effort to conserve energy focuses on reducing the consumption of purchased energy--i.e., fossil fuels and electricity. In 1977, purchased energy represented 54.5 percent of the industry's total energy use, as shown in Table 2 (API 1978a & b). In response to a federal call for a 20 percent reduction in the unit consumption of purchased energy in the pulp and paper industry between 1972 and 1980, the industry-wide conservation effort has taken two approaches: first, the replacement of purchased energy through the use of hydropower and process waste fuels; and second, conservation of total consumed energy through

TABLE 2: ENERGY CONSUMED IN PULP, PAPER, AND PAPERBOARD INDUSTRY, 1972 AND 1977

	1972 Energy Consumed *(10^6 Btu/ton product)*	1972 Percent of Total	1977 Energy Consumed *(10^6 Btu/ton product)*	1977 Percent of Total	PERCENT CHANGE
Purchased Energy[1]	19.011	58.4	16.997	54.5	-10.6
Self-generated Energy[2]	13.557	41.6	14.207	45.5	+4.8
Total Energy	32.568	100.0	31.204	100.0	-4.2

1. Includes purchased electricity, steam, coal, fuel oil, natural gas, and other energy forms.
2. Includes hogged fuel, bark, spent liquor, self-generated hydropower, and other energy forms.

Sources: API 1978a, 1978b.

changes in process design. The implications of the first approach for the Westbrook plant are discussed in other sections of this appendix. The opportunities for process conservation at the Westbrook mill are discussed below.

Conservation efforts have been underway at the Westbrook mill for the past six years. Table 3 outlines the progress that has been achieved in the production of writing paper, the Westbrook mill's principal product. An overall decrease in the consumption of energy has occurred both industry-wide and at S.D. Warren. While S.D. Warren consumes more energy than the industry average, this disparity can be attributed to the extreme age of the mill and the specialty nature of its products.

S.D. Warren Company has undertaken a variety of energy-conserving projects. Insulation of heating systems, installation of thermostats, and increased steam-trap maintenance are representative housekeeping measures undertaken as a part of normal operations.* Metering of energy consumption by various processes is being improved to establish energy accountability in different parts of the mill. Currently, one of the mill's steam systems is being converted to operate at a lower pressure in order to use existing capacity more efficiently. S.D. Warren has also developed a list of long-range projects that will be examined and evaluated over the next five years. The principal components of this effort are shown in Table 4. As a result of these projects and others, it is estimated that an additional savings of 5 to 9 percent can be economically justified within the next five years (Rolfe 1979a).

Additional major energy savings would be possible if radical changes in pulp and paper-making processes were instituted. A recent study (ADL 1976) examined a group of process changes with varying potential for energy conservation. Of the group selected

*Another change at S.D. Warren over the past several years has been the addition of extensive environmental control equipment. Although figures were not available for this mill, research on other facilities indicates that approximately 3.8 percent of the energy used by the industry in 1977 was by such equipment (Wilczynski 1978). This would represent between 1.3 and 1.5 x 10^6 Btu per ton at the Westbrook mill.

TABLE 3: ENERGY REQUIREMENTS FOR THE MANUFACTURE OF WRITING PAPER[1]

(10^6 Btu/ton product)

	1971	1972	1977	Short-term Potential
Industry Average	33.5[2]		27.3-30.5[3]	
S.D. Warren[4]		42.0	40.0	37.2-38.0
Current State of the Art[5]				24.2

1. *Manufacture is assumed to take place in integrated mills.*
2. *Derived from Gordian 1975.*
3. *Source: Hein & Lower 1978.*
4. *Source: Rolfe 1979a.*
5. *Source: Broglio 1979.*

TABLE 4: PROJECTED ENERGY SAVINGS WITH FIVE-YEAR S.D. WARREN ENERGY CONSERVATION PLAN

Selected Projects	Projected Annual Energy Savings in 1984 (10[9] Btu)	(10[6] Btu/ton product)[1]
Power Factor Improvement	13	0.007
Paper Machine Computer	3	0.001
Paper Machine Heat Recovery	130	0.756
Condensate Return	138	0.802
Insulation	34	0.020
Compressed Air System Renovation	1	0.001
Additional projects to be evaluated[2]	1,286.1	7.477

1. *Assumes current levels of production.*
2. *Includes only those projects not dependent on new boiler construction.*

Source: Rolfe 1979b.

as suitable for commercial demonstration, one process, Rapson kraft pulping, reportedly could be retrofitted to existing bleached kraft pulping operations. The advantages of this process include:

- the elimination of water effluents from the pulping process;
- 1 to 2 percent higher pulp yield;
- better strength and brightness stability;
- reduced steam consumption in the bleaching process; and
- increased steam generation due to a higher recovery of combustible organics.

The net energy savings are estimated to be approximately 2.75 x 10^6 Btu per ton of pulp. The first commercial demonstration of this process is currently underway at Great Lakes Paper Company's new pulp mill at Thunder Bay, Ontario. It is believed that a successful demonstration of the process at full-scale operation would stimulate interest among existing mills using the conventional kraft process (ADL 1976).

Economics

Because of the difficulty in accurately estimating the potential energy savings at the Westbrook mill and the processes that would be affected, it is not possible to describe the specific economic implications of an energy conservation program. Conservation efforts at Westbrook in the recent past, however, have clearly been effective and are judged to be economically justifiable (Rolfe 1979a).

Currently, S.D. Warren Company plans to replace worn-out equipment with more energy-efficient equipment as part of normal plant maintenance (Rolfe 1979a). A preliminary financial evaluation of the long-range conservation program at S.D. Warren is shown in Table 5. Experience at pulp and paper mills around the country indicates that many of the energy-saving process changes described previously have an excellent return on investment. Table 6 illustrates this experience for a representative group of process changes undertaken at several specific mills.

The economics of the Rapson effluent-free process are outlined in Table 7. For purposes of comparison, figures are given

TABLE 5: ECONOMIC RETURNS WITH FIVE-YEAR S.D. WARREN ENERGY CONSERVATION PLAN

Project Description	Required Capital[1] *($1,000)*	Expected Internal Rate of Return *(%)*
Power Factor Improvement	100	74
Paper Machine Computer	600	53
Paper Machine Heat Recovery	725	38
Condensate Return	400	22
Insulation	100	18
Compressed Air System Renovation	200	15
Additional projects to be evaluated[2]	5,955	21-50

1. *1979 dollars.*
2. *Includes only those projects not dependent on new boiler construction.*

Source: Rolfe 1979b.

TABLE 6: RETURNS ON INVESTMENT FOR ENERGY CONSERVING PROJECTS IN PULP AND PAPER MILLS

Project Description	Annual Return (%)
Conversion of batch digesters from indirect to direct heating of pulping liquor	30.3
Recovery of pulp digester blow-heat for use in demineralization system	23.2
Recovery of pulp digester blow-heat for unspecified heating purposes	50.0
Recovery of heat from the exhaust of paper machine hoods to preheat incoming hood air (more easily justified in northern climates)	33.3
Insulating pipe systems operating between 100°-220°F in the causticizing area	108.9
Use of hot product lime to heat secondary air for the limekiln	50
Use of flashsteam from vented condensate tanks to heat demineralized water	100
Cascading cooling water through various equipment for eventual use in the demineralizer	200
Replacement of mill lighting systems with more efficient fixtures	33-50

Source: Marlow 1978.

TABLE 7: COMPARISON OF THE RAPSON PROCESS WITH STANDARD KRAFT SLUSH PULP PROCESS: ECONOMICS[1]

	Plant Investment[2] *($ million)*	Operating Costs[2] *($/air-dried ton)*	Purchased Energy Requirements *(10^6 Btu/air-dried ton)*
Rapson	140	259	2.1
Standard Kraft	154	290	7.4

1. *New mill basis.*
2. *Includes pollution control costs.*

Source: ADL 1976.

for both the Rapson and conventional kraft processes. The figures were developed for a new, 800-ton per day pulp mill. Cost estimates for a retrofitting operation are not available.

Environmental Impacts

As described in the Policy Statement, a successful energy conservation project would allow the S.D. Warren Company to replace its existing boilers with a smaller energy system. The environmental impacts of this alternative can be related to both the conservation measures and the reduced energy requirements.

Construction and operation impacts. Some conservation programs, including the procedures described in the previous section, have only limited environmental impact while others, such as the implementation of a radically different pulping process, may have quite significant effects. Reclamation of waste heat and more efficient management of steam demand offer the most potential for energy conservation in the short term. To a lesser extent, electrical load management can also make a contribution to energy savings. Installation of a Rapson process pulping operation, while requiring a substantial retrofitting effort, could contribute to significant long-range energy savings.

The discernable impacts of these activities are primarily local and environmentally beneficial. Regional impacts, while perhaps not individually detectable, could become significant in conjunction with similar projects in a larger area.

The principal local impact will be a reduction of thermal emissions per ton of paper produced. Thermal contamination aggravates the existing water quality problems along the Presumpscot River by lowering dissolved oxygen levels. Any improvement in this condition would benefit water quality and the local aquatic ecosystems (see Appendix C). The actions taken to reduce and reclaim waste heat would, in general, increase the internal recycling of exhaust air, process water, and other liquids. This should reduce waste flows and concentrate pollutants, which should in turn facilitate effective treatment.

The beneficial environmental impacts of the Rapson process are substantial due to the elimination of water effluents from the pulping process. Table 8 compares the effluent flows from this process to those in the standard kraft process on the basis of a new, 800-ton per day mill. Substantial water quality improvements are expected with this process, along with an increase in species diversity in the local aquatic ecosystem. Air emissions are comparable to those of the conventional kraft process (ADL 1976).

Production of the materials used in the energy conservation program--such as insulation, ducting, and electronic components--generate additional environmental impacts in proportion to the increment of increased demand for necessary raw materials. In comparison to the national demand for these materials, this increment would not be detectable; an accurate assessment of the cumulative effects of similar energy conservation projects is beyond the scope of this analysis.

The socioeconomic impacts of the conservation effort are few, although the increased efficiency of the mill's operations would help to safeguard the long-run economic viability of the operation by reducing its sensitivity to energy costs. The retrofitting of the current pulping equipment to use the Rapson process would temporarily employ some additional workers. The reduction of electrical demand would slightly reduce growth of electrical generating requirements in the region. This effect would become significant only if it occurred as part of a wider conservation effort throughout Maine and New England.

If an expanded conservation program were implemented at S.D. Warren Company, the construction and operational impacts of the cogenerating facility would be identical in type, though of lower intensity, to those of the facility currently proposed (see Chapter 3). The degree to which these impacts would be reduced depends on the extent of the energy conservation effort. The principal difference in the construction phase would be a slightly smaller work force with a resultant reduction in expenditures for payroll and local services.

A smaller replacement facility in operation would emit lesser

TABLE 8: COMPARISON OF THE RAPSON PROCESS WITH STANDARD KRAFT SLUSH PULP PROCESS: EFFLUENT FLOWS[1]

	Water Volume[2] *(10^3 gallons/ton)*	Biological Oxygen Demand *(lbs/ton)*	Total Suspended Solids *(lbs/ton)*	Color *(lbs/ton)*
Rapson	20	0	0	0
Standard Kraft	31	66	66	300

1. *New mill basis.*
2. *Water effluent is distilled water from evaporators and cooling water from evaporators, boilers, turbines, and chemical production.*

Source: ADL 1976.

amounts of air and water contaminants and would require less fuel. Employment would be the same as for the existing and the proposed facility (see Appendix E).

Fuel procurement and transportation impacts. The conservation alternative would reduce the impacts associated with both fuel procurement and transportation. These impacts depend on the characteristics of the replacement energy facility and are described elsewhere in this appendix.

Relationship to national, state, or local plans and policies. The most significant national policy which relates to this alternative is derived from the Energy Policy and Conservation Act of 1975 and the National Energy Conservation Policy Act of 1978. These acts created and modified, respectively, the Voluntary Industrial Program under which energy efficiency improvement targets were established by the Federal Energy Administration and are now administered by the Department of Energy. An energy conservation program at the Westbrook mill would help the pulp and paper industry meet these targets.

The improvement of the local air and water quality supports federal and state efforts to attain the goals established by the Federal Water Pollution Control Act (Clean Water Act) of 1972, as amended, and the Clear Air Act of 1977, as amended.

Summary of long-term effects. The actions undertaken in an energy conservation program could reduce thermal emissions, wastewater effluent, and overall fuel consumption. Water quality would improve as a result of reductions in thermal emissions, biological oxygen demand, and suspended solids levels. These improvements would reduce the stress on local aquatic ecosystems. The reduction in fuel consumption would reduce local air pollution levels. Long-term socioeconomic effects would stem from the benefits associated with an increase in the long-term economic viability of the Westbrook mill. The magnitude of these effects would depend on the extent of the conservation efforts.

Purchase Of Steam

Policy Statement

As an alternative to the proposed action, the S.D. Warren Company could attempt to purchase steam.

Description

If a nearby producer of steam or steam-electric power had excess steam available, the S.D. Warren Company could obtain a right-of-way and construct a steam line to transport the energy from its point of origin to the Warren complex.

This alternative is not feasible. The S.D. Warren Company is the largest consumer of steam in the Greater Portland area, using 483,000 pounds per hour (Finn 1979a). There are no major steam generating facilities in the Westbrook area with sufficient surplus or waste capacity to supply this amount of steam (Atlass 1978).

Coal

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a coal-fired cogenerating station as a replacement for the existing oil-fired facility at the Westbrook mill.

Description

Coal has been used for the generation of process steam and electrical energy since the beginning of the industrial age. The technology is well developed and widely available. The site and energy transmission requirements of a coal facility are, for the most part, identical to those of the proposed action (described in Appendix A). Fuel requirements, availability, and procurement issues represent significant differences between the two options, as do the the on-site coal storage and pollution control problems.

In 1974, all of the coal used in New England came from Appalachian fields. Approximately three-quarters of the coal used in Maine was mined in northern Appalachia, principally in the fields of central Pennsylvania, U.S. Bureau of Mines District #1 (Edelston & Rubin 1976). The reserves in the northern Appalachian fields have been estimated at approximately 66 billion tons, 90 percent recoverable by underground mining and 10 percent by strip-mining (MITRE 1975). The typical ash, sulfur, moisture, and Btu contents of coal from that region are shown in Table 9.

If it is assumed that the proposed wood-fired facility would utilize 5.4 x 10^{12} Btu annually at 71 percent efficiency for the production of process steam and electricity (see Appendix A), the quantity of coal required is approximately 171,000 tons annually, allowing for the higher efficiencies of coal-fired boilers (calculated from Sherwood & Meadows 1978; Hall et al. 1976; KCIM 1976; Dvorak et al. 1977).

Railroads are the most economical means of moving the required amounts of coal from the northern Appalachian region to inland sites in Maine. Approximately 1,680 railcars annually would be required for the coal-fired facility. The hauling distance from these coal fields to Maine is approximately eight- hundred miles and some question exists as to the availability of unit trains for a facility of this size (generating 510,000 pounds of steam per hour or the equivalent of fifty megawatts).

The on-site engineering requirements for a coal-fired facility differ from the proposed wood-fired plant with respect to fuel storage areas, sulfur dioxide control equipment, and solid waste disposal. The dust and runoff from the coal storage piles must be contained and treated to meet federal and state environmental quality standards. A 45-day supply pile would cover approximately 0.2 acres (Dvorak et al. 1977). The Clean Air Act of 1977, as amended, requires the use of flue gas desulfurization and particulate control equipment. Disposal of sulfur dioxide scrubber sludge, recovered fly ash (particulates), and boiler ash is generally accomplished by ponding and/or landfilling. The fuel consumption of this facility would generate the demand for approximately 19 and 8.15 acre-feet of landfill capacity annually would be required for the disposal of scrubber sludge and ash, respec-

TABLE 9: CHARACTERISTICS OF COAL FROM PENNSYLVANIA (PITTSBURGH SEAM)

	Ash Content (%)	Sulfur Content (%)	Moisture Content (%)	Btu/pound
Range	4.2-10.8	0.7-3.3	1.1-3.9	13,040-14,340
Median	7.5	2.0	2.5	13,690

Source: KCIM 1976.

tively, assuming recovery rates of 90 percent for sulfur dioxide and 99.5 percent for particulates (Le, Rubin & Meier 1978).

Economics

The cost of a coal-fired cogenerating facility is comparable to that of the proposed action. The capital investment required is outlined in Table 10. Operating and maintenance expenses are estimated to be approximately 2.5 percent of capital cost or $1.6 million annually (Manar 1979a). The sulfur content of the coal will affect costs to the extent that expensive flue gas desulfurization and scrubber sludge disposal operations are necessary. The cost of generating power from high-sulfur coal is sensitive to pollution control costs (Hall et al. 1976).

The cost of the coal itself, taken principally from underground operations in northern Appalachia, is approximately $28 per ton delivered at the mine (Harvey 1978; Graham 1978). This is roughly the price that utilities in northern New England are paying and compares favorably with the figures used for a hypothetical 50-megawatt coal-fired station in Vermont (Hall et al. 1976). The transportation costs for the Vermont facility were estimated to be $17.80 per ton in 1978 between central Pennsylvania (USBM District #1) and central Vermont (Hall et al. 1976). The slightly greater distance to the Westbrook, Maine, site is assumed to increase this figure to $18 per ton. Total fuel costs then would be approximately $46 per ton delivered, or $7.9 million annually.

The use of the costs presented above to calculate a unit production cost, such as mills per kilowatt hour or dollars per million Btu, is subject to many variables. The nature of the plant site and its location affect the cost of capital, maintenance, operation, and fuel. Construction time, financing, and the existing tax climate will influence the annual charges on investment. Recent changes in the investment tax credits and depreciation allowances enacted by the Energy Tax Act of 1978 will have an important influence on the choice of fuel for energy facilities. For these reasons, it is beyond the scope of an environmental impact statement to predict precise unit costs.

TABLE 10: ESTIMATED CAPITAL, OPERATING AND MAINTENANCE, AND FUEL COSTS FOR A 50-MW COAL-FIRED COGENERATING FACILITY[1]

	1979 Dollars (*millions*)
Installed Capital Cost[2]	66.0
Annual Operating and Maintenance Cost[3]	1.6
Annual Fuel Cost[4]	7.9

1. *These estimates will vary substantially from site to site and should only be considered approximate.*
2. *Calculated from Manar 1979b.*
3. *Assumed to be 2.5% of installed capital cost: Manar 1979a.*
4. *Sources: Harvey 1978; Graham, 1978; Hall et al. 1976. Based on 171,000 tons/year at $46/ton.*

The capital, operating, maintenance, and fuel costs presented in Table 10, however, do indicate that this alternative is at least marginally commercial and that consideration of its environmental impacts is justified.

Environmental Impacts

Construction impacts. These impacts will be similar to those outlined in Appendices B and C for the wood-fired facility. The site preparation required for the coal storage pile should be less than that required for chip storage. This reduction, however, would be balanced by the need to construct larger settling ponds for the scrubber sludges and boiler ash. The construction of additional pollution control equipment, particularly the sulfur dioxide scrubbers, could result in a slightly larger work force during the construction phase.

Operation impacts. Local air quality would be affected by a coal-fired facility. The contaminants of most concern include sulfur oxides, nitrogen oxides, carbon monoxide, hydrocarbons, particulates, and trace elements. A summary of the estimated emissions of these pollutants from a 50-megawatt coal-fired facility is contained in Table 11. The Clean Air Act amendments of 1977 require best available control technology for new sources of air pollutants. In this case, 90 percent reduction in sulfur dioxide and 99.5 percent reduction in particulate emissions are assumed.

Secondary contaminants are created from coal-burning as the result of chemical reactions in the atmosphere involving sulfur oxide and nitrogen oxide emissions. These include ozone, peroxyacetyl nitrate, and acid rain. Potential sources of airborne dust emissions are the coal storage and handling operations. Control methods generally involve water and/or chemical sprays (Dvorak et al. 1977).

Concern has been expressed over the radioactive emissions resulting from the combustion of coal (McBride et al. 1978). Although insufficient data were available to estimate the possible radioactive emissions from a 50-megawatt coal-fired facility, analysis of Pennsylvania coal samples showed a range of uranium

TABLE 11: AIR EMISSIONS FROM A 50-MW COAL-FIRED COGENERATING FACILITY

(tons/year)

Air Pollutants[1]	Emissions
Nitrogen Oxides	1,539.0
Sulfur Dioxide	649.8
Carbon Monoxide	85.5
Particulates	51.3
Hydrocarbons	25.6
Trace Elements[2]	
Barium	0.071
Cobalt	0.018
Chromium	0.036
Copper	-
Lead	0.036
Manganese	0.018
Mercury	0.032
Molybdenum	-
Nickel	-
Selenium	0.071
Vanadium	0.036
Zinc	0.071

1. *Assumes 90% sulfur dioxide removal, 99.5% particulate and trace element removal. Source: EPA 1976.*
2. *Calculated from assumptions in Dvorak et al. (1977), modified for a 50-Mw facility.*

- indicates data not available.

concentrations between 20 and 190 parts per million (Dvorak et al. 1977).

The operational impacts of a coal-fired facility on water quality are generally similar to those described in Appendix C, with the following exceptions. Runoff from the coal storage pile is likely to contain coal fines, humic acids, sulfuric acid, and trace elements. The concentrations of these materials depend on the duration of exposure to the local climate, local precipitation levels, and the acidity of local precipitation (Dvorak et al. 1977). Runoff containing these contaminants can be expected to reach surface and ground waters unless appropriate diversion and treatment measures are taken.

Disposal of boiler ash, fly ash, and scrubber sludge can also have impacts on water quality. Table 12 describes the chemical constituents of coal ash. The substance can be used as a fertilizer and as a filler in asphalt and cement products (Hecht & Duvall 1975). However, it is most commonly disposed of in settling ponds and landfills. If these disposal areas are not lined with impervious material such as clay, leachate contamination of groundwater can occur. The same holds true for the disposal of scrubber sludges, which are moderately acid (pH of 5 to 5.5) and are principally comprised of calcium sulfite, calcium sulfate, and water (Dvorak et al. 1977). Five elements have been found to be of special concern in ash and scrubber sludge due to their leachability. These are barium, boron, chromium, mercury, and selenium (Dvorak et al. 1977). Total trace element flows from coal pile, slag, and collected fly ash are shown in Table 13.

The effluent of scrubber sludge and ash dewatering operations can have a high chemical oxygen demand and may require secondary treatment before discharge (Cooper 1975).

The effect of the above contaminants on local ecosystems can be subtle and pervasive. Although a great deal of research has investigated the effects of individual pollutants at high concentrations, very little work has been done on the long-term or chronic effects of the combinations of pollutants that would actually be found in the vicinity of the plant.

TABLE 12: MAJOR CHEMICAL CONSTITUENTS OF COAL ASH

Constituents	Composition (%)
Silica (SiO_2)	20-60
Alumina (Al_2O_3)	10-35
Ferric Oxide (Fe_2O_3)	5-35
Calcium Oxide (CaO)	1-20
Magnesium Oxide (MgO)	0.25-4
Titanium Dioxide (TiO_2)	0.5-2.5
Potassium Oxide (K_2O)	1.0-4.0
Sodium Oxide (Na_2O)	0.4-1.5
Sulfur Trioxide (SO_3)	0.1-12
Carbon (C)	0.1-20

Source: Dvorak et al. 1977.

TABLE 13: TRACE ELEMENT FLOWS FROM A HYPOTHETICAL 50-MW COGENERATING FACILITY[1]

(tons/year)

Trace Element	Total Flow
Barium	23.359
Cobalt	5.787
Chromium	8.059
Copper	4.189
Lead	1.669
Manganese	6.816
Mercury	0.039
Molybdenum	3.266
Nickel	6.461
Selenium	1.136
Vanadium	10.970
Zinc	7.313

1. *Calculated from assumptions in Dvorak et al. (1977), modified for a 50-Mw facility. Includes elements in coal, slag, and fly ash.*

Sulfur dioxide and nitrogen oxides have been shown to damage vegetation over a range of concentrations. Emissions of these compounds also contribute to the phenomenon of "acid rain," which has become increasingly prevalent throughout the northeastern United States as the result of industrial emissions throughout the Midwest and North Atlantic states (Dvorak et al. 1977). Acidic precipitation is suspected to be the cause of an observed trend of decreasing pH in many lakes in the Northeast. It has been suggested that hydrologic drainages with low natural buffering capacity are particularly susceptible to this effect. The granitic regions of the White Mountains in New Hampshire and western Maine have this susceptibility (Gerlach 1970). Acidification of surface waters affects organisms at all trophic levels and interferes with reproductive mechanisms and disrupts the food web. The overall effect is to reduce species diversity. A secondary effect may be to increase the mobility of specific trace elements (Dvorak et al. 1977).

Trace elements emitted as particulates and vapors may become relatively immobile after deposition, depending on soil characteristics (Brady 1974). It is possible, however, for plants to extract and accumulate trace elements in their tissues. Trace elements may be introduced into the food chain either by the ingestion of contaminated material or by direct inhalation of particulates and vapors. Damage to links of food webs is often caused by chronic exposure rather than acute poisoning (Dvorak et al. 1977). Although mechanisms of transport differ, the general effects and pathways of trace elements in terrestrial and aquatic ecosystems are similar. Bioaccumulation is probably the most significant mechanism affecting the mobility and impact of trace elements.

The socioeconomic impacts of operating a coal-fired system would be similar to those associated with the wood-fired facility, described in Appendix E.

The land use and noise impacts of the coal-fired facility's operation would be similar to those outlined for the wood-fired plant in Appendix G and H, respectively.

Fuel procurement. The impacts of procuring the estimated 171,000 tons of coal per year required for the coal-fired facility are primarily related to the necessary mining operations. Coal obtained from northern Appalachian fields is likely to be deep mined. Although some strip mining does occur in northern Appalachia, the majority of the reserves there are recoverable only by underground mining techniques (Edelston & Rubin 1976). The principal effects associated with underground mining are acid mine drainage and human health impacts.

The acidity of water actively and naturally drained from mines is primarily the result of the oxidation of iron sulfide. This acidity facilitates the transport of metal ions in solution, which may have additional ecological effects. Of most concern are aluminum, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, and zinc (Dvorak et al. 1977). The neutralization of this acidity results in a higher load of dissolved solids and some precipitation of the metals. All of these mechanisms degrade water quality and can have severe effects on the biota of receiving waters. A variety of mining procedures and wastewater treatment methods can be employed to control these effects. Federal water quality standards and coal mining regulations have required the implementation of these methods throughout the coal mining regions.

Estimates of fatalities due to the mining requirements of the coal-fired facility can be derived from statistics assembled by the U.S. Mining Enforcement and Safety Administration. Fatal accidents in the period 1971 to 1975 have varied between approximately 0.25 and 0.54 per million tons of underground mined coal (Dvorak et al. 1977). It is probable that the coal consumption of this alternative plant could result in one to three deaths over the thirty-year plant life. The Federal Coal Mine Health and Safety Act of 1969 may diminish this impact by requiring health and safety measures that would reduce fatal accidents. Coal workers' pneumoconiosis, or black lung, has long been one of the more debilitating diseases caused by coal mining. Statistics for underground miners prior to 1969 indicated that 11.2 percent of the work force had some form of "black lung." Chronic bronchitis and emphysema accounted for additional disabilities (Dvorak et al. 1977). The Coal Mine Health and Safety Act of 1969 established a limit on respirable coal dust at two milligrams per cubic meter, which should greatly diminish the prevalence of these disabilities.

Transportation impacts. Transporting coal from the mines to the Westbrook site would impact water and air quality. Approximately 1,680 railcars could be expected annually. The volume of this traffic would be partially offset by the replacement of approximately 1,200 to 2,700 oil-carrying railroad cars in the same period (Lapikas 1979; S.D. Warren 1978).

Windblown coal dust and accidental coal spillage can have detrimental effects on local air and water quality. Materials leached from the coal that is lost in this fashion could have negative effects on ecosystems adjacent to the tracks. Improved rail systems and coal cars could mitigate these impacts.

Estimated air emissions from the trains used to transport the coal from the western Pennsylvania fields are shown in Table 14. The impact of these emissions, dispersed over the 800-mile hauling distance, is slight.

Although the local rail system is adequate to handle the traffic supplying coal to Westbrook, the initiatives to increase coal production and use nationwide will require substantial renovation and construction of rail lines and handling facilities (Dvorak et al. 1977). Impacts on all aspects of the environment are possible, although the increment attributable to the Westbrook facility would be negligible.

The noise levels associated with the coal trains would generally not be important in comparison to the noise levels of Westbrook, the S.D. Warren mill, and existing rail traffic. In comparison to the noise generated by the chip vans used for the wood-fired facility, the coal trains would be more intermittent and less obtrusive.

TABLE 14: TRANSPORTATION-RELATED EMISSIONS FROM A 50-MW COAL-FIRED COGENERATING FACILITY[1]

Pollutants	Pounds/10^6 ton-miles	Tons/year[2]
Nitrogen Oxides	1,848.5	126.4
Sulfur Dioxide	131.8	9.0
Carbon Monoxide	1,425.6	97.5
Particulates	142.6	9.7
Organics[3]	145.3	9.9

1. *Emissions from trains required to supply facility.*
2. *Calculated from Hall et al. 1976.*
3. *Includes hydrocarbons.*

Due to the small numbers of people typically employed, rail transportation would have negligible effects on local employment, health, and safety.

Relationship to national, state, or local policies and plans. The construction and operation of a coal-fired cogenerating facility is in accord with major energy plans and policies. This facility would support the purposes of the Powerplant and Industrial Fuel Use Act of 1978, which generally promotes the use of coal while encouraging the conservation of natural gas and petroleum. Federal and state air quality improvement efforts under the Clean Air Act of 1977, as amended, would not be hindered if the appropriate pollution control devices were incorporated in the design of the facility. Compatibility with state and federal water quality management plans mandated by the Clean Water Act of 1977, as amended, would depend on strict control of effluents from all operations, especially ash and scrubber sludge.

Summary of long-term effects. The construction and operation of a coal-fired cogenerating facility would have long-term effects similar to those outlined for the proposed wood-fired power plant with the major exceptions described below.

For the life of the plant, local air quality would be affected by the emissions of the contaminants outlined in Table 11. The emission of the trace elements contained in the coal could have effects lasting beyond the life of the plant, although these would be expected to be minimal.

The disposal of boiler ash and scrubber sludge represents a long-term problem with implications for land use and water quality. Adequate treatment of these materials and isolation of any hazardous residues is necessary to avoid serious surface and groundwater contamination. An analogous, though lesser, issue involves the runoff of the coal storage pile, which must be diverted and treated to avoid water quality deterioration.

The coal mining undertaken as a result of the demand created by this facility will have small but incremental long-term effects on miners' health and mining-related land and water quality.

Oil/Wood

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could support the installation of a 50-megawatt cogenerating facility fired with oil and wood fuels at the Westbrook mill. The wood-to-oil ratio, on a Btu-input basis, would range between one-to-one and three-to-one, depending on the economic availability of wood fuel. For the purpose of this discussion, a one-to-one mix will be assumed.

Description

Boilers fired with both oil and wood have been in use for some time in the forest products industry and have recently been employed by an electric utility (Hewett & High 1979). Such a system requires procurement operations as well as storage and handling facilities for both fuels. The on-site requirements include rail connections, oil storage tanks, a wood chip handling area and storage pile, and a fuel feed system for both materials. The boiler system itself must be able to burn a variable mixture of oil and wood from separate fuel injection systems. All of these requirements are similar to those described for the proposed action, although several significant differences exist.

The use of oil to provide 50 percent of the fuel input for the plant would require continuation of rail tank car traffic to Westbrook, but at a level below the current level. Depending on the capacity of the cars, between fourteen and thirty-four tank cars per week would be needed to deliver approximately 385,000 barrels of oil annually (Lapikas 1979).

If the plant were to burn residual oil with a 2 percent sulfur content, comparable to that currently burned at the Westbrook mill (S.D. Warren 1978), it would not meet the new source performance standards established by the U.S. Environmental Protection Agency (CFR 1978) unless sulfur dioxide scrubbers were used in addition to the particulate control equipment described in Appendix A. It is possible that other pollution control methods could be employed, such as the use of the low-sulfur oil.

Fuel handling and storage facilities would include both the oil facilities presently in existence at the Westbrook mill and the wood systems of the proposed plant, described in Appendix A. Approximately 340,000 tons of wood and 385,000 barrels of oil would be required annually.

Solid wastes generated by an oil/wood facility include both scrubber sludges and ash. Approximately 3.8 acre-feet of scrubber sludge annually would be generated (Le, Rubin & Meier 1978), along with roughly 8,000 to 17,500 tons per year of ash (Hall et al. 1976).

Economics

The costs of this facility are presented in Table 15. With the exception of fuel, the annual costs of an oil/wood-fired boiler are nearly identical to those of the proposed wood-only installation. The extra fuel-firing capacity does not significantly increase the overall plant cost; in fact, reduction in wood-handling costs may reduce operating costs slightly. As indicated above, the existing oil-handling and storage facilities at the S.D. Warren mill could be used to supply the oil/wood boiler.

Adjusted fuel requirements do represent a change in the annual cost of the facility, however. Current oil prices and the expected wood fuel prices, \$14.80 per barrel (EIA 1978) and \$12.50 per ton (Allison 1979) respectively, result in a total annual fuel cost of \$9.9 million.

The use of the costs presented above to calculate a unit production cost, such as mills per kilowatt-hour or dollars per million Btu, is subject to many variable factors. Construction time, financing, and the existing tax climate would influence the annual charges on investment. Recent changes in the investment tax credits and depreciation allowances enacted by the Energy Tax Act of 1978 will have an important influence on the choice of fuel for energy facilities. For these reasons, it is beyond the scope of an environmental impact statement to predict precise unit costs. The capital, operating, maintenance, and fuel costs presented in Table 15, however, do indicate that this alternative is at least

TABLE 15: ESTIMATED CAPITAL, OPERATING AND MAINTENANCE, AND FUEL COSTS FOR A 50-MW OIL/WOOD COGENERATING FACILITY[1]

	1979 Dollars *(millions)*
Installed Capital Cost[2]	63.0
Annual Operating and Maintenance Cost[3]	1.6
Annual Fuel Cost[4]	9.9

1. These estimates may vary substantially from site to site and should only be considered approximate.
2. Calculated from Manar 1979b.
3. Assumed to be 2.5% of installed capital cost: Manar 1979a.
4. Based on fuel prices of $14.80/barrel (EIA 1978) and $12.50 /ton (Allison 1979).

marginally commercial, and that consideration of its environmental impacts is justified.

Environmental Impacts

Construction impacts. The impacts of constructing a 50-megawatt oil/wood cogenerating facility would be identical to those associated with the proposed all-wood facility.

Operation impacts. The operation of an oil/wood facility would result in a wide range of environmental impacts. Many of these impacts would be similar to those of the wood-fired and coal-fired facilities described in the preceding "Coal" section of this appendix and the other technical appendices accompanying this document. The quantities of pollutants emitted, however, would be quite different. The projected emission of air contaminants and generation of solid wastes is presented in Table 16. A one-to-one ratio of fuels was assumed; however, it should be noted that as the proportion of wood fuel increased, the quantities of wood ash and particulates generated would increase, while the contaminants associated with oil, principally sulfur dioxide and scrubber sludge, would decrease.

Several trace elements are present in fuel oil, including arsenic, nickel, vanadium, and yttrium. Emission of these materials may pose demonstrated or suspected ecological and human health hazards (OWHM 1974; Newkirk 1976; Magee et al. 1973). In addition, vanadium is thought to catalyze the oxidation of sulfur dioxide to sulfur trioxide which, in turn, encourages the formation of acidic aerosols and acid rain (Dvorak et al. 1977). The value of vanadium for various metallurigical uses has encouraged efforts to recover vanadium from boiler and fly ash (OWHM 1974).

Fuel procurement. The environmental impacts of oil procurement occur principally during the extraction and refining processes. Oil residuals and brine from extraction processes contribute to water contamination. Various methods exist for separating oil from the wastewater flow and for reinjecting brine into the well. Blowouts and accidental spills also constitute a source of pollution. Air emissions and water effluents, however, are most significant during the refining process. The quantities of air contaminants emitted during the refining process are comparable to those emitted during boiler operation on a Btu basis (SPPP 1975). The oxygen demand of wastewater effluents, sulfur oxides, nitrogen oxides, and hydrocarbon emissions are considered to have the most significant impacts (SPPP 1975).

For the most part, proven methods exist for the effective control of effluents and emissions from extraction and refining processes. No incremental ecological and socioeconomic impacts would result from refining or extraction for this alternative since the current oil consumption at the Westbrook mill would be reduced by about 265,000 barrels annually (S.D. Warren 1978).

Impacts of procuring the 340,000 tons per year of wood fuel are described in the other technical appendices.

<u>Transportation</u>. The environmental impacts of transporting the fuel oil would depend in large part on the source of the crude oil and where it is refined. Most of New England's residual fuel oil is imported by tanker or barge from foreign sources (Bronheim 1978). The oil/wood alternative would reduce the existing S.D. Warren Company requirement for tank cars, by approximately eight to seventeen tank cars per week. An increase in truck traffic, however, would result from the collection of wood chips. A fleet of approximately twenty vans would be required. The impacts of this collection operation are described in Appendix F.

<u>Relationship to national, state or local plans and policies</u>. A new 50-megawatt oil/wood cogenerating facility apparently would conflict with the national policies established by the Powerplant and Industrial Fuel Use Act of 1978; however, formal regulations for the enforcement of the Act have not yet been promulgated. Section 202 (a) of this act generally prohibits the use of natural gas or petroleum as a primary energy source in a new major fuel-burning installation consisting of a boiler. It is possible that the Secretary of Energy could grant a permanent exemption under Section 212 (a) (1)(A) or (c)(1) in order to promote the use of alternative fuels and cogeneration. The policies of the Maine Office of Energy Resources generally support both the use of wood fuels and cogeneration (MOER 1976).

TABLE 16: ESTIMATED AIR EMISSIONS AND SOLD WASTE FLOWS FROM A 50-MW OIL/WOOD COGENERATING FACILITY

Air Pollutants[2]	Emissions[1] (tons/year
Nitrogen Oxides	1,357 - 1,788[3]
Sulfur Dioxide	431
Sulfur Trioxide	3
Carbon Monoxide	339
Particulates	161
Hydrocarbons	43

Solid Wastes	Quantity (tons/year)	Quantity (acres-feet/year)
Collected Ash[4]	6,766 - 14,545	-
Scrubber Sludge[5]	6,621	3.8

1. *Assumes 90% reduction in SO_x emissions and 99.5% reduction in particulate emissions.*
2. *Emissions from oil combustion are derived from EPA 1976. Emissions from wood are adapted from the analysis of the proposed action: see Appendix B.*
3. *Emissions depend on choice of firing mode for oil, i.e., tangential or horizontal.*
4. *Calculated assuming 2-4.3% ash content in wood: Hall et al. 1976. No conversion factor to acre-feet available.*
5. *Source: Le, Rubin & Meier 1978.*

Summary of long-term effects. The most significant long-term effects of this alternative result from the impact of increased wood demand on the area's forest resources. This demand, as described throughout these technical appendices, would have lasting implications for the management of forest and related ecosystems. Alternative uses of these resources for recreation, water quality management, and other forest industries could be affected, both positively and negatively.

An additional long-term effect of this alternative would be to continue and extend the region's dependence on oil, a finite and uncertain source of energy. This continued dependence would appear to be in conflict with national policy.

Alternative Supplementary Fuels

Policy Statement

As an alternative to the proposed action, the Department of Energy could support the installation of an energy system at the S.D. Warren mill that utilized limited quantities of supplementary fuels in addition to wood, the primary fuel source. These supplementary fuels, which include used railroad crossties, discarded rubber tires and processed municipal solid waste, would provide up to 22percent of the total annual fuel requirements (see below). This alternative would reduce the required amount of fuelwood.

Description

The facility design and construction requirements for combustion of supplementary fuels are similar to those for the proposed wood-fired system. The overall steam-producing process is the same, as are the site and power transmission requirements. If the total quantities of municipal solid waste and rubber were kept small, changes in boiler equipment would not be required. Additional handling and storage facilities might be necessary.

The major difference among the supplementary fuels is the contribution each could make to the total fuel requirement of the facility. The use of each is limited by its heating values and combustion characteristics, as well as by the total quantity that is available.

Municipal solid waste. The composition of municipal solid waste varies greatly and depends on the season of the year and the sources from which it is obtained (see Table 17). Raw municipal solid waste consists mostly of paper and biodegradable materials, although metal and glass also constitute a significant portion. The moisture content can range between 3 and 63 percent, with an average of roughly 27 percent. If municipal solid waste is to be used as a supplementary fuel, it must be preprocessed (Ruane 1977a). Preprocessing, which removes noncombustible materials such as metal and glass and shreds and bales the remaining materials, yields a higher overall heat content (between 5,000 and 6,500 Btu per pound) and simplifies fuel transportation and handling.

Solid waste can be harmful to boilers due to the presence of such compounds as polyvinyl chlorides, hydrochlorides, and salts. On combustion, these produce hydrochloric acid and other corrosive substances that may damage boilers and heat exchangers. Refuse also tends to produce more ash than wood and consequently will reduce heat transfer and erode convection heating surfaces. In a municipal refuse incinerator, special metallurgy and boiler design are used to help control these problems. A wood boiler could not handle large amounts of refuse without considerable additional expenses for boiler and fuel-handling design and construction (Cover 1978; Cheremisinoff & Morresi 1976).

Some plants currently burn waste in combination with conventional fuels. Union Electric Company in St. Louis, Missouri, ran a pilot plant which burned the light, combustible fraction of municipal solid waste in a pulverized-coal burner. The waste provided 10 percent of the fuel heating value (Klumb & Brendel 1977). The combined firing of waste with the coal was halted when the demonstration project ended. The plant reports no corrosion problems.

It would be technically feasible for the S.D. Warren plant to utilize small quantities (up to 10 percent) of meter-fed municipal

TABLE 17: PROJECTED COMPOSITION OF RAW MUNICIPAL SOLID WASTE

Component	Percent by Weight 1970	1980	1990
Paper	37.4	40.1	43.4
Glass	9.0	10.2	9.5
Metal	8.4	8.9	8.6
Plastics	1.4	3.0	3.9
Leather & Rubber	1.2	1.2	1.2
Textiles	2.2	2.3	2.7
Wood	3.1	2.4	2.0
Food Wastes	20.0	16.1	14.0
Yard Waste	13.9	12.9	12.3
Miscellaneous	3.4	2.7	2.4

Source: Ruane 1977a.

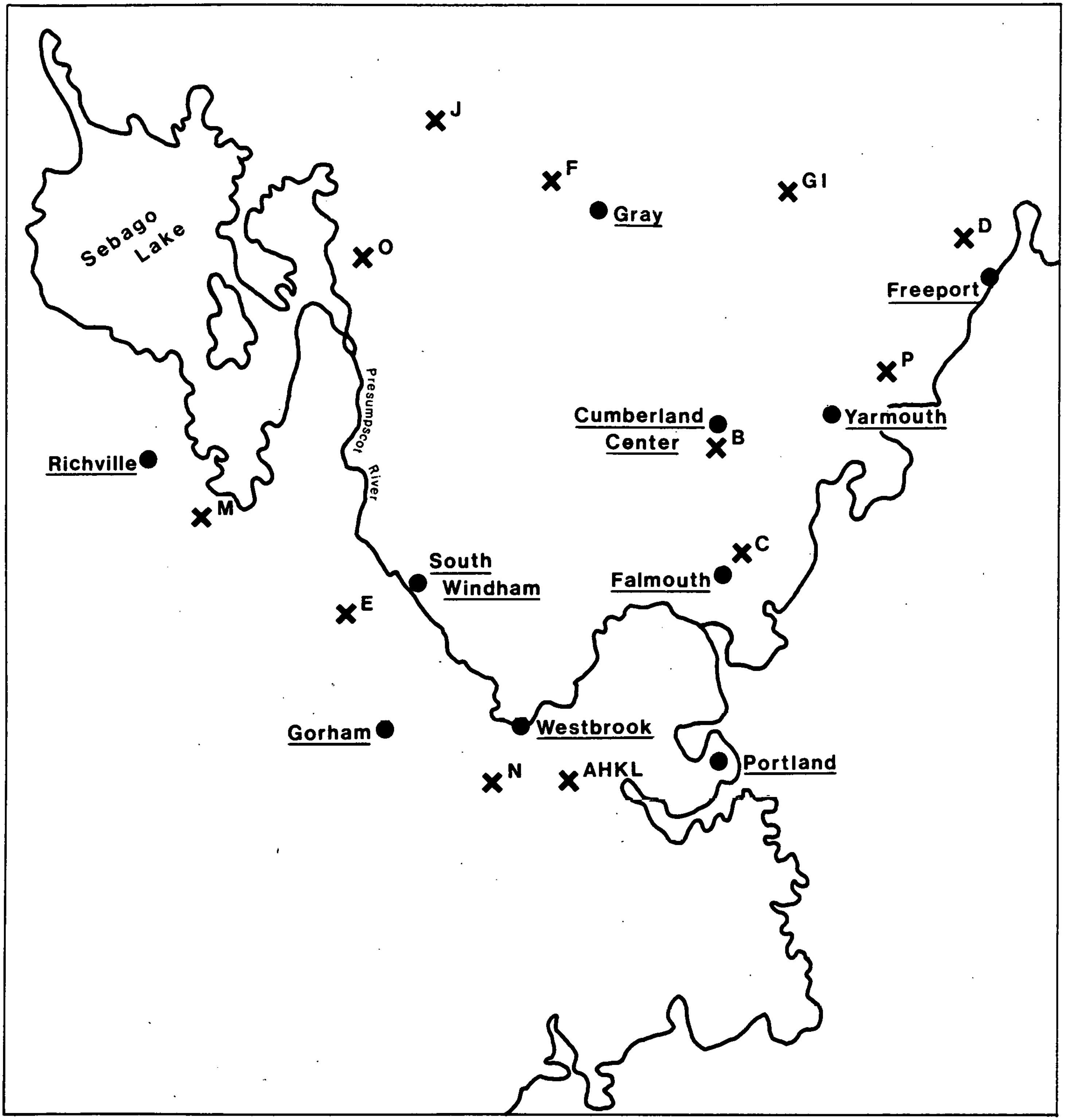
solid waste as a supplementary fuel if it were available in processed form. There is presently no facility in the Westbrook area that can sort, shred, and bale municipal solid waste. However, if such a facility were to be built at or near S.D. Warren, there would be sufficient quantities of municipal solid waste available to provide 10 percent of the proposed wood-fired boiler's total fuel requirements.

The Greater Portland Council of Governments has set up Regional Waste Systems Incorporated to handle the disposal of the region's solid waste. This organization serves Portland, South Portland, Cape Elizabeth, and Scarborough, which have a combined population of approximately 110,000. Regional Waste Systems operates a baler and landfill operation with a maximum capacity of 250 tons per day (see Table 18). The City of Westbrook also operates a municipal landfill with an average capacity of 44 tons per day. Thus, the total quantity of raw municipal solid waste available in the metropolitan area immediately surrounding Westbrook is about 300 tons per day. A survey for the Greater Portland Council of Governments indicates that roughly 430 tons per day are available within a twenty-mile radius of Portland (GPCOG 1977) This amount includes refuse from several small towns which currently operate open dumps, each with a capacity between one and five tons per day. Figure 1 shows the location of the major dump sites within the twenty-mile radius (GPCOG 1977).

The wood-fired power plant will require roughly 1.6 x 10^{10} Btu per day of fuel (2,000 green tons of wood per day). Ten percent of this is 1.6 x 10^{9} Btu, or roughly 120 tons of processed municipal solid waste at 25 percent moisture content each day. This amount is less than one-third of the total amount available in the area.

Rubber tires. The kinds of rubber tires that are discarded vary in size and composition. The different kinds of tires include nylon-and rayon-belt plies, fiberglass-belt polyester cord, and steel-belted polyester plies. Tires may be either passenger tires (average size: 30-inch diameter by 12 inches thick; weight: 21 pounds) or truck tires (average size: 44 by 12 inches;

FIGURE 1: LANDFILL SITES IN GREATER PORTLAND AREA[1]



1. *Key to map is given in Table 18.*

TABLE 18: LANDFILL AND OPEN DUMPING SITES WITHIN 20-MILE RADIUS OF PORTLAND

Map Key [1]	Site	Tons/day
A,H,K,L	Portland, S. Portland, Scarborough, Cape Elizabeth	250
B	Cumberland	17
C	Falmouth	15
D	Freeport	25
E	Gorham	25
F	Gray	11
G,I	North Yarmouth, Pownal	3
J	Raymond	4
M	Standish	13
N	Westbrook	44
O	Windham	24
P	Yarmouth	15
	Total	432

1. See Figure 1.

Source: GPCOG 1977.

weight: 125 pounds). Ground rubber and rubber dust from retreading operations is also available (Noyes 1974).

The physical and chemical characteristics of rubber tires make them difficult to burn, although there are plants in both the United States and Great Britain that currently find it technically feasible to utilize them for all or part of their total fuel input (Stribling 1973). If the tires are to be burned in combination with some other fuel, they must be chopped or shredded in order to be accommodated by the fuel-handling equipment. Because the melting of the beadwire in the tires can cause clogging problems in the furnace, it is wise to debead the tires as well. Complete combustion of the rubber-hydrocarbon content of the tires requires furnace temperatures higher than those required for wood (Stribling 1973). In order to avoid the addition of a separate boiler, the percent of rubber in the total fuel mixture must be kept fairly low. The Georgia Pacific Corporation of Toledo, Oregon, burns tires in their 300,000 pound per hour bark boiler and finds that the optimum firing for rubber is about 10 percent of the total steam generated: i.e., 30,000 pounds per hour. The maximum level is about 15 percent. Above that level the temperatures in the furnace exceed the design capacity of the boiler equipment and can damage the boiler tubes (Meffert 1978).

There are five major tire companies in the Westbrook area that produce significant amounts of scrap tires and rubber dust. Table 19 presents the quantity of scrap rubber that is available in the Westbrook area. These estimates are conservatively derived from information provided by the five tire companies listed. The ratio of car tires to truck tires in the waste stream is not known; therefore, the number of tires available per week, roughly 6,000, was converted using the weight of an average car tire (21 pounds). The weight of rubber dust is estimated to be 26.4 pounds per cubic foot (Noyes 1974). The 177.5 tons of rubber per week (or 35.5 tons per day) at 15,000 Btu per pound (Noyes 1974) is equivalent to 1.065×10^9 Btu, or roughly 7 percent of the total daily required Btu input for the power plant.

TABLE 19: SCRAP RUBBER AND RUBBER DUST AVAILABLE IN WESTBROOK AREA

(tons/week)

	Tires		Rubber Dust
Yudi Tire Co. Westbrook, Maine	16		11
Noyes Tire Co. Westbrook, Maine	16		21
L & A Tire Co. Lewiston, Maine	10.5		2.5
Snows Tire Co. Lewiston, Maine	26		47.5
Century Tire Co. Portland, Maine	16		11
Total	84.5	+	93 = 177.5 tons rubber/week

Sources: Detwyler 1978; Harmon 1978; Hobart 1978; Hunt & Babcock 1978.

Railroad crossties. Crossties are made from oak, pine, and cedar, and, less frequently, from chestnut and hemlock. Each tie weighs about two hundred pounds. Most railroad ties are treated with creosote, although older ties were made of cedar and may or may not have been treated with a wood preservative. Creosote in a mixture with coal tar of petroleum is the most commonly used wood preservative in the New England region.

The average Btu content of creosote-treated railroad crossties is estimated at 6,250 Btu per pound (Johnston 1978). This assumes an average moisture content of 25 percent. In order to be burned as fuel, the crossties would have to be chipped and meter-fed to the boilers with wood.

Approximately 21,000 tons of used railroad crossties are available annually in southern Maine from three railroad companies: Central Maine, Boston and Maine, and Bangor and Aroostook (Bell 1978; Peters 1978; Hughes & Denio 1978). A fourth company (Grand Trunk) also produces scrap ties but currently disposes of them under contract to a company in Canada. Boston and Maine presently hauls old ties as far as one hundred miles to dispose of them. About 3 percent of all ties in an area must be replaced each year. An average tie has a useful life of about thirty-five years. With roughly 3,000 ties per mile, this means that about ninety old ties are made available annually from each mile of track. This figure will be doubled on routes that have double tracks (Hughes & Denio 1978). The 21,000 tons of crossties at 6,250 Btu per pound would supply roughly 5 percent of the total Btu input required by the proposed wood-fired power plant.

Economics

Central Maine Railroad currently sells scrap crossties to individuals at $2.50 apiece, although other companies give them away for free. Prices for old crossties sold in quantity as fuel would probably range from $12.00 to $14.50 per ton delivered (Johnston 1978). Municipal solid waste and scrap rubber tires are both considered to be waste problems and are disposed of at a cost to the producer. Disposal costs for unprocessed municipal solid waste in the Westbrook area range from $5.00 to $9.00 per ton

(Allen 1978). The cost of disposing of rubber tires is approximately $14.00 per ton (Noyes 1974). It is not known what the costs of these materials would be if they were sold as fuel. The fact that these substances are currently a waste disposal problem indicates that obtaining them as supplementary fuels would be economically feasible.

As mentioned previously, a municipal solid waste processing facility does not currently exist in the Westbrook area. Such a plant with a capacity of 500 tons per day would cost roughly $5.4 million to construct (Paskert & Gallagher 1977). Given the small percentage of municipal solid waste that the wood-fired plant could use for fuel, it would be uneconomical for S.D. Warren to install its own processing facility. However, in the event that such a facility was built, municipal solid waste could be a feasible supplementary fuel.

Environmental Impacts

Construction impacts. The construction impacts of the facility using supplementary fuels would be the same as those described for the wood-fired facility.

Operation impacts. The environmental impacts of operation with supplementary fuels are similar to those of combustion of wood alone. Differences in air emissions and the chemical content of boiler ash are significant, however.

o Municipal solid waste. Processed municipal solid waste has the following chemical composition: ash, 19 percent; carbon, 28 percent; hydrogen, 6.9 percent; nitrogen, 0.6 percent; oxygen, 45 percent; and sulfur, .2 percent (Ruane 1977a). The emissions resulting from the combined firing of municipal solid waste with coal are given in Table 20 for the St. Louis, Missouri, plant described earlier. The processed municipal solid waste contributed from 9 to 27 percent of the total heat input. Particulate emissions (not shown in Table 20) also increased when processed municipal solid waste was fired with the coal, but these could be controlled by adjusting the electrostatic precipitator (Ruane 1977a).

The amount and form of ash resulting from the combustion of municipal solid waste depends on the degree of preprocessing and

TABLE 20: EMISSION FROM COMBINED COAL/MUNICIPAL SOLID WASTE PLANT

Compound	Coal	Coal and Municipal Solid Waste
Water	6.8 percent	8.6 percent
Sulfur Dioxide[1]	943 ppm	1,067 ppm
Sulfur Trioxide	9 ppm	8 ppm
Nitrogen Oxide	298 ppm	285 ppm
Chlorine ions	335 mg/cu m	402 mg/cu m

1. The increase in sulfur dioxide emissions during the firing of coal with municipal solid waste resulted from an increase in the sulfur content of the coal burned.

Source: Ruane 1977a.

the completeness of combustion. About one-fifth of raw municipal solid waste is converted to ash (Ruane 1977a). Boiler residues from the St. Louis plant were four to seven times as high when municipal solid waste was burned. The ash consisted of some glass, metals, and other inert particles, as well as unburned materials such as wood and leather (Ruane 1977a).

From 4.75 to 5.75 percent of the residue from combusted raw municipal solid waste is water-soluble and may leach out at landfill sites. Due to the highly variable chemical composition of municipal solid waste, it is impossible to predict precisely the kind or concentration of materials present in leachate from disposal sites. It is possible that potentially harmful substances could be present. Table 21 shows the substances found to be present in the water-soluble portion of municipal solid waste.

o Rubber tires and rubber dust. Burning rubber generates smoke which is more noxious and acrid than that of most other solid fuels. This is because it is difficult to ensure the complete combustion of all the constituents of rubber. The main components of rubber tires are: carbon, 82.06 percent; hydrogen, 10.94 percent; sulfur, 0.96 percent; zinc oxide, 3.25 percent; other additives, 2.79 percent (Stribling 1978). A test-firing using samples from the Noyes Tire Company in Westbrook yielded the fuel values and combustion characteristics shown in Table 22.

The high particulate emissions (138 pounds per ton: EPA 1976) make it difficult for plants that burn only rubber waste to meet state opacity and particulate standards. However, the Georgia Pacific plant, which uses tires as 10 percent of its fuel mixture with bark, has proven the practice feasible, showing no increase in particulate emissions (Meffert 1978). The sulfur content of tires is between 1 and 2 percent (Noyes 1974). The Georgia Pacific plant demonstrated no increase in sulfur dioxide emissions when rubber fuel was burned. There was a slight increase in nitrogen oxides; this was attributed to the higher furnace temperatures produced by rubber.

Zinc oxide is also present in the boiler emissions and may be present in fly ash, although Georgia Pacific has not done measure-

TABLE 21: AVERAGE ANALYSIS OF WATER SOLUBLE PORTION OF RESIDUE

(Percent by dry weight of sample)

	Batch-Feed Incinerator	Continuous-Feed Incinerator
Hydrocarbon concentration	6.1666	9.1666
Alkalinity	0.1156	0.1865
Nitrate nitrogen x 10^{-4}	4.0078	3.48
Phosphate x 10^{-4}	2.75	4.416
Chloride	0.1221	0.0771
Sulfate	0.0813	0.2447
Sodium	0.04675	0.197
Potassium	0.04230	0.048
Iron	0.00617	0.015

Source: Rubel 1974

TABLE 22: FUEL VALUES AND COMBUSTION CHARACTERISTICS OF RUBBER TIRES

	Btu Per Pound	Ash[1] (percent)	Sulfur (percent)	Volatile[2] (percent)
Nylon	16,592	6.10	1.53	69.7
Rayon	15,323	7.34	1.91	70.7
Fiber Glass Polyester	16,301	7.60	1.65	67.2
Steel Belted Radials-Uncured	14,179	*	*	*
Steel Belted Radials-Scrap	14,112	7.76	*	56.2
Ground Rubber	17,134	2.49	1.45	69.5

1. Burned at 1,000° F
2. Up to 1,000° F.
** Not tested*

Source: Noyes 1974

ments for the latter. Zinc oxide fumes have a low toxicity to humans in most cases, although some researchers believe the compound might be carcinogenic in high concentrations over extended periods (Sax 1975). The small percentage of rubber in the total fuel mixture has not necessitated additional air pollution control measures at the Georgia Pacific plant. The composition of the rubber ash is: mineral matter, 58.7 percent; iron, 40.6 percent (as $Fe_2 O_3$); Zinc, .04 percent (as ZnO); and carbon, .43 percent (Stribling 1978): The presence of zinc in the boiler ash may require special disposal precautions since zinc is a heavy metal that may be toxic in high concentrations to animal life (Sax 1975).

o Railroad crossties. If railroad ties are completely burned, then the creosote in them will be converted to harmless emissions (Thomae 1978). However, if incomplete combustion occurs, then the boiler emissions will contain hazardous black coal tar creosote smoke. Coal tar creosote consists of more than 300 different chemical compounds. These compounds may be grouped into three classes (Hunt 1938):

1. tar acids (less than 5 percent): phenols, cresols, xylenols, napthols;
2. tar bases (about 5 percent): pyridines, quinolines, acridines;
3. hydrocarbons (more than 90 percent): benzene, toluene, napthalene, acenapthene, phenanthrene, anthracine, fluorene.

All of these compounds are toxic. Most of them are carcinogenic.

Creosote is a recognized carcinogen (Sax 1975) although it is not classified as a hazardous substance under current pollution laws. If the amount of unburned creosote in the exhaust gases violates state standards regulating particulate emissions or stack gas opacities, then the boiler may not operate. Likewise, emissions of large quantities of unburned hydrocarbons may not be permitted under federal Prevention of Significant Deterioration regulations. If, in the future, creosote smoke falls under federal hazardous substance regulations, no railroad crossties may be burned. At present however, only state and federal particulate and opacity regulations affect the burning of railroad crossties.

Trace amounts of herbicides may be present on railroad crossties as a result of periodic weed control spraying along track beds. The following herbicides have been used at various times by the three railroad companies that would be expected to supply ties:

Atrotol 80W	75% AAtrex (2-Chloro-4-ethylamino-6-isopropylamino-s-triazine) 5% Prometon (2,4-bis (Isopropylamino)-6-methoxy-s-triazine)
Banvel	(3,6-Dichloro-o-Anisic Acid or 3,5,6-Trichloro-o-Anisic Acid)
Princep	(2-chloro-4,6-bis (ethylamino)-s-triazine)
Ammate	(Ammonium sulfamate; $NH_4OSO_2NH_2$)
2,4-D	(2,4-Dichlorophenoxyacetic acid)
2,4,5-T	(2,4,5-Trichlorophenoxyacetic acid)
Evik	(2-Ethylamino)-4-(isopropylamino)-6-(methylthio)-s- triazine)
Karmex	(3-(3,4-Dichlorophenyl)-1-methylene)
2,4-D Amine	

The herbicides are sprayed on weeds at one- to three-year intervals. Brush is sprayed about every five years. Less traveled tracks are treated less frequently. Most railroad personnel believe that very little of the herbicide is sprayed on the crossties themselves, especially where the track bed is of crushed stone and weeds are less likely to be a problem. All of the active ingredients present in the above listed herbicides are degradable by biological, physical, or chemical means. The mobility and ecological impacts of these compounds, especially 2,4-D and 2,4,5-T, are controversial (Heinrichs 1979; Popovich 1978). Between 99 and 100 percent of the active ingredients in most pesticides and herbicides degrade during complete combustion. Potentially harmful emissions resulting from incomplete combustion include particulates from solid formulations, phosphorus pentoxide from phosphorus-based formulations, carbonyl/chloride/hydrogen chloride from chlorinated hydrocarbons, cyanogen from nitrogen-containing organics, nitrogen oxide, and sulfur dioxide. The solid residues left from incineration of pesticides and herbicides are very low (less than twenty parts per million for combustion of pure pesticides) and leachate from ash disposal sites should not represent a pollution problem due to (EPA 1976).

Fuel procurement impacts. Since the supplementary fuels described in this section are generally regarded as waste materials, the net effect of obtaining and utilizing them would be positive. There are some alternative uses for old crossties and discarded rubber tires. Crossties are frequently used as fence posts, erosion control structures, and building material for rough or temporary structures. Rubber tires can be used for erosion control, artificial turf, road surfacing, and crash barriers. If supplementary fuels were used, the amount of wood required by the facility would be reduced.

Transportation impacts. It is possible to transfer each of the supplementary fuels in 24-ton vans if the materials are processed (i.e., chipped, shredded, or baled) at the collection sites. Given the total quantities of fuel that could be delivered per day to S.D. Warren, the number of vans that would be required per week for supplementary fuel transport would be sixty-three (thirty-eight for municipal solid waste, seven for rubber tires, and eighteen for crossties). This is less than the number of vans that would be required to deliver an equivalent amount of green wood fuel. For this reason, the amount of overall truck traffic would not increase. It is likely that crossties may be delivered by rail. In this case, the truck traffic would be even less. Since these waste materials are already being trucked from the source of their production to a disposal site, there would be no additional transportation impacts in these areas. However these trucks may have to travel greater distances to the S.D. Warren plant than to the previous disposal sites.

Relationship to national, state, or local policies and plans. The federal government encourages systems which demonstrate the feasibility of utilizing solid waste for energy under the Resource Conservation and Recovery Act of 1976. Although there are no specific local or state plans for the use of these supplementary fuels, their use would be compatible with local waste disposal plans.

Summary of long-term effects. The principal long-term environmental effects center around the potential release of contaminants from the supplementary fuels, the reduction of the primary fuel requirements, and the alleviation of local solid waste disposal problems. Environmental contaminants, particularly in the form of airborne particulate and leachable hazardous materials, can be controlled by existing methods. The limited use of supplementary fuels also mitigates the impacts of these contaminants. The impacts associated with combustion, procurement, and transportation of the fuelwood would be reduced in proportion to the use of the supplementary fuels. The use of solid waste fuels would alleviate the pressures on regional and local sanitary landfill operations.

Other Fuels

Oil

Policy Statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a 510,000 pound per hour oil-fired cogenerating facility at the Westbrook mill as a means of demonstrating and encouraging industrial cogeneration.

Description. The Powerplant and Industrial Fuel Use Act of 1978 (202(a)) specifically prohibits the use of petroleum as a primary energy source in a new major fuel-burning installation. The definition of a major fuel-burning installation includes a facility with boilers designed to consume fuel at a rate of 100 million or more Btu per hour. A cogenerating facility producing 510,000 pounds per hour is well in excess of this threshold, with a fuel consumption capacity on the order of 600 million Btu per hour. The Act further allows the Secretary of Energy to order the conversion of existing facilities from natural gas or petroleum to coal or other alternative fuels.

Because of these prohibitions, an oil-fired cogenerating facility is not a feasible alternative.

Natural Gas

Policy statement. The U.S. Department of Energy could support a cogenerating plant at S.D. Warren that used natural gas as a fuel.

Description. The Powerplant and Industrial Fuel Use Act of 1978 specifically prohibits the use of natural gas as a primary energy source in new major fuel-burning installations (see above discussion). Because of these prohibitions, a natural gas-fired cogenerating facility is not a feasible alternative.

Geothermal

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support a cogenerating plant that extracts heat in the form of steam from the earth's interior. The steam may be used for industrial processing or to produce electricity.

Description.* Hydrothermal power is naturally available where underground aquifers or water bodies come in contact with hot bedrock. There are many hydrothermal reservoirs in the western United States, but none are known to exist in Maine. However, areas in Maine do exist where hot bedrock lies close to the surface. At these locations, it may be possible to inject surface water into the hot rocks and then extract it in the form of steam via another nearby well.

In order for the water and steam to flow, the hot bedrock must be made porous through fracturing techniques. To date, only hydraulic fracturing has been actively investigated; this technique has been demonstrated successfully at Los Alamos, California. Continuous steam extraction has not yet been achieved, however, due to technical difficulties.

While dry rock geothermal energy may be commercially feasible by the late 1980s, the technology is presently still in experimental and small-scale demonstration stages. For this reason, geothermal energy is not currently a reasonable alternative to the proposed project.

---

* Source: Waterflow 1977.

Solar

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a solar-powered cogenerating steam-electric plant.

Description. Two systems have been developed which collect solar radiation and convert it to high temperature thermal energy. The first system, called a central receiver solar furnace, utilizes a field of mirrors (heliostats) to focus the sun's rays on a receiver mounted on a tall tower. This concentrated thermal energy heats water and produces steam. The steam may be used immediately or transferred to a thermal storage system where heat is held for later use (Bereny 1977; Geary & Jones 1977; Williams 1974).

The second system employs a "solar farm" composed of linear, fixed-mirror collectors which concentrate insolation (solar radiation) onto long pipes containing heat-retentive fluids. These fluids flow to a central storage system where the heat is used to produce steam (Bereny 1977; Geary & Jones 1977; Williams 1974). Both systems require a master control unit to coordinate the heliostats and to regulate the delivery of steam and transfer of heat. Conventional steam turbines and electrical generators can be used with either system.

Solar thermal systems are technically feasible. The Department of Energy is funding the development of one 5-megawatt demonstration plant and one 10-megawatt pilot plant in the southwestern United States, the region that shows the highest promise for near-term use of solar-powered steam-electric plants. Operation of a large-scale commercial plant is not foreseen, even in that region, until sometime after the mid 1980s (Geary & Jones 1977).

Recent estimates indicate that between 160 and 625 acres would be required at a solar power station to produce the energy to be supplied by the proposed wood-fired boiler (Geary & Jones 1977). S.D. Warren Company currently owns about 180 acres, half of which is occupied by existing plant structures. The Company does not have access to sufficient acreage to meet its energy needs with a solar thermal system because the area surrounding its property is either developed or zoned for nonindustrial uses.

Furthermore, currently available storage systems to supply energy during cloudy periods must be recharged every three days (Ruane 1977b), whereas the Northeast occasionally experiences as many as six consecutive days without sun.

It is highly unlikely therefore that a commercially viable solar thermal-electric system will be located in Maine in the near future. Due to site restrictions, it would not be feasible for one to be located at the S.D. Warren site in Westbrook.

ALTERNATIVE METHODS OF ELECTRIC POWER GENERATION

The alternatives described in this appendix are intended to describe methods of generating or conserving twenty-five megawatts of electrical power to replace the capacity represented by the proposed facility. These alternatives involve projects which could be undertaken within the area affected by the proposed facility: i.e., anywhere within fifty miles of Westbrook, Maine.

No New Capacity

Policy Statement

The U.S. Department of Energy could support a load management and electricity conservation project in Maine as an alternative to building twenty-five megawatts of new cogenerated electric capacity.

Description

This alternative would consist of a concurrent effort to reduce peaks in electricity demand and to reduce the overall consumption of electricity. Load management involves a shifting of peak electricity use to times of the day or year characterized by low demand. The creation of a relatively even demand for electricity enables the use of less expensive and more efficient base- and intermediate-load power in place of peaking capacity. This approach may not reduce total consumption of electricity but it can reduce the use of fuel oil to produce peaking power and forestall or eliminate the need for additional peak load capacity.

Load management can be accomplished through a variety of measures, including differential rate structures, remote control by the utility of electrical appliances, and space heat storage. Differential rate structures employ economic incentives for the consumer to reduce consumption of electricity during peak hours. A utility can shut off appliances, including air conditioners and water heaters, owned by cooperating consumers when demand for electricity exceeds a pre-specified level. Such consumers usually receive a preferred rate charge in return for their contribution to reducing peak demand. Heat storage systems employ a thermal mass to store heat when demand for electricity is low and reradiate it during peaking hours when demand is high.

A recent study has indicated that successful load management could reduce the 1985 peak demand for electricity in New England by 2.4 percent or 544 megawatts (ACE 1977).

Conservation of the total amount of electricity consumed can be attained by improving the efficiency of electrical appliances and by reducing the use of such appliances. Conservation programs also could be directed toward reducing unnecessary use of electric space heating and lighting systems. It has been estimated that, in Maine, between 5.7×10^8 and 21.9×10^8 kilowatt-hours of electricity could be conserved annually in 1985 (Jones et al. 1977). This is equivalent to the output of a 92- to 357-megawatt generating facility operating at 70 percent capacity.

This potential for load management and conservation could delay the construction of new electric-generating capacity in southern Maine.

Economics

Load management and conservation have been demonstrated to be economically viable in specific situations in the United States (Rodemann 1978; Vumbaco 1978). In addition, load management has been extensively employed in Europe for many years as a means of optimizing the use of baseload generating capacity (Laaspere 1974; Converse 1974). Research also indicates that energy-efficient electrical appliances are economically viable (NEEC 1978) and could be employed to a greater degree.

Environmental Impacts

The environmental impacts of an electric energy conservation program are primarily beneficial. An overall reduction in the amount of electricity consumed would reduce the amount of fuel consumed to generate that electricity. Successful load management would allow more efficient use of baseload generating stations, which typically consume less energy per kilowatt generated than do intermediate and peakload facilities. The result would be to reduce the operating impacts of electric-generating facilities.

These reductions would occur principally in chemical and thermal emissions to air and water.

An additional effect of a conservation program would be to defer the need for additional generating capacity and the related environmental impacts of construction of new facilities. Discussion of the impacts of construction and operation of energy facilities occurs throughout this document.

Some socioeconomic impacts could also occur. While only 5 percent of Maine's housing units are electrically heated, this use accounted for 12 percent of the total residential electricity consumption in 1977 (Jones et al. 1977). A program to improve the insulation in these homes would generate local employment. While this effect and others similar to it might be considered beneficial, the deferral of constructing new capacity must be considered as negative from the labor viewpoint. It is possible, however, that a conservation program of significant scope would require the skills of these workers to retrofit new, energy-efficient equipment into existing homes and commercial, industrial, and utility facilities.

A conservation program would be compatible with both the Energy Policy and Conservation Act of 1975 and the National Energy Conservation Policy Act of 1978. These acts established conservation programs and efficiency standards for electrical appliances. This alternative would also be compatible with the policies established by the Maine Office of Energy Resources (MOER 1976).

Purchase of Electricity

Policy Statement

As an alternative to the proposed action, the electric utilities in southern Maine could purchase twenty-five megawatts of electric generating capacity from a utility outside their service areas.

Description

The purchase of electric power as an alternative to the proposed action can be a "firm purchase agreement," a contract between two utilities for the output from a given amount of generating capacity. A utility can also enter into a mutual construction program with other utilities to build new power plants. The latter option allows utilities to supplement their power supplies through ownership of new generating capacity.

Central Maine Power Company is the utility presently serving the Portland area and most of southern Maine. Central Maine Power Company in 1977 purchased approximately 110 megawatts of capacity and expects to continue purchasing capacity in varying amounts over the coming years (CMP 1977). As a member of the New England Power Pool (NEPOOL), Central Maine Power Company has a "capability responsibility" calculated under the provisions of the NEPOOL agreement to provide a certain amount of power. Subject to certain restrictions, the purchase of electric power is a means of meeting this responsibility (NEPOOL 1971). NEPOOL itself purchases power from outside the New England area. NEPOOL is expected to purchase roughly 600 megawatts of capacity annually during the next five to ten years (ACE 1977).

Central Maine Power Company also owns shares in several existing and planned plants that comprise a major portion of its capability responsibility. These shares amounted to 384.6 megawatts of capacity in 1977 and are expected to amount to 1,392.5 megawatts by 1990 (CMP 1977).

Either of these two methods of purchasing twenty-five megawatts of electric generating capacity is a feasible alternative to the proposed project.

Economics

The cost of electric power purchased under a firm purchase agreement, the method most often employed for the acquisition of supplemental power, is determined by establishing a fixed capacity charge and adding an energy charge. The capacity charge, in dollars per kilowatt per year, includes the fixed annual costs and return on investment of the capacity purchased. The energy charge primarily represents the variable fuel costs (Lowery 1979). The cost of electric power obtained from a newly constructed, jointly owned plant is determined on a conceptually similar basis. A comparison of the two methods is difficult, however, due to the variety of conditions that affect the economics of the surplus capacity and the new capacity.

The widespread employment of both practices demonstrates the economic feasibility of purchasing power.

Environmental Impacts

The environmental consequences of purchasing power depend on the choice of purchasing arrangement. If electricity or capacity is simply purchased from a neighboring utility, the environmental impacts are directly proportional to the additional fuel consumed, since the supplier of electricity is utilizing existing surplus capacity.

If, on the other hand, the purchasing utility were to enter into a joint construction effort on a large new plant, the environmental effects of purchasing power would involve an increment of the construction as well as operation impacts. The large new facilities that are to be built in New England in the future are most likely to be nuclear and coal plants. An estimate of the impacts associated with twenty-five megawatts of capacity in either of these types of power plant is beyond the scope of this analysis. A number of environmental impact statements providing analyses of these impacts have been prepared (BLM 1976; AEC 1974).

Central Maine Power and NEPOOL project a decline over the next ten years in the amount of electricity purchased under contract (CMP 1977; ACE 1977). The environmental impacts of a purchased power alternative therefore will stem principally from the joint construction option.

Relationship to national, state, or local plans or programs. The Public Utilities Regulatory Policy Act of 1978 supports the efficient use of energy-generating resources, including physical facilities and capital. The purchase of surplus generating capacity and joint construction of new capacity both contribute to this goal.

Summary of long-term effects. Because most joint construction projects will be for plants that are nuclear- or coal-fired, the purchase of electricity option represents a continued investment in nonrenewable energy systems. This investment will further delay a regional transition to locally available, renewable sources of power. The joint construction option also carries with it the long-term impacts of construction and operation of new plants.

Coal

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a 25-megawatt coal-fired electric generating station in southern Maine.

Description

A 25-megawatt coal-fired facility operating at a capacity factor of .7 would produce 153.3 million kilowatt-hours of electricity per year. This power could be sold to industrial customers in southern Maine, to the regional electric grid, or to both. With a heat rate of 10,500 Btu per kilowatt-hour, such a plant would require approximately 59,000 tons of coal per year (KCIM 1976). A 25-megawatt plant would be generally similar to the 50-megawatt coal-fired cogenerating station described in the "Coal" section of the previous chapter. However, the quantities of coal required by the facility would be too small to support the economic use of unit trains for the delivery of the fuel. If the plant were sited at an ocean or deep-water river port, transportation of the coal by barge would provide an economic alternative. Otherwise, the coal would probably have to be delivered by rail freight at relatively high car-lot rates.

Economics

The economic requirements of a 25-megawatt coal-fired electric generating facility are given in Table 23. Unless the plant could be sited near an ocean port with handling facilities to receive coal barges, the unavailability of unit trains for a plant of this size would mandate higher fuel costs than those shown.

TABLE 23: ESTIMATED CAPITAL, OPERATING AND MAINTENANCE, AND FUEL COSTS FOR A 25-MW COAL-FIRED ELECTRIC GENERATING FACILITY[1]

	1979 Dollars *(millions)*
Installed Capital Cost[2]	45.0
Annual Operating and Maintenance Cost[3]	1.1
Annual Fuel Cost[4]	2.7

1. *These estimates would vary substantially from site to site and should only be considered as approximate.*
2. *Calculated from Manar 1979b.*
3. *Assumed to be 2.5% of installed capital cost: Manar 1979a.*
4. *Sources: Harvey 1978; Graham 1978; Hall et al. 1976. Based on 59,000 tons/year at $46/ton.*

The use of the costs presented in the table to calculate a unit production cost, such as mills per kilowatt-hour or dollars per million Btu, is subject to many variables. The nature of the plant site and its location affect the cost of capital, maintenance, operation, and fuel. Construction time, financing, and the existing tax climate will influence the annual charges on investment. Recent changes in the investment tax credits and depreciation allowances enacted by the Energy Tax Act of 1978 will have an important influence on the choice of fuel for energy facilities. For these reasons, it is beyond the scope of an environmental impact statement to predict precise unit costs.

The capital, operating, maintenance, and fuel costs presented in Table 23, however, do indicate that this alternative is at least marginally commercial and that consideration of its environmental impacts is justified.

While this alternative may be economically viable, an electric utility investing in additional generating capacity would be more likely to seek the economies of scale available in larger coal-fired facilities. For example, Central Maine Power Company is planning to build a 600-megawatt coal-fired plant in Maine and retain 463 megawatts of capacity for its own use, while selling the rest to other utilities (CMP 1977).

Environmental Impacts

The environmental impacts of a 25-megawatt coal-fired electric generating plant would be similar to those described in the previous "Coal" section for a 50-megawatt cogenerating facility. The smaller size of the plant and the reduced fuel requirements would diminish all of the impacts described.

Air emissions and volumes of solid wastes generated by the plant are outlined in Table 24. Although it is assumed that sulfur dioxide scrubbers will be employed as air pollution control devices, it is possible that other means of meeting air quality standards, such as burning low-sulfur coal, could be used.

If the plant were sited on the coast to allow service by coal barges rather than unit trains, air emissions from the transport of coal would be reduced, as towboats emit fewer pollutants per

TABLE 24: ESTIMATED AIR EMISSIONS AND SOLID WASTE FLOWS FROM A 25-MW COAL-FIRED ELECTRIC GENERATING FACILITY

Air Pollutants	Emissions[1] *(tons/year)*
Nitrogen Oxides	531.0
Sulfur Dioxide	224.2
Carbon Monoxide	29.5
Particulates	17.7
Hydrocarbons	8.5

Solid Wastes[2]	Quantity *(tons/year)*	Quantity *(acre-feet/year)*
Collected Ash	4,879	2.8
Scrubber Sludge	10,803	6.5

1. *Assumes 90% reduction in SO_2 emissions and 99.5% reduction in particulate emissions. Source: EPA 1976.*
2. *Source: Le, Rubin & Meier 1978.*

ton of material hauled than do railroad engines (Dvorak et al. 1977). Accidental and routine coal spillages would affect aquatic ecosystems in a manner similar to that described in the previous "Coal" section. Fatal accidents associated with coal barge traffic would be lower than those associated with rail shipment (Dvorak et al. 1977).

Location of a coal-fired electrical generating station on a nonindustrial site adjacent to the ocean or a navigable waterway raises concern over the limitation of free access to a public resource. Although the Great Ponds Act in Maine guarantees access to most freshwater areas, public access to the ocean shore is extremely limited in Maine at present.

All other impacts, policy implications, and long-term effects are described in the previous "Coal" section.

Alternative Supplementary Fuels

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could assist the development of an electrical generating plant that utilized limited quantities of supplementary fuels in addition to fuelwood.

Description

This alternative is similar to that discussed in the "Alternative Supplementary Fuels" section of the previous chapter, except that the plant would not be a cogenerating facility. The steam created would be used only to generate electricity and would not be used for heating or processing. Therefore it would require less fuel than the plant described in the previous chapter and would not necessarily have to be located at S.D. Warren or a similar industrial facility. The technical restrictions on the percentage of municipal solid waste and rubber that could be burned are the same as those described earlier (i.e., 10 percent processed municipal solid waste and 10 percent rubber).

A 25-megawatt electric generating plant, operating at a 70 percent plant capacity factor and with a heat rate of 10,500 Btu per kilowatt-hour would require approximately 1.6 x 10^{12} Btu per year. Ten percent of this figure is approximately equivalent to 12,300 tons of processed municipal solid waste. There would be sufficient supplies of processed municipal solid waste in the area to meet this demand. There are also 9,230 tons of rubber available annually, which is enough to supply about 17 percent. There are about 21,000 tons of crossties available per day. This amount would supply about 16 percent of the total daily Btu input. The total supplementary fuel contribution could therefore be about 43 percent.

The economics and environmental impacts of this alternative are the same as those described in the previous chapter.

Hydroelectric

Policy Statement

As an alternative to the proposed action, the U.S. Department on Energy could develop hydroelectric potential in southern Maine to produce the twenty-five megawatts of electricity that the proposed plant is expected to supply. The hydroelectric alternative would supply power to the regional grid from several scattered low-head dams. Hydroelectric plants could be located at renovated existing dams, or they could be new facilities at undeveloped sites.

Description

Table 25 lists potential hydroelectric sites within the major river basins of southern Maine and eastern New Hampshire. It includes both undeveloped potential and currently existing dams that could be expanded. Table 26 lists existing, nonoperating dam sites of capacities greater than one megawatt that could be renovated. The proposed plant is expected to create an additional twenty-five megawatts of capacity for the region. An electric generating facility with that capacity operating at a plant capacity factor of .7 would supply roughly 153.3 million kilowatt-

TABLE 25: HYDROELECTRIC POTENTIAL IN FUELWOOD HARVEST REGION

	River	Capacity (Mw)	Capacity Factor	Annual Output (10^6 kwh)	Head Height (feet)
New Dam Sites[1]					
Steep Falls	Saco	30	.18	47.7	38
		15	.36	48.0	
Pejepscot	Androscoggin	10	.59	52	22
Lewiston	Androscoggin	30	.49	130	55
Great Falls	Saco	40	.25	87	111
Expanded Dam Sites[2]					
Cataract	Saco	10	.45	40	42
West Buxton	Upper Saco	5.4	.33	16	28
Bonny Eagle	Saco	7.8	.38	26	37

1. *Source: FPC 1977, except figures for 30-Mw facility at Steep Falls, which come from NEFRC 1976.*
2. *Dams currently operating, but with potential for expansion. Source: FPC 1977.*

TABLE 26: DAM SITES IN FUELWOOD HARVEST REGION WITH POTENTIAL FOR RENOVATION[1]

River Basin	Site	Location	Capacity *(Mw)*	Energy *(Mwh)*
Saco *(ME & NH)*	Spring Brook	Biddeford, ME	8.1	28,560
	Swan Falls	Fryeburg	2.6	9,288
	Ledgemere	Limerick	1.0	3,648
	Ossipee	Porter	1.2	4,200
	Central Maine Power Co.	Effingham, NH	1.9	6,858
	No Name Brook #2	Conway	1.5	5,322
	Saco River	Conway	1.7	5,941
Androscoggin *(ME)*	Cabot Manufacturing Co.	Brunswick	20.7	71,269
	Worumbo Manufacturing Co.	Lisbon Falls	20.5	70,433
	Pejepscot Paper	Topsham	24.1	82,764
	Town of Turner	Turner	1.8	6,006
	Minot Corner	Minot	1.1	3,751
	Mechanic Falls	Mechanic Falls	3.1	10,492
	Little Fields	Auburn	2.4	8,273
	Central Maine Power Co.	Topsham	22.0	75,460
	Max Miller Co.	Lisbon Falls	20.5	70,433
	Barker Mill	Auburn	4.5	15,400
Maine Coastal *(ME)*	Westbrook Dam #1	Westbrook	3.7	12,927
	Westbrook Dam #2	Westbrook	4.5	15,737
	Gorham Dam #1	Gorham/Windham	2.9	10,261
	Gorham Dam #2	Gorham/Windham	2.5	8,722
	Gorham Dam #3	Gorham/Windham	3.5	12,313
	Gorham Dam #4	Gorham/Windham	6.6	23,045
	Gorham Dam #5	Gorham/Windham	4.3	15,259
	Sebago Lake	Standish	3.2	11,118
	Route 4	South Berwick	1.8	6,169
Piscataqua *(NH)*	Cocheco River #2	Dover	1.6	5,792
	Cocheco River #4	Dover	1.8	6,346

TABLE 26 - Continued

River Basin	Site	Location	Capacity (Mw)	Energy (Mwh)
Piscataqua *(NH)*	Salmon Falls River #1	Rollingsford	1.3	4,739
	Salmon Falls River #2	Rollingsford	3.0	10,557
	Salmon Falls River #1	Somersworth	2.2	7,818
	Salmon Falls River #2	Somersworth	3.9	13,850

1. Sites with capacity greater than 1 Mw.

Source: NERBC 1979.

hours (kwh) annually. While none of the sites in Tables 25 or 26 alone has the potential to generate 153.3 million kwh, a combination of two or more of them could supply this amount. The number and kind of sites that would need to be developed in order to supply this power depends on many variables and options concerning hydroelectric development in general.

Small vs. large scale. The size of a hydroelectric facility is determined by available stream flow, hydraulic head, and potential water storage capacity. These characteristics are a function of local topography, geology, and hydrology. All of these factors are highly variable and site-specific. However, it is generally true that the majority of existing and potential sites in New England are small and would allow annual electricity outputs of less than 100 million kwh (NEFRC 1976). "Low head" is a term usually applied to dams with hydraulic heads of less than fifty feet. "Low head" does not necessarily mean "small scale," although most sites in Tables 25 and 26 would involve small dams.

Peak power or base-load operation. The water flows in New England river basins, combined with the high capital costs of constructing hydroelectric facilities, enable the production of electricity which can best be sold at the time of peak load demand. As hydroelectric facilities have the technical ability to respond quickly to demand peaks, they provide the electric grid with additional operating efficiencies when operated in this manner. Most of the sites listed in Tables 25 and 26 could be operated as peaking stations (NEFRC 1976).

Run-of-river vs. storage. If there is a reliable annual stream flow, then the hydro plant may be operated as a "run-of-river" facility. In New England, however, a storage reservoir in the river valley immediately above the dam is usually necessary. Many dams that are termed "run-of-river" facilities are actually dependent on large storage reservoirs and associated flow management practices at points further upstream. Most of the sites listed in Table 25 and 26 will depend on stored water, either on site or from large upstream reservoirs from which the flow is regulated.

Renovated vs. new. To produce 153.3 million kwh would not necessarily require new hydroelectric facilities. Table 25 and 26 indicate that there already exist dams that are either not generating electricity or else have potential for expansion.

The specific construction and operation requirements depend on which combination of the above options is used; however, some generalizations can be made. The major raw materials required for construction of a new hydro facility are earth, rock, concrete, lumber, and steel for a dam, outlet, spillway, and access roads. Most of this material is available locally. Renovation of existing dams requires considerably fewer raw materials, although generating equipment is required for both existing and new facilities.

The availablility of water to power the turbines is highly site-specific and depends on the precipitation and runoff characteristics of the drainage basin above the dam. The availability of water can sometimes be a problem for peaking facilities during summer drought periods. Greater than average reservoir drawdown may be necessary during these periods. For new dams, unpaved access roads ususally must be built during the construction phase and some of these may be paved for later permanent use. During the operation phase there will be no major transportation requirements since the fuel is made available on site and is self-renewing. High tension transmission lines usually must be constructed with the length of the corridors depending on the remoteness of the dam from existing transmission lines.

Several tidal hydroelectric sites have been studied along the eastern Maine coast, adjacent to New Brunswick (NEEC 1978). While the technological development of tidal facilities is somewhat less advanced than that of conventional hydroelectric plants, with only two operating plants in the world, interest has been rekindled in several proposals for developments in eastern Maine and Canada (NOAA 1978). Tidal hydroelectric systems are conceptually similar to fresh water systems although the logistics of operation and economics are more complex. In addition, the impacts of tidal power developments are largely speculative and unknown at this time (although the parameters of potential impacts have been described: see Duff 1978; NEEC 1978; NOAA 1978).

Recent research conducted for the Department of Energy has identified potential sites in Maine and Alaska (Wayne 1979). The Department of Energy currently has let a small contract to the Maine Passamaquoddy Indian tribe to study the feasibility of a small-scale pilot tidal power plant at Half Moon Cove in Cobscook Bay. The U.S. Army Corps of Engineers is also conducting an analysis, scheduled for completion in 1981, of several possible projects in Cobscook Bay. Because the identified tidal power sites in Maine are under active consideration by federal agencies, tidal power is not specifically discussed further in this alternative.

Economic

The cost per kilowatt of installed capacity for hydro projects in New England averages between $1,000 and $1,200, which is comparable to the installed cost of thermal plants (ACE 1977, GCHEE 1977). Operation and maintenance costs are usually less than those for thermal plants and fuel is essentially free. In New England, however, potential hydroelectric plants will be more expensive to operate than fossil-fueled plants because they will operate far fewer hours per year. This low capacity factor produces high annual costs per unit of power generated. Recent studies indicate that the cost of producing peaking power at hydroelectric stations ranges between 37 and 136 mills per kilowatt hour (ACE 1977). Peaking power currently sells at a price of 40.8 mills per kilowatt hour on the southern Maine electric power grid (Sherburne 1979). Thus, the more cost-efficient hydroelectric stations could produce power at a commercially competitive price.

Environmental Impacts*

Construction impacts. Construction of a new hydroelectric facility can cause a variety of physical, chemical, ecological, aesthetic, and socioeconomic impacts. The clearing and stripping

* Information on construction, operation, fuel procurement, and transportation impacts comes from EPA 1974.

of vegetative cover on the reservoir site causes soil erosion. This increases the turbidity and temperature of waters receiving runoff. Removal of vegetation also increases the rate of surface runoff during the construction period. Clearing of the site would remove forest and field habitat and result in the displacement or destruction of terrestrial ecosystems. The existing aquatic ecosystem would be disrupted due to:

- the turbidity and erosion problems created during construction,
- increased water temperature,
- increased runoff rates,
- downstream sedimentation,
- physical removal of habitat due to straightening or alignment of channels.

These changes may result in the loss of certain plant or animal species from the aquatic system.

In the period immediately following reservoir filling, decomposition of organic material in the reservoir area would lower the level of dissolved oxygen and result in a decline in water quality, both in the reservoir and in the downstream outflow.

The aesthetic value of the area may decline due to the removal of trees, land shaping, and temporary exposure of soil at the reservoir site, as well as the introduction of construction equipment, access roads, power lines, the dam structure itself, and related support facilities. Air quality may be slightly affected. Noise may increase in the vicinity of the dam site due to the operation of construction equipment and an increase in the amount of traffic.

The environmental impacts that result from the renovation or expansion of existing dams are considerably less than those associated with completely new projects. In most cases, a reservoir has already been established, access roads are present, and fewer raw materials would be required. Surrounding terrestrial ecosystem characteristics would not change substantially as a result of renovation activities. Downstream water quality impacts would be similar to those for a new facility, although the degree of the change would depend on the amount of stream rerouting required for improvement of the existing structure. The aesthetic and socio-economic impacts associated with the construction phase would be similar in nature to those of a new facility but smaller.

Operation and maintenance impacts. Permanent water quality changes result from the impoundment and regulation of free-flowing water. Impounding the stream prevents turbulent mixing and raises the overall temperature of reservoir waters. This promotes algal growth, which in turn increases the biological oxygen demand. The new ecosystem that is created contains warm water organisms adapted to low dissolved oxygen content and slow water flow. Low dissolved oxygen content also reduces the stream's ability to assimiliate organic wastes such as sewage.

Thermal stratification of the reservoir waters causes seasonal variations in downstream water temperatures when water is released from the dam. The regulation of water flow at the dam site also alters the water level and flow regime of downstream water. Rapid changes in water pressure occuring within the turbine can saturate the water with nitrogen. Some micro-nutrients, such as iron and manganese, may settle to the bottom of the reservoir and be prevented from reaching downstream waters. All of these changes in water quality can adversely affect downstream aquatic organisms by directly threatening their survival or by upsetting their life-cycles. Anadromous and other migrating fish are particularly affected by the construction of an impoundment since it prevents them from reaching their upstream spawning areas. This impact may be lessened by constructing fish ladder, although this is quite expensive.

Normal operation affects the littoral habitat around the reservoir due to variations in water level. The result of this fluctuation is a sparsely vegetated zone that can generate severe odor and aesthetic problems.

Socioeconomic impacts stem from loss of recreation activities associated with free-flowing water and the creation of a reservoir that may attract other types of freshwater recreation. Of particular importance in the case of dams with already-existing reservoirs are the impacts on activities that depend on the abandoned, nonfluctuating reservoir. These activities include recreation, drinking water supplies, and flood plain development. Operation of the reservoir will disrupt these activities and may cause physical, managerial, or financial problems within the local community.

Employment impacts due to the operation and maintenance of the hydroelectric facility are small. Few employment opportunities are created.

Fuel procurement impacts. The fuel procurement impacts of a low-head, peaking facility are caused by the reservoir drawdown and stream flow changes and are described above.

Transportation impacts. Because the fuel does not need to be delivered to the hydro site, additional traffic in the area of the dam would be insignificant once the dam has been constructed. Transportation of raw materials (earth and gravel in particular) during the construction phase of a new dam would create increased truck traffic in the vicinity of the dam site. Existing transportation routes may have to be relocated if they lie in the area to be inundated by a reservoir. If a reservoir is created that also serves as a recreation area, some traffic congestion may occur during periods of recreation activity.

Relationship to national, state or local plans and policies. The Public Utility Regulatory Policies Act of 1978 specifically encourages the development of new or additional hydroelectric generating capacity at existing dam sites by offering loans for feasibility studies and for projects and by simplifying and expediting the loan procedures. It does not, however, encourage the construction of new dams or other impoundments. The Maine Office of Energy Resources recommends that hydroelectric development be given priority consideration over other available alternatives if it is economically feasible. This office also recommends that the potential for increased water storage of spring runoff waters be reevaluated in order to allow for increased energy output from existing and future hydroelectric facilities (MOER 1976). New Hampshire also encourages the development of small hydro-electric projects between 50 and 500 kilowatts (New Hampshire Revised Statutes Annotated 362:2).

Summary of long-term effects. The long-term impacts of the hydroelectric alternative would depend primarily on the types of facilities chosen. As described in the text, the impacts for new and renovated facilities can be quite different. These impacts include (for new dams):

- permanent removal of supportive habitat for terrestrial organisms in the area of the reservoir,
- creation of a new aquatic environment and ecosystem in the reservoir area due to the impoundment of previously free-flowing waters,
- odor and aesthetic problems during periods of reservoir drawdown,
- disruption of homes or business located on or adjacent to a reservoir site,
- possible attraction of secondary development to the area of the facility, including new industries and recreation facilities.

The principal impact of renovating dams is the possible creation of community resistance to water level variation in cases where it disturbs established uses of the abandoned reservoir and changes the characteristic downstream flow. Impacts of both kinds of facilities include changes in downstream water quality and aquatic ecosystems due to temperature stratification, decreased oxygen content, nitrogen saturation, and stream flow fluctuation.

Other Fuels

Natural Gas

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a 25-megawatt gas-fired electric generating facility in southern Maine.

Description. The Powerplant and Industrial Fuel Use Act of 1978 specifically prohibits the use of natural gas as a primary energy source in a new electric power plant. The definition of an electric power plant includes stationary electric generating facilities with boilers designed to consume fuel at a rate of 100 million or more Btu per hour. A generating facility producing twenty-five megawatts of electricity is well in excess of this threshold, with a fuel consumption capacity on the order of 200 to 300 million Btu per hour. The Act further allows the Secretary of Energy to order the conversion of existing facilities from natural gas or petroleum to coal or other alternative fuels.

Because of these prohibitions, a gas-fired cogenerating facility is not a feasible alternative.

Geothermal

Policy statement. The U.S. Department of Energy could choose to support the development of a 25-megawatt electric generating plant powered by steam that is derived from the natural heat of the earth's interior.

Description. The use of geothermal energy for the production of electricity is not feasible in Maine for the reasons discussed in the "Other Fuels" section of the previous chapter.

Solar

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a 25-megawatt solar electric generating plant in southern Maine. The plant could use photovoltaic cells to convert solar radiation directly into electricity, or it could be a solar-powered steam-electric plant.

Description. Photovoltaic cells consist of differently charged layers of crystals connected by one electrical circuit. When solar radiation passes through the layers, a small electric current is created in the circuit. Individual cells are connected in series to provide direct current. The direct current must then be changed to alternating current in an inverter if it is to be fed into the regional transmission grid. The electric power generated in this way can be stored in a battery for use during nights and cloudy periods (Geary & Jones 1977).

Photovoltaic technology has been successfully demonstrated in small or specialized electrical appliances (e.g., satellites, two-way radios, remote signaling and meteorological equipment) (Bereny 1977). However, the use of photovoltaics for the production of electricity on a large scale has not been demonstrated and is an unlikely near-term alternative in New England for several reasons:

1. The efficiencies of solar cells are very low. A commercially produced cell can realize an efficiency of about 15 percent with a theoretical maximum of about 23 percent (Geary & Jones 1977). The conversion of direct current to alternating current has a typical efficiency of 85 percent. Thus, total photovoltaic cell efficiencies are about 10 percent if they are used for central-station electricity production. This low efficiency dictates a very large collection field for even small central-station facilities.

2. A central-station photovoltaic plant would require roughly twice the amount of land needed by a solar thermal plant (Geary & Jones 1977) or nearly one-half of one square kilometer for a 25-megawatt plant in the Southwest. Because solar radiation in New England is less than in the Southwest, the amount of land required would be roughly one square kilometer (Geary & Jones 1977). The requirement for large amounts of flat, open space limits the applicability of large-scale photovoltaics in southern Maine.

3. Sudden changes in insolation (solar radiation) quickly increase or decrease the power output of a photovoltaic plant. Undependability of this nature could cause difficulties for utilities, which require predictable power supplies. This problem can be offset by electric storage systems that have short response times. The only known electric storage technology that would be suitable on a large scale is a super conducting magnetic system (Ruane 1977c). However, such systems are only in the research stages and are not currently available.

For the above reasons, a 25-megawatt photovoltaic electric generating plant is not currently a feasible alternative method of producing electricity in southern Maine. A 25-megawatt solar thermal generating system would not be feasible for the reasons discussed in the "Other Fuels" section of the previous chapter.

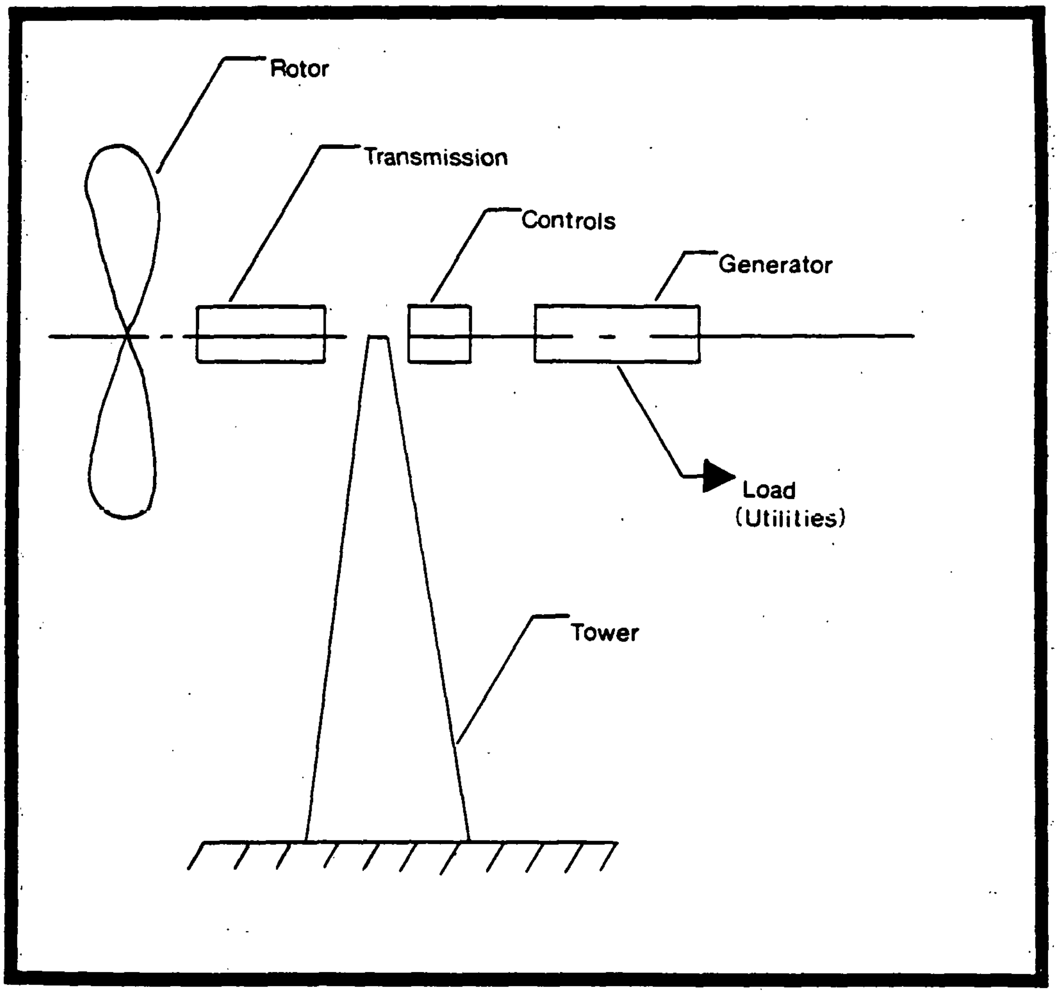
Wind

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a series of electric generating devices that extract energy from the wind. In combination, the wind-powered generators would add 25-megawatts of electric generating potential to the southern Maine power grid.

Description. The process for converting the kinetic energy of wind into electrical energy is straightforward. The drag and/or lift forces of wind act against some type of blade or propeller to turn a drive shaft connected to a gearbox and electric generator. There are many different designs for wind energy conversion devices but most can be classified as having rotors with either a horizontal or a vertical axis (Eldridge 1975). Horizontal axis designs require fewer materials and have had a higher conversion efficiency than most vertical axis designs that have been developed so far. Vertical axis units have the advantage of being independent of wind direction, as well as allowing for drive systems to be located on the ground instead of on tall towers (Black 1976). Largely for reasons of economy, horizontal designs have been used in the designs for most large-scale electric generating systems (Jones & Ruane 1977).

Figure 2 shows the basic components of a horizontal-axis wind energy system. Except for the rotor blades, all of the components represent proven and reliable technologies. Currently, the blades must be specially made and there is still further work to be done to determine the optimum blade shape and construction materials. Wind energy machines of 100 kilowatts and larger have been constructed and successfully operated on a short-term basis in New England. The largest electric generating wind turbine ever built was located near Rutland, Vermont. It generated 1.25-megawatts of electricity in winds of thirty miles per hour or more, and ran intermittantly between 1941 and 1945. Current large-scale wind projects involve designs with rated capacities of several hundred kilowatts. The largest wind-powered turbine in operation today is a pilot 100-kilowatt project in Sandusky, Ohio.

FIGURE 2: HORIZONTAL AXIS WIND ENERGY SYSTEM



Source: Jones & Ruane 1977

The size of a wind-driven generator is limited by the fact that wind is dispersed. The only way to increase the rotor power in large wind-powered generators is to increase the amount of wind intercepted by lengthening the rotor bladees. A 1.5-megawatt wind turbine generator, proposed by the Department of Energy and the National Aeronautic and Space Administration, will have a 200-foot diameter rotor. With currently available engineering materials, rotors larger than this cannot be safely designed (Black 1976).

Because the wind speed is rarely constant, the actual daily and seasonal power output from a wind-driven generator would be highly variable and unpredictable. An array of generators spread out geographically over areas with different wind regimes would mitigate some of this variability. In this system, there would always be some power input, though it would be less than the combined potential of all the generators in the network. In order to compete directly with central power stations, some kind of energy storage system would be required in conjunction with the wind system (Eldridge 1975). Systems capable of storing wind-generated electricity are listed in Table 27. Of these, only pumped hydro, compressed air, and thermal energy storage are near-term options on a large, utility-size scale (Labuszewski 1977). The others will not become available until after 1985, given current research efforts (Jones & Ruane 1977). Only pumped storage is currently developed for commercial operation (ACE 1977).

Although wind-powered electric generators are technologically possible, they will require further testing in order to ensure their feasibility on a commercial scale. The U.S. Energy Research and Development Adminsitration already has a wind energy program underway. So far, only experimental large-scale demonstration units have been constructed. Multi-unit demonstrations, which would be required for this alternative, are not scheduled until the mid 1980s (ERDA 1976). Factory-scale facilities will not be developed until after 2000. Therefore, in view of current development efforts and level of available technology, a large-

TABLE 27: STORAGE SYSTEMS FOR WIND-GENERATED ELECTRICITY

<u>MECHANICAL STORAGE SYSTEMS</u>

Hydro Pumped Storage
Compressed Air Storage
Thermal Energy Storage
Flywheel Energy Storage

<u>CHEMICAL STORAGE SYSTEMS</u>

Battery Energy Storage
Hydrogen Storage

<u>ELECTROMAGNETIC STORAGE SYSTEMS</u>

Superconducting Magnetic Energy Storage

Source: Jones and Ruane 1977

scale wind energy project is not a feasible alternative at this time.

Ocean and Tidal River Currents

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a series of small electric generating devices that extract energy from ocean or tidal river currents. In combination, the devices would supply an additional twenty-five megawatts of electric power to southern Maine.

Description.* The force of moving water in river and ocean currents is a potential source of usable energy. Off the coast of Maine, nontidal ocean currents are very weak. The strongest ocean current, in the Gulf of Maine, flows at only .2 knots, which results in a power density of only .57 watts per square meter. However, currents in some tidal rivers and narrow inlets along the Maine coast have enough kinetic energy to drive turbines, paddlewheels, or rotors. Power densities between one and five kilowatts per square meter have been estimated for some sites in Maine.

There are two devices that have been designed to extract energy in the form of electricity from currents: the screw turbine and the Savonius rotor. These devices rely on drag or lift forces of the moving water to rotate a drive shaft or turbine, which is connected to an electric generator. The process is very similar to that employed in wind-powered generators. The efficiencies of these devices can range between 30 and 45 percent. As with wind power generators, the direct current must be converted to alternating current, resulting in a decrease in overall system efficiency. Hydroelectric plants located in dammed tidal rivers are another way to use the force of tidal currents. However, these plants operate on the same principle as conventional hydroelectric plants and therefore will not be discussed here.

* Source: Mays 1977b.

The problems associated with tidal current energy conversion devices are similar to those of wind machines. In addition, they must be capable of operating when the water flows in alternate directions as the tide floods and ebbs. The systems are also subject to periodic increases and decreases in power production as currents change, although the variability is predictable and less severe than it is for wind-powered systems. Weathering and, especially, corrosion are problems that require further design consideration.

Generally, tidal current energy systems are technically feasible, although no large-scale projects have yet been implemented. Because of the the periodicity and relatively small power densities of available flows, these energy systems cannot supply base-load power. The systems will have to be operated as "fuel savers," helping to reduce the amount of fossil fuels used. If large-scale electrical storage systems were available, then the power produced by tidal current energy devices could provide an additional twenty-five megawatts, but no such systems suitable for utility use have been developed as yet. For these reasons, tidal current energy does not represent a currently feasible alternative method of creating additional electricity for southern Maine.

Wave Energy

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of devices that convert the kinetic energy of waves into electricity. A combination of these devices would supply twenty-five megawatts to southern Maine.

Description.* Wave energy extraction devices rely on the kinetic energy of waves to drive pumps, flywheels, compressors, and turbines. The mechanical energy imparted to this machinery is transferred to an electric generator. Although no large-scale wave conversion systems have ever been implemented, there have been many designs proposed. Three designs currently receive the most attention from researchers.

---

* Source: Mays 1977a.

1. Wave power absorbers rely on the oscillating motions of tethered rafts floating on the ocean surface to power a hydraulic system connecting the rafts. The pressurized working fluid drives a turbine-generator.

2. Buoy-shaped turbine generators use the "heave" or up-and-down motion of waves, to move a piston. The piston pressurizes a working fluid, which drives a turbine-generator.

3. Salter cams depend on the oscillation of waves to swing a pendulum-type device (cam) within a buoy. The cams drive rotary pumps which are connected via hydraulic motors to electric generators.

Wave energy is a renewable energy source with no apparent major technological barriers to its development. However, the design experience is extremely limited and unproven and there is a general lack of reliable wave data off the Maine coast. Indeed, the principal problems with wave energy conversion for Maine stem from the wide daily and seasonal variability in wave action. This variability requires a conversion system that will function in a wide range of ocean conditions. Such systems have not been developed except on an experimental basis. For this reason, wave energy is not currently a feasible alternative method of producing twenty-five megawatts of electricity in southern Maine.

Ocean Thermal

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of ocean thermal energy conversion plants to supply twenty-five megawatts of electric power to southern Maine.

Description.* Ocean thermal energy conversion power plants are heat engines that use the temperature differential between the surface waters and deep ocean layers to evaporate and condense a working fluid that has a low boiling point (e.g., ammonia or freon). The fluid is vaporized in the warm upper layers and drives a turbine electrical generator. The fluid is condensed in the cool bottom layers and then pumped again to the surface. The plant is anchored in the ocean and electricity is transmitted via an underwater cable to shore.

* Source: Ruane 1977b.

Ocean thermal plants have low efficiencies (between 2.5 and 3.0 percent) because the temperature gradient is small and the volume of water that must be processed is very large. The technology for these plants is still in the research stage and has not been demonstrated on a large scale. In particular, fabrication and maintenance problems associated with the evaporator and condenser have not yet been solved, although the Department of Energy is planning to begin testing an ocean thermal plant in 1986.

Ocean thermal plants would not be feasible off the Maine coast due to the small differential between surface and deep water temperatures.

Nuclear

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a 25-megawatt nuclear power plant in southern Maine.

Description. Nuclear steam cycle plants use the heat released by the fission of uranium atoms to create steam. The steam is used to drive a turbine-generator. The total cost of a small nuclear plant is not proportionately less than that of a large one, due to the substantial investments required for safety, support facilities, back-up systems, waste disposal, and other features. For this reason, it is uneconomical to construct small nuclear plants. There are no nuclear power plants under construction in the United States that are smaller than 527 megawatts (Nuclear Industry 1979). Therefore, it would not be feasible to build a nuclear plant of only 25-megawatt capacity. The purchase of a 25-megawatt block of power from a nuclear power plant would result in an increment of environmental impacts of that facility. Analysis of these impacts is beyond the scope of this study. (For a full discussion of these impacts, see AEC 1974.)

ALTERNATIVE USES OF WOOD

Use of Wood for Space Heat

Domestic Space Heat

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the use of wood for home space and water heating.

Description. The proposed action involves the use of approximately 680,000 tons of wood per year in an industrial boiler producing steam and electricity. This wood could instead be used for home heating if steps were taken to encourage its use in that sector. Assuming an average consumption of twelve tons of wood (five cords) per household, roughly 57,000 households could be heated by this wood. The average household in Maine today used 1,100 gallons of oil per year or 1.54×10^8 Btu for space heating. Twelve tons of wood would displace about two thirds of the average household's oil consumption. Thus, a statewide annual savings of at approximately 40 million gallons of imported oil could be realized if the wood were used for home heating.

The Department of Energy could adopt a number of approaches to stimulate increased domestic use of wood for space heating. The reliability of supply and quantity of wood furnished to the market could be increased through programs for landowners and firewood producers. Educational programs for landowners could inform them of the advantages of having low-quality wood removed from their forests and instruct in the negotiation of economically and environmentally sound contracts with harvesters to accomplish this providing assistance in and incentives for long-term planned management of forest lands could encourage landowners to thin and maintain their woodlots, which would also bring a steady stream of low-quality wood into the energy market. For example, increased support for the Cooperative Forest Management Program, which uses U.S. Forest Service funds to enable state service foresters to advise land-owners on management of their forest lands could stimulate landowner willingness to market low-quality wood. Sharing the cost of forestry consulting fees with landowners or initiating a fuelwood management program with staff foresters would also stimulate landowner interest in fuelwood harvesting.

To aid loggers, steps could be taken to improve the economics of cutting and selling fuelwood for domestic use. The Scandanavian countries currently are developing small-scale harvesting equipment suitable for the removal of small, poor-quality trees from small landholdings. Support of research and development of this type of equipment in the U.S., combined with a tax incentive program for harvesters acquiring such machinery for fuelwood production, could reduce logging operator costs and increase the amount of wood available to the consumer at a reasonable price. Likewise, educational programs to assist loggers in improving the efficiency of their harvesting operations, to assist them in sound business management and investment, and to demonstrate the relatively minor costs associated with meeting environmental constraints could reduce logger costs and increase the land base available for cutting.

Federal programs could also be devised to stimulate the willingness of homeowners and tenants to use wood-burning appliances for space heating purposes. A tax incentive program to reduce the financial burden of conversion to wood heating facilities could increase the use of fuelwood. Increased federal support for design of more convenient and less expensive wood appliances, such as automatic-stoking pellet furnaces or gasifiers suitable for retrofitting oil-burners, could also increase the use of wood for space heating and decrease nationwide reliance on imported oil. Finally, an educational program on the safe installation and operation of wood appliances and chimneys could increase homeowner willingness to convert to wood.

Demonstration projects for improved marketing systems for wood are another way to encourage wood use for domestic space heat. At the present time, most logging operators market their own wood and the consumer finds a supplier through newspaper classified advertising or by word of mouth. Consumer skepticism of supply reliability could be relieved through establishment of centralized distribution and processing centers, or fuelwood marketing cooperatives. The development of such centers could also relieve the loggers' uncertainty about the opportunity for marketing fuelwood and could enable loggers to make commmitments to the fuelwood market.

Economics. The most significant economic impact of this alternative would result from the replacement in Maine of roughly one million barrels of oil by 680,000 tons of locally produced wood. At most, four cents per gallon of heating oil accrues to the regional economy at present (see Appendix E) or about $1.6 million annually for the oil that would be replaced by this fuelwood. Conservatively assuming a price of $21 per ton (2.4 tons per cord) for domestic fuelwood, approximately $14 million of revenue would be generated from the sale of 680,000 tons of wood; most of this revenue would go into the regional economy (see Appendix E).

A regional program to introduce forest landowners to the benefits of fuelwood extraction for forest improvement could cost between $100,000 and $200,000 for personnel, media presentations, production of printed materials, and the use of forestry field personnel for assistance at seminars and other presentations (Swain 1979; Turner 1979). Such a program could be expected to reach 2,000 to 3,000 landowners during the first two years of operation.

A regional assistance program to help landowners implement plans that take advantage of the fuelwood market and to market poor quality trees would cost approximately $17,000 per field forester employed. Each forester could reach approximately 200 landowners per year, each owning an average of fifty acres. Using ten foresters, 2,000 landowners could be reached at a cost of about $170,000.

An effective program for education and assistance of logging operators would cost substantially less, as there are far fewer loggers than landowners. A $50,000 program of educational and demonstration sessions could probably reach most interested logging operators in the fuelwood harvest region. Additional funds would be required to assist harvest operators with time and motion studies to improve the efficiency of on-the-ground harvest operations.

An average wood stove costs between $300 and $400; the installation or improvement of a chimney may double or triple this price. The cost of 57,000 woodstoves at $350 each is $19,950,000. If taxpayers (average 30 percent tax bracket) were allowed to deduct the total purchase price, but not the cost of improvements to their chimneys, the federal treasury could lose $5,985,000 in attempting to stimulate the use of the same amount of wood to be used in the proposed wood-fired power plant. However, some of these funds would benefit this country, due to the retention of the fuelwood payments within the United States economy.

The costs of research and development programs for improved harvesting equipment and home wood appliances have not been assessed for this study.

<u>Environmental impacts</u>.

o Construction. The installation of home stoves or furnaces involves little construction; chimney building or repair is the major alteration. Neither air and water quality nor any ecosystem would be significantly affected. Increased sales of new wood burning equipment would benefit manufacturing and retail stores and local employment. Masons and masonry suppliers would also benefit from new domestic wood heating operations. Employment and income in the oil furnace installation business would drop, but this decline would be offset if those companies became appliance dealers.

The construction impacts of building a pelletizing plant or chipping yard are discussed in the following part of this chapter entitled "Commercial Space Heat," since it is likely that pellets or chips will first be used by commercial and small industrial establishments.

o Operation. There are no federal or state regulations that control air emissions from residential heating units. Thus, the operation of wood stoves could deteriorate air quality. Particulate emissions from wood stoves depend more on how the stove is operated than on its design. The moisture content of the wood, how the fire is built, the draft settings, and other user variables determine the amount and composition of emissions.

In a preliminary study of particulate emissions, a Model 2 Franklin (doors closed) and a Model 602 Jotul (an air tight) were tested using various draft settings and wood species (7 to 11 percent moisture content). The results are shown in Table 28. The large variation in emissions is attributed to variations in burning conditions. Emission rates were higher during the smoldering stage than during open flame pyrolysis or the final stages of burning. With a decrease in available air, emissions increased. In communities where wood stoves carry a large part of the heating load, air quality problems could arise. More research is needed on the relation of emissions to stove design, wood type, and operating mode (Butcher & Buckley 1977).

Using Butcher and Buckley's (1977) emission factors, burning 680,000 ton of wood in stoves would create between 693 and 6,800 tons of particulates per year. In addition, approximately 84,000 tons of carbon monoxide would be released into the air (EPA 1978). These emissions would be significant if concentrated in a large metropolitan area. However, the dispersion of home wood burning in rural areas close to the fuel resource where other emissions are low would tend to lessen air quality problems.

The nature of the particulates, which is important in assessing potential impacts, was not examined in Butcher and Buckley's study, nor were gaseous emissions analyzed. The amount of these emissions and the way each is dispersed and changed in the environment are not known (Shelton 1976; 1978).

Ash is another by-product of burning. Ashes from stoves and furnaces can end up in public land fill areas. They may instead be used in driveways to prevent skidding, or on gardens as a soil conditioner. The ash content of wood is typically between 2 and 4.3 percent (Hall et al. 1976). The dispersed nature of domestic wood-burning would weigh against any significant impact from disposal.

TABLE 28: PARTICULATE EMISSIONS FROM TWO TYPES OF WOOD STOVES

Stove	Wood	Draft Setting	Number of Runs	Emission Factor (grams/kilogram wood) Average	Standard Deviation	Range
Jotul	Pine	1/2 open	6	4.5	1.0	2.9 - 5.6
Jotul	Pine	1/4 open	5	10	8	4.5 - 25
Jotul	Oak	1/2 open	6	1.7	0.9	0.7 - 2.8
Jotul	Oak	Open	2	1.17	0.01	1.16- 1.18
Jotul	Birch	1/2 open	2	2.3	1.7	1.1 - 3.5
Franklin	Oak	*1*	15	2.8	1.0	1.2 - 4.4
Franklin	Oak (very dry)	*1*	3	1.02	0.10	0.91- 1.08

1. The small draft adjustments were made for the Franklin stove, but no significant variations of the emission factor were observed as a function of the draft setting. This probably results from the large amount of air able to leak in around the doors of the Franklin stove independently of the draft setting.

Source: Butcher & Buckley 1977.

Any increase in the use of wood stoves is apt to result in increased incidence of chimney fires. An educational program emphasizing proper installation, operation, and maintenance of wood burning appliances could lessen the severity of this safety hazard.

Increasing wood use for home heating would result in local business opportunities for chimney sweeps, woodcutters, stove shops, hardware stores, and retail businesses selling stove assessories and wood processing tools (axes, chainsaws, mauls). At the same time, fuel oil sales and the demand for oil burner maintenance would decline. The higher labor intensity of fuelwood production and the circulation of resulting income within the regional economy would result in a net socioeconomic improvement, however.

People living in wood-heated homes tend to alter their lifestyle as a result of wood use. Operating a wood stove requires more effort than regulating a thermostat. Storage and handling of wood fuel requires more space and time than fossil fuels. Debris from wood, such as bark, dirt and insects, are an additional concern. With wood stoves, household activity tends to center in the room where the stove is located; there is often less effort given to heating other rooms. Wood-burning furnaces can be used for central heating, but until chip or pellet burning appliances with automatic stoking are commercially available, wood handling will remain a necessary chore for the wood burner.

Increases in the use of firewood may increase the price of pulp and fuel chips if competition for stumpage or labor increases.

o Procurement. Firewood procurement will continue to be in large part, a by-product of other harvesting operations. Whole-tree chipping will not be used to harvest domestic fuel until a home chip burner is commercially available. The use of traditional harvesting techniques for firewood offers the opportunity to improve forest growth, as does whole-tree harvesting. Nutrient losses may be less with the merchantable bole harvesting method (see Appendix D). On the other hand, uncontrolled expansion of firewood cutting could threaten the resource with overcutting, mismanagement, or erosion. Because per acre yields are lower with traditional harvesting than with whole-tree chipping, more areas may be affected by firewood harvesting than by cutting the same amount of wood to fuel a cogenerating facility.

o Transportation. Both the points of origin and the destinations of the fuelwood would be dispersed with home firewood use. All wood and trucks would not converge on one place over a few roads, as would happen at a wood-fired power plant. Many types of trucks are used for firewood delivery, whereas whole-tree chips are transported exclusively in vans. In New Hampshire, 32 percent of the vendors delivered wood in a pickup truck, 32 percent used a dump truck, 14 percent used a one- to two-ton flatbed, and 7 percent used log trucks (Andrews & Dammann 1979). It seems likely that with market development, more fuelwood will be moved in larger trucks to concentration yards. Dispersion of the trucking will minimize the impact of moving the wood. Impacts of transportation to and from chip yards and pelletizing plants would be similar to those discussed in Appendix F.

o Relationship to national, state or local plans and policies. The Maine Comprehensive Energy Plan (MOER 1976) advocates the direct combustion of wood for home heating. The plan recommends pilot programs for coördinating fuelwood buyers and sellers, and for the development of efficient, safe wood combustion equipment. The encouragement of home fuelwood use by the Department of Energy would complement the goals of the plan.

The Goals and Objectives report (Threshold 1977) of the Threshold to Maine Resource Conservation and Development Project includes plans to develop "alternative woodland marketing sources to better utilize the area's woodland products." Specific projects outlined are development of a fuelwood concentration yard, publication of a fuelwood producers list, and investigation of whole-tree chipping techniques for fuelwood procurement and timber stand improvement. These projects could be complementary to a Department of Energy program for encouraging residential use of wood fuel.

o Summary of long-term impacts. Encouraging home use of fuelwood for space heating raises concern for air quality in residential areas. Where wood replaces oil as a fuel, sulfur emissions will be reduced but particulates and hydrocarbon emissions could increase. Proper stove use can reduce emission.

Home wood use would make oil available for use in installations incapable of burning solid fuels. In addition, money that now leaves New England to pay for imported fuels would recirculate locally, providing additional local employment and income. The home fuelwood market would probably become more sophisticated, specialized, and centralized. With more sophisticated marketing, increased sales, and rising fuelwood prices, competition for wood between the firewood market and other markets might occur.

Impacts on the forest resource are a primary concern. Uncontrolled expansion of firewood cutting could threaten the resource with overcutting, mismanagement, or erosion. Because per acre yields are lower with traditional harvesting than with wholetree chipping, more acres may be affected by firewood harvesting than by harvesting the same amount of fuel for a wood-fired power plant.

Commercial and Industrial Space Heat

Policy statement. As an alternative to the proposed action, the U.S. Department of Energy could support the use of wood for commercial and industrial space heating.

Description. The proposed cogenerating facility will use approximately 680,000 tons of wood per year. This wood could instead be used for space heating in industries, apartment buildings, motels, greenhouses, shopping centers, and other commercial and small industrial establishments. Businesses using wood fuel should be somewhat buffered from rising costs of fossil fuels and the uncertainty of fossil fuel supplies.

The fuelstock for commercial or industrial wood-burning units is wood chips or preprocessed, densified wood pellets. Wood residue from manufacturing processes can also be burned, however. As with domestic firewood, marketing and delivery systems for such fuels are not fully developed.

The Department of Energy could attempt to stimulate the market for commercial wood fuel by assisting the establishment of wood chip dealerships. At present, potential consumers of chips are hesitant to invest in combustion equipment without an assured fuel supply; wood suppliers are skeptical about market opportunities and are reluctant to invest in chipping equipment. Support for a concentration yard for chips from several suppliers might be part of the solution to these problems.

Wood fuel has low density, irregular size, high moisture content, and a tendency to bridge in handling; these characteristics favor its use close to the point of origin, particularly by wood industries that have equipment for, and experience in, wood handling. Even for these firms, transporting, unloading, sizing, preparing, storing, retrieving, and metering wood fuel may be as important as boiler technology in determining the economic viability of conversion (Hoff 1976). The Department of Energy could stimulate wood fuel use by research, development, and demonstration of handling systems for industrial and commercial wood energy systems.

Small firms may be unable to afford the capital investment in new burners and pollution control equipment. The Energy Tax Act of 1978 is meant to alleviate the financial burden of conversion to "new" energy technologies by providing for a business investment credit. Technical assistance for small companies, supported by the Department of Energy, would further encourage conversion. Many firms need technical, economic, and environmental information to help them assess conversion to wood fuel and to assist them in choosing a system suited to their circumstance.

Gasification may be the best alternative for retrofitting existing gas- and oil-fired boilers. For larger boilers multiple gasifiers can be used. Gasification was used prior to World War II; however, certain problems in the design of the grate and the gas burner and in vessel construction require process improvements (Voss 1977). The Department of Energy could support research and development efforts to solve these problems.

Densified biomass fuel (wood pellets) has some advantages over chips; it is uniform in size, shape, and moisture content and has better burning properties than do green chips. The higher Btu content per pound and per unit volume lowers the transportation costs per Btu. For industry there is the question of whether the added processing costs are justified by easier handling and improved burning efficiencies (Zerbe 1978). Since moisture content is the key factor in combustion efficiency the lower mosture content of pellets means lower capital investment due to reduced capacity requirements. Emission control savings are also achieved with drier fuels (USFS 1976). The technology for pellet use to replace or supplement coal is available (Reed & Bryant 1978). In addition, pellets can be used in gasification and have potential use for home heating. The Department of Energy could attempt to encourage the development of this fuel by financial and/or technical support for pilot demonstration facilities.

Economics. The most significant economic benefit of this alternative derives from the replacement of fossil fuels by wood fuel. If gasifier efficiency is 90 percent (Voss 1977), 4.9×10^{12} Btu could be provided by the use of 680,000 green tons of wood for commercial and industrial fuel. This is equivalent to about 34 million gallons of oil. Revenue generated by harvesting, processing, and selling the wood would accrue to the region, rather than to foreign oil-producing nations. In addition, businesses using wood fuel should be somewhat insulated from rising fossil fuel costs; they may gain a competitive advantage that allows them to stay in New England and continue to contribute to employment and the economic stability of the nation.

Environmental impacts.

o Construction. The installation of wood-fired boilers or gasifiers in small industries and commercial buildings would involve little outside construction to retrofit existing structures. Air and water quality would not be significantly impacted. Local businesses could benefit from hardware sales and services required by installation.

A plant producing 250 to 300 tons per day of pellets requires about five acres of land and takes about six months to build (Blackman 1978; BSRD 1978). This plant would require approximately 500-600 green tons of wood per day (Chamberlain 1979). Air and water quality impacts would be minimal; only the terrestrial ecosystem of the plant site would be severely affected during construction. Since most plant components are prefabricated, employment increases during construction would be small and of short duration.

o Operation. Maine state air quality regulations control emissions and require air pollution licenses from boilers with rated outputs of 10 million Btu per hour or greater. Particulate standards apply to equipment fired at 3 million Btu per hour, and all boilers are subject to visible emission standards (Berger & Lohnes 1979). The operation in one geographic region of numerous boilers with inputs less than 3 million Btu each could result in local air quality problems. Regulation of larger boilers should adequately limit total emissions, however.

Ash from wood boilers will probably be disposed of in landfills but should not result in other significant impacts if the landfills are properly designed. The ash could also be used as a soil conditioner.

o Fuel procurement impacts. Fuel procurement impacts for commercial and industrial applications would be similar to those for the proposed wood-fired power plant. Whole-tree chipping would be necessary.

o Transportation impacts. Transportation impacts would be similar to those of the proposed plant; chips would be delivered by vans. Dispersion of deliveries would minimize traffic problems, although the establishment of a central concentration yard or pelletizing plant would have local impacts on traffic similar to those of the wood-fired power plant.

o Relationship to local, state or national plans and policies. This alternative would further the goals of the National Energy Acts (1978), the Maine Comprehensive Energy Plan (1976), and the Threshold to Maine Resource Conservation and Development

Project (1977). It would complement the Small Business Administration's Small Business Energy Loan Program, and other federal loan programs related to energy conservation and economic development.

o Summary of long-term impacts. Harvesting presents the impacts of primary concern for this alternative. These impacts are discussed throughout this document. The use of wood as a fuel will create jobs in the region and contribute to the improvement of the balance of payments. Fossil fuels would be released for other uses.

Synthetic Fuels

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could support the use of wood for the production of synthetic fuels.

Description

The Department of Energy could encourage the use of wood for the production of synthetic fuels such as methanol, ethanol, oils, or charcoal. These fuels offer advantages over green chips in ease of handling, Btu content, and fuel uniformity. However, low processing efficiency reduces the value of these products except in special circumstances.

Methanol is produced synthetically from carbon monoxide and hydrogen. It can be synthesized from any carbonaceous material, such as coal, wood waste, agricultural residues, or garbage (Hokanson & Rowell 1977). Methanol production from coal is under intense development; synthesis from municipal solid waste has been successful. However, methanol is presently produced most economically and efficiently using natural gas. Conversion from solid materials requires additional processing and is more energy-intensive than the process using natural gas (Hokanson & Rowell 1977). Plant efficiency with wood feedstock is only 38 percent; for gas, it is 61 percent (see Table 29) (Saeman 1977a).

TABLE 29: COMPARISON OF GAS, COAL, AND WOOD AS SOURCES OF METHANOL[1]

Raw Material	Product Output (10^6 *gal./yr*)	Plant Efficiency[2] (*percent*)	Plant Investment (*million dollars*)	Selling Price (*dollars/gallon*)
Gas	50	61.3	23.1	.46
Coal	50	59.0	74.4	.98
Wood	50	38.0	64.0	.98
Gas	200	61.3	61.0	.35
Coal	200	59.0	178.0	.78
Wood	200	38.0	169.0	.83

1. Assumptions: 30% profit on investment, 15% after federal taxes; natural gas at 1,000 Btu/cubic foot, $1.75/thousand cubic feet; coal at 19% ash, 8,660 Btu/pound, $38/ton; wood waste (Douglas fir) at 25% bark, 9,000 Btu/pound, $34/ton.

2. Plant efficiency = heat value of methanol as percent of total energy input into plant.

Source: Saeman 1977a.

Coal is a more efficient fuelstock than wood (plant efficiency is 59 percent) because of its higher carbon and lower oxygen content (USFS 1976). In addition, coal is a centralized resource while wood is dispersed; large transportation costs must be incurred to collect wood in the quantities required for centralized production.

The efficiency of methanol production from wood depends on improvements in the gasification process (Inman 1977). At the present, methanol production from wood does not appear to be economically feasible (Hokanson & Rowell 1977).

The biology of the fermentation process used to produce ethanol from wood is well known, but wood feedstock requires energy-intensive and expensive pretreatment to break down the cellulose crystals and lignin association (Brenemann 1978). The complexity of the process is reflected in the high investment requirements. Production from ethylene or grain is less expensive (see Table 30).

A multiproduct firm might produce ethanol more profitably, but marketing the fixed ratios of ethanol, furfural, and phenols over the lifetime of the plant make it a high risk investment (Saeman 1977b). One profitable multiproduct plant would increase the nation's production of furfural by two-thirds (Saeman 1977a). Experience with the hydrolysis of hardwoods is limited to pilot plant studies (Saeman 1977b). Since the low-quality wood available in Maine is primarily hardwood and bark, a multiproduct plant is not yet commercially viable.

Production of furfural in a single-product plant is economically infeasible. Phenol production data is speculative (Saeman 1977a).

An experimental hydrogenation plant producing two barrels of oil per ton of dry wood chips is operating in Albany, Oregon, with Department of Energy support. Production of liquid fuel from coal is more economic, however (Zerbe 1978).

Pyrolysis produces gases, oil, and charcoal. The oils tend to be corrosive and viscous and to have a low heat of combustion (Brenemann 1978). The process can be modified to alter the mix of

TABLE 30: SELLING PRICE OF ETHANOL FROM WOOD, ETHYLENE, AND GRAIN[1]

Raw Material	Product Output *(10^6 gal./yr.)*	Wood Input *(tons/day)*	Plant Investment *(million dollars)*	Selling Price *(dollars/gallon)*
Ethylene	25	--	20	0.91
Grain	25	--	25	1.43
Wood	25	1,480	70	1.90
Ethylene	100	--	53	0.76
Grain	100	--	66	1.23
Wood	100	6,000	185	1.42

1. Assumptions: 30% profit on investment, 15% after federal taxes; ethylene at $.11/pound; grain at $3/bushel; wood waste at $34/ton.

Source: Saeman 1977a.

products. If the gaseous products of pyrolysis can be burned before production heat is lost, process efficiencies of 85 percent can be attained (Zerbe 1978). A new pyrolysis process producing a fuel composed of a fifty/fifty char-oil mix and a combustible gas is being tested at the Georgia Institute of Technology (Zerbe 1978).

In addition to problems with process efficiency and economics, synthetic fuels suffer from transportation and delivery inefficiencies. When wood is burned to create space heat or to fuel a power plant, the fuel is transported to a central location and used at the point of delivery. Wood transported to a synthetic fuel plant must be processed into a different form and then delivered to its point of ultimate use. This two-step process reduces the overall efficiency of using wood to produce synthetic fuels and favors the use of coal, which is mined in large quantities at one location.

While the technology for synthetic fuels is progressing, none of the processes appear commercial at the present time:

> "The characteristics of wood reduce its usefulness as a source of clean liquid and gaseous fuels or as a versatile starting material for high-volume organic chemicals. It is a safe generalization to say that for the next decade at least, the most efficient way to use wood as a source of gas or liquid fuels will be to divert such fossil fuels from furnaces and burn wood instead. With rare exceptions, organic chemicals can be made more efficiently from petroleum saved by burning wood than directly from wood itself." (Saeman 1977a).

Since the proposed project is intended to demonstrate the immediate commercial feasibility of producing energy from wood, none of the synthetic processes is a viable alternative to the wood-fired power plant. The Department of Energy, however, is supporting research to design and test intermediate and long-term prospects for the production of synthetic fuels from wood. Therefore, this alternative is not considered further here.

Nonenergy Uses of Wood

Consumptive Uses

Policy statement. As an alternative to the proposed action, the federal government could encourage the use of wood to produce materials such as reconstituted wood products, pulp, and paper.

Description. In stimulating the use of 680,000 tons of wood annually as an energy source for cogeneration, the U.S. Department of Energy would promote the use of rough and rotten wood, the by-products of timber stand improvement, and manufacturing residues. This poor-quality material was unmarketable until the high costs of oil made wood more valuable as a fuel resource. Recent technological developments, however, are also improving the ability of the forest products industry to utilize poor quality wood for reconstituted wood products and pulp manufacture. Products made from wood fibers, strands, or flakes do not use the high quality of wood raw material required for plywood. Traditional particleboard is used in furniture stock, floor underlayment, and panel stock. Structural particleboard, such as strandwood, can be used in place of structural plywood.

Reconstituted wood products account for an increasing percentage of the structural wood consumed in this country. By 2020, board consumption is expected to range from 34 to 54 billion square feet; in 1974 consumption was 12 billion square feet (three-eighths-inch basis) (Stone 1977). Changes in the size and quality of the forest raw material, changes in construction techniques, and improved processing technology will reinforce this trend (Jahn & Preston 1976). The raw material requirements for particleboard are not critical, the production process is automated, and yields are on the order of 75 to 80 percent. Particleboards have advantages over traditional wood material: low variability in properties, dimensional stability, good weathering characteristics, good strength- and stiffness-to- weight ratios, and good fastening properties (Saeman 1973). According to Jerome Saeman and Robert Youngs of the Forest Products Laboratory (1978): "the greatest contribution of wood to our energy budget is an indirect one achieved by using wood in place of energy-intensive alternatives."

Reconstituted wood products can be used as a substitute for more energy intensive materials such as steel, aluminum, and brick. According to a study by the Committee on Renewable Resources for Industrial Materials, steel floor joists require fifty times as much energy as wood joists; aluminum framing is twenty times as energy-intensive as wood framing; brick siding requires twenty-five times the energy of wood-based siding. In addition, wood's insulating properties are superior, providing savings in energy for space heating. Not only are energy requirements for wood products low, most wood processing firms are at least partially energy self-sufficient, using their own wastes for energy (Jahn & Preston 1976). Manufacture of reconstituted boards require 7.5 to 20 million Btu per ton. This is higher than for lumber or veneer, but the yield of product per ton of wood is also higher (Koch 1976).

The federal government could support the annual use of 680,000 tons of low-quality wood as a material by helping to finance a plant producing particleboard, strandwood, or another appropriate composite board. At least one firm has announced plans to build and operate a plant for the manufacture of strandwood in New England. The federal government could provide financial support and/or technical assistance for such a project.

Research on adhesives used in reconstituted products is ongoing in the U.S. Forest Service Forest Products Laboratory in Madison, Wisconsin. Present adhesives are derived from petroleum. Adhesives derived from other sources would enhance particleboard production (Saeman 1978). Lignin is one potential source of adhesives (Jahn & Preston 1976).

Increasingly lower grades of wood are being utilized in the pulp industry (Hokanson & Rowell 1977; Jahn & Preston 1976). New technologies improve the yield of pulp from the same amount of wood (Jahn & Preston 1976). Pulp mills in Maine, as elsewhere, are installing more efficient equipment. The federal government could encourage this trend by supporting research on technology that is more efficient, and by supporting the demonstration of these new technologies.

Economics. In the long run, the fuel value of wood sets its minimum value for more involved uses (Saeman 1977b). For example, pulp has a product value about three times that of wood waste converted to methanol (Hokanson & Rowell 1977). Value is added in processing wood as a material with resulting indirect stimulation of the local economy. These plants can be relatively energy self-sufficient by using process wastes and other wood for process and space heat. Wood used in the manufacture of materials can be recycled; once converted to a fuel and burned, it is lost for other uses.

Marketing and purchasing strategies favor larger, capital intensive plants; the economies of scale are dictated by off-the-shelf equipment. In 1976, a plant consuming 200,000 to 280,000 green tons of wood annually and producing panel-type composites cost about $10 million. A smaller installation was feasible at that time with a captive or controlled market (Gatslick 1977). Yield of composite board is about 416 square feet per ton of wood (UNH 1966). Thus, the use of 240,000 tons per year would produce roughly 100 million square feet per year. The annual requirement of 680,000 tons of wood for the proposed project could supply both material and energy for a plant of this size.

A feasibility study for a proposed strandwood operation in Massachusetts concluded that a $20 to $30 million plant would process 250,000 green tons per year to produce 160 million square feet (three-eighths-inch basis) of product. This plant would require 80 percent softwood (Cady 1979).

Environmental impacts. The nature of the construction impacts of a reconstituted board plant would be similar to those for the proposed project, although the scales would differ. In addition to buildings, equipment, and wood storage facilities for materials manufacture, a wood energy system would be required to provide space and process heat for the facility.

Particleboard manufacture is a dry process; no water would be discharged. Emissons from the gluing process apparently are negligible, although fumes inside plants using urea-formaldehyde as an adhesive can cause concern (Marra 1979). Operation requires process heat that can be produced by burning wood. Impacts of process heat would be similar to those for the proposed project, although smaller in scale. Wood handling facilities would also be similar to those of the proposed project, although there would be one system to handle material feed and another to handle fuel chips. Jobs would be created by operation of the plant, and benefits from employment would accrue to the local economy. One proposed plant, using 160,000 green tons of wood and producing 100 million square feet of particleboard per year (three-eighths-inch basis) planned to employ 101 people and projected the creation of 350 secondary jobs (Valley News 1978).

Impacts of wood procurement would be similar to those for the proposed project. Transportation impacts would also resemble those for the proposed wood-fired power plant. However, transportation of products from the plant to wholesale distributors would add to the amount of truck traffic and the overall energy budget.

This alternative would enhance local and state programs to create jobs and industry using local resources. The goals of the National Energy Plan would indirectly be served, since wood materials are more energy-efficient than substitutes. However, this alternative would not produce energy directly or contribute to the commercialization of wood energy systems.

Utilizing 680,000 tons of wood annually for the manufacture of composite products would create jobs and benefit the economy. However, the long-term management and productivity of the forest must be preserved with the same sound forest practices that are required for the proposed project and for alternative uses of the wood to generate energy.

Nonconsumptive Uses of Forests

Policy statement. As an alternative to the proposed action, the United States government could support nonconsumptive uses of forest lands.

Description. Federal agencies could encourage uses of Maine woodlands that do not require the harvest of wood. Funding could instead be provided for the improvement of woodland wildlife habitat, including fisheries, in cooperation with the Maine Department of Inland Fisheries and Wildlife or private conservation organizations.

Wilderness or natural area protection or acquisition could be promoted through appropriate state agencies and private landholding organizations such as the Audubon Society or the Nature Conservancy. Federal funds encouraging acquisition and transfer of property or conservation easements would support this end.

Undisturbed ecosystems serve as a benchmark against which changes in the unprotected landscape can be measured. Scientific study of these natural areas provides important information on plant and animal lifecycles, succession, and other natural phenomena vital to our knowledge of the natural systems that man manages, uses, and, sometimes, abuses. Funding for land acquisition should include provisions for maintenance of the property.

Protected wilderness areas, if accessible, also provide an outdoor laboratory for educational purposes. Undisturbed processes of growth, decay, and ecosystem development can be observed. Natural areas provide the opportunity for "wilderness experiences" for recreationists seeking solitude, natural surroundings, and wildlife viewing. Hunting and fishing may or may not be allowed.

Environmental impacts. The impacts of this alternative will result from the removal of the wood resource from direct economic use. Locally, wilderness designation can affect the livelihoods of woodsworkers and employees of the wood products industries, and may produce adverse public reaction. On the other hand, increased environmental awareness and improved scientific knowledge would benefit society as a whole. In addition, natural area designation helps to protect threatened and endangered species and to preserve the diversity of the native gene pool.

Wilderness recreation is enhanced by preserving natural areas, but this may be at the expense of more intensive recreational uses. People lacking the stamina or skills to enjoy the back country are excluded from use of wilderness areas by the lack of access roads and developed facilities.

Relationship to national, state, or local plans and policies. The Maine Critical Areas Program has identified noteworthy natural features in the state for inclusion in Official Register of Critical Areas. The program was created by the state legislature in 1974 to encourage and coordinate the conservation of such areas. Areas identified by this program would have priority in a federal program to preserve natural areas.

Both the Time and Tide and the Threshold to Maine Resource Conservation and Development Projects identify fish and wildlife habitat improvement and recreational development as project objectives. The Time and Tide Program of Action also encourages preservation of unique natural areas. Coordination with Resource Conservation and Development Project activities could enhance nonconsumptive uses of forested land through local support.

The Maine Statewide Outdoor Recreation Plan calls for the acquisition of land for recreation, including wilderness and wildlife areas. In particular, for southwestern Maine, acquisition of land to fill in the boundaries of the Evans Notch District of the White Mountain National Forest and the Rachel Carson National Wildlife Refuge is recommended. The Plan also recommends that the Maine Bureau of Parks and Recreation prepare a State Park Plan to address specific needs of the State Park System. A State Park Plan would provide guidelines for land acquisition and preservation.

On the federal level, the Roadless Area Review and Evaluation (RARE II) of the U.S. Forest Service has recently reviewed areas in the National Forest System for wilderness designation. While no lands in Maine have been designated under this program, RARE II has brought wilderness designation to the public attention in New England. Removal of timberland in the White Mountains of New Hampshire from harvestable status because of its designation as a roadless area could increase pressure on the forest resource of

Maine and prompt conservationists to push for more wilderness areas in the state.

This alternative would not produce energy directly and would not contribute to a reduction in the national dependance on non-renewable energy sources.

ALTERNATIVE PLANT DESIGNS

Generation of Steam Only

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a wood-fired steam generating facility producing 510,000 pounds of steam per hour at the Westbrook mill.

Description

A steam boiler operating at 510,000 pounds per hour producing industrial steam for the S.D. Warren Company would require approximately 3.5 percent less fuel annually than the proposed action as a result of not incorporating electric generation into the facility design. Harvested fuelwood chips would still provide the bulk of fuel to the boiler and millwood residues would supply a significant component (up to about 40 percent). A turbine-generator-condensor would not be required in this alternative which would eliminate the need for a cooling tower. All other characteristics and requirements of this system would be similar to those of the proposed facility.

Economics

The capital, operating and maintenance, and fuel costs of a 510,000 pound per hour steam generating facility would be similar to those of the proposed facility except that no turbine generator or cooling tower would have to be purchased, erected, or operated. Reduced pressure requirements for the steam would enable construction of a slightly smaller boiler, which could reduce boiler construction costs by a few percent. Similarly, fuelwood costs and operation and maintenance costs would be somewhat reduced though not by more than 3 to 4 percent. The cost of this alternative are outlined in Table 31.

The use of the costs presented in Table 31 to calculate a unit production cost, such as mills per kilowatt-hour or dollars per million Btu is subject to many variable factors. Construction time, financing and the existing tax climate will influence

TABLE 31: ESTIMATED CAPITAL, OPERATING AND MAINTENANCE, AND FUEL COSTS OF A 510,000 POUND PER HOUR WOOD-FIRED BOILER[1]

Capital Costs	1979 Dollars *(millions)*
Installed Capital Cost[2]	53.0
Annual Operating and Maintenance Cost[3]	1.3
Annual Fuel Cost[4]	8.5

1. *These estimates would vary from site to site and should only be considered as approximate.*
2. *Calculated from Manar 1979b.*
3. *Assumed to be 2.5% of installed capital cost: Manar 1979a.*
4. *Based on a fuel price of $12.50/ton (Allison 1979).*

the annual charges on investment. Recent changes in the investment tax credits and depreciation allowances enacted by the Energy Tax Act of 1978 will have important influence on the choice of fuel for energy facilities. For these reasons, it is beyond the scope of an environmental impact statement to predict precise unit costs. The capital, operating, maintenance and fuel costs presented in Table 31, however, do indicate that this alternative is at least marginally commercial, and that further consideration of its environmental impacts is justified.

Environmental Impacts

Construction impacts. The environmental and socioeconomic impacts of constructing a 510,000 pound-per-hour steam generating facility would be similar to those of the proposed cogenerating plant. The elimination of the electric generating equipment, the switch yard, and the cooling tower would not significantly affect the amount of site preparation required.

Operation impacts. The impacts of operation would be similar to those associated with the proposed action. The very slight reduction in fuel requirements would not significantly lower the emissions described in Appendix B for the proposed facility. Because of the elimination of the cooling tower used for the cogenerating facility, thermal effluents would be released in the plant's waste water. The quantity of heat released, however, would have no significant impact on the receiving waters (Manar 1979a).

Fuel procurement impacts. The 3.5 percent lower fuel requirement would allow a steam-only facility to rely somewhat more heavily on mill residues. The impacts of procuring and transporting the fuel would not be significantly different from those of the proposed cogenerating facility.

Relationship to national, state, or local plans and policies. This alternative is compatible with federal and state policies, encouraging the use of wood fuels. A decision, however, to construct an industrial boiler producing steam only does not reflect federal and state policy on cogeneration. The Public Utility Regulatory Policies Act of 1978 (PL95-617) encourages the cogeneration of energy under a variety of regulatory mechanisms to be developed and exercised by the Federal Energy Regulatory Commission. The Maine Office of Energy Resources encourages the development of cogenerating facilities as a means to more efficiently utilized energy resources (MOER 1976).

Summary of long-term effects. The long-term effects of a 510,000 pound per hour steam generating facility would be similar to, although less intense than, those of the proposed facility described throughout these appendices. The facility would lessen national dependence on a limited supply of imported fossil fuels.

Generation of Electricity Only

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could support the construction of a 50-megawatt wood-fired electric generating station.

Description

A 50-megawatt wood-fired electric generating station would require between 708,000 and 843,000 tons per year of wood fuel (Sherwood & Meadows 1978). The fuel would be obtained from harvesting operations and wood residue producers. The facility could be located at any of numerous sites in Maine where the transportation system and water source were adequate. The characteristics of this facility would be similar to those of the proposed 50-megawatt cogenerating facility, except that the steam would be used only to generate electricity.

Economics

The costs associated with a 50-megawatt electric generating plant are presented in Table 20. With the exception of the expense for a larger turbine generator, these costs are identical to those associated with the proposed action.

The use of the costs presented in Table 32 to calculate a unit production cost, such as mills per kilowatt hour or dollars per million Btu, is subject to many variable factors. The nature of the plant site and its location affect the cost of capital,

TABLE 32: ESTIMATED CAPITAL, OPERATING AND MAINTENANCE, AND FUEL COSTS OF A 50-MW WOOD-FIRED ELECTRIC GENERATING FACILITY[1]

	1979 Dollars *(millions)*
Installed Capital Cost[2]	57
Annual Operating and Maintenance Cost[3]	1.4
Annual Fuel Cost[4]	8.8 - 10.5

1. *These estimates would vary from site to site and should only be considered as approximate.*
2. *Calculated from Manar 1979c.*
3. *Assumed to be 2.5% of installed capital cost: Manar 1979b.*
4. *Based on a fuel price of $12.50/ton: Allison 1979.*
   Based on fuel consumption of 708,000 to 843,000 tons of wood per year: Sherwood & Meadows 1978.

maintenance, operation and fuel. Construction time, financing and the existing tax climate will influence the annual charges on investment. Recent changes in the investment tax credits and depreciation allowances enacted by the Energy Tax Act of 1978 will have important influence on the choice of fuel for energy facilities. For these reasons, it is beyond the scope of an environmental impact statement to predict precise unit costs. The capital, operating, maintenance and fuel costs presented in Table 32, however, do indicate that this alternative may be marginally commercial and that further consideration of its environmental impacts is justified.

Environmental Impacts

While the environmental impacts of a 50-megawatt wood-fired electric cogenerating plant are similar to those of the proposed facility, the location of the plant could alter the impacts and might affect public recreational access to Maine's inland or coastal water resources. Emissions and effluents should be identical to those of the proposed action, except that somewhat more waste heat may be discharged and a less efficient use of energy attained.

Relationship with national, state, or local plans and policies. While this alternative is compatible with federal and state initiatives to utilize wood as an energy source, the choice of an electric-only facility over a cogenerating facility would not reflect the policies established by the Public Utilities Regulatory Policy Act of 1978 and the Maine Comprehensive Energy Plan of 1976.

Summary of long-term effects. The fuel procurement program needed to supply this facility would have significant implication for the management of forest and related ecosystems in southern Maine. The potentially positive and negative impacts of wood fue collection are fully discussed throughout these appendices, particularly C and D. This alternative would assist a regional transition from dependence on nonrenewable sources of energy to a sustainable energy system.

Alternative Engineering Systems

The information presented below was suppled by the Rust Engineering company (Finn 1979b) and describes the alternative system designs that were evaluated during the design of the proposed wood-fired power plant.

Cooling System Design

The proposed wood-fired power plant will employ a one- or two-cell, induced draft, cross flow cooling tower to reject heat from the proposed wood-fired boiler. Two alternatives to this system were evaluated during the design of the cooling system: straight-through cooling with a direct discharge to the Presumpscot River and a combination straight-through/cooling tower system. Preliminary calculations were run to assess the impact of these systems on the thermal quality of the Presumpscot River. These calculations showed that a once-through cooling system or a combined system would result in violations of the allowable temperatures in the Presumpscot during certain operation times including periods of high thermal discharge in summer coupled with low river flows. Discussions with the Maine Department of Environmental Protection indicated that the Board of Environmental Protection would not allow once-through or partial systems in this case.

Ash Handling and Disposal

Both dry and wet ash-handling systems were evaluated for use in the proposed plant. A system featuring dry handling for the precipitator and siftings hopper, and wet handling for the boiler ash has been chosen. The dry handling systems were chosen because their compact size allows them to fit within the space available near the precipitator and the siftings hopper. The wet handling system for boiler ash disposal was chosen to reduce fire hazard in the overall ash-handling system. Initially, a pneumatic ash-handling system was considered as the method to remove and convey the fly ash to silos. This system was rejected because of explosion and fire hazard resulting from the hot char that is handled along with the fly ash through the pneumatically-operated system.

Dewatering bins were also considered as an intermediate step in the ash-handling system between ash collection and deposition into the ash ponds. The short retention time in the bin, however, would have resulted in a contaminated water overflow which would have been prohibitively costly to treat before discharge into the Presumpscot. Additionally, an unacceptably large flow would have been generated with the use of dewatering bins. For these reasons, this system was discarded and the ash will flow directly into ash ponds. The water used to convey the ash will be recirculated in an essentially closed loop.

The alkaline properties, potash content, and mineral content of the wood ash make it a suitable soil conditioner or, with additives, a fertilizer. If a market for the wood ash can be established, an ash-handling system can be provided wherein the ash would be packaged and delivered to potential retailers or wholesalers. This possibility is under continuing investigation.

Water Treatment System

Three water treatment systems for the preparation of high-quality feedwater for the wood-fired steam generator were considered. These systems included:

A. Anthracite-sand filtration and activated carbon filtration followed by two-bed and mixed-bed ion exchangers;

B. Activated carbon filtration followed by two-bed and mixed-bed ion exchangers;

C. Activated carbon filtration followed by mixed-bed ion exchangers.

System C was selected because it will generate less wastewater and the wastewater will have a pH compatible with the U.S. Environmental Protection Agency's regulations. Additionally, System C requires less space than the other systems and has lower capital and operating costs.

Pressure Level of the Boiler

Current technology in the burning of wood-fuel limits the pressure level of the boiler to an operating level of 1,500 pounds per square inch guage (psig). A range of operating pressures was considered for the proposed boiler and levels lower than 1,500 psig could be employed at the proposed plant site. However, the 1500 psig level provides the highest cycle efficiency and has been chosen for that reason.

Steam Cycles

Alternative heat balances and steam cycles were evaluated for cogeneration at the S.D. Warren Company mill. Because of the high expense associated with reworking existing steam facilities used in the pulp and papermaking process, turbine extractions were selected to be compatible with the existing S.D. Warren steam system.

Fuelwood Drying

Predrying fuelwood before injecting it into the boiler reduces the moisture content of the wood and thus improves the efficiency of combustion. Three systems were considered for predrying the wood:

A. Separately fired bark dryers which dry the fuelwood through combustion of wood or some other fuel prior to the fuelwood's entry into the boiler feed system;

B. Hot hogs which dry the fuelwood while processing the wood chips to make them more uniform in size;

C. Flue-gas dryers which use heat in the stack emissions stream to dry chips prior to injecting them into the boiler.

Flue-gas bark dryers were selected because they have been operated successfully and economically in the past.

Generator Cooling System

Two generator cooling systems were considered for the proposed wood-fired power plant: air-cooled systems and hydrogen-cooled systems. Although hydrogen-cooled systems operate more efficiently than air-cooled systems, their higher initial capital costs could not be justified and thus air-cooled generators were chosen.

ALTERNATIVE BIOMASS SUPPLY SYSTEMS

Alternative Harvesting Strategies

Policy Statement

The proposed wood-fired power plant will receive fuelwood in the form of chips that have been processed at the harvest site by a whole-tree chipper and transported to the facility in chip vans. As an alternative, standard logging procedures could be employed to produce logs to be chipped at the power plant.

Description

Fuelwood for the proposed action will be harvested from the region's forests with mechanized operations that produce one- to two-inch chips from whole trees. These chips will be procured from private logging contractors who in turn will acquire cutting rights (stumpage) from individual landowners. It is expected that a wide variety of harvest systems (clearcutting, shelterwood, selective) and thinning strategies will be employed to supply these chips. The impacts of these various methods are discussed in Appendices C and D.

Two major alternatives exist for the procurement of fuelwood. Wood could be grown and harvested on silvicultural energy plantations. This intensive system is not economically feasible in view of the less expensive, abundantly available, low-quality wood in the region's forests. Also, because of the long start-up time, wood would not be immediately available from this source. The Department of Energy is investigating the intermediate and long-term feasibility of this alternative in other research programs; consequently it will not be considered further here.

The most feasible alternative to whole-tree chipping would be standard logging operations to cut logs which could then be chipped or hogged after delivery to the power plant. With this type of operation, better quality trees would be harvested, since the inefficiencies of transporting crooked logs constrain their use. If only the boles were taken, at least 50 percent of the combustible fiber would be left in the forest as tops and branches. Therefore, it is likely that almost twice as much land would be necessary to produce a given amount of wood for energy with the bole-only alternative.

Economics

Employment of bole-only harvesting may result in higher prices for fuelwood than those that would prevail if whole-tree chipping were employed. The major expense of acquiring and using wood resources results from the costs associated with handling the bulky, heavy, irregularly-sized trees. Whole-tree chipping at forest landings reduces the fiber from the whole tree into a much more uniform and readily transportable material.

Stumpage fees for the bole-only system may be as high or higher than those for whole-tree removal. As stated earlier, shipment of logs necessitates leaving the tops and branches in the forest. Thus the fee paid to the landowner per unit of material recovered may be substantially higher with the bole-only alternative. Also, handling and chipping logs at the power plant site is more expensive and time-consuming than processing chips.

One advantage of bole-only harvesting is that less capital investment is required of logging contractors in the fuelwood business. The necessity of having a chipper operating at the landing can substantially increase harvesting capital costs (see Appendix E) and may prevent some contractors from entering the market.

Environmental Impacts

The environmental impacts of this alternative would be similar to those described for the proposed action. The major differences result from the disposal of tops, branches, and deformed trees left in the forest as slash. The exact nature of the resulting impacts would depend on how the slash was managed. If typical practices for the Northeast are followed, the slash would be left where the trees were felled and would be allowed to decompose slowly on the site. In this case, the slash would provide some shading for the forest floor following the removal of the tree canopy. Shade slows the rates of soil litter and organic matter decomposition (see Appendix D) and provides variations in soil microclimate that may favor more diverse regeneration of the stand.

Initial regeneration failure has been observed on south-facing slopes in Vermont following slash removal, whereas similar slopes have regenerated successfully following a bole-only harvest. However, slash may also impede reproduction of the stand as a result of heavy shade, mechanical suppression, or provision of a microclimate suitable for competitive herbaceous plants and shrubs (Smith 1962).

As the slash decomposes over a period of ten to twelve years, it provides a substantial nutrient input to the new or remaining stand and typically improves the physical properties of forest soils (Smith 1962). This effect is enhanced because decomposing slash serves as a site for nitrogen fixation by decomposing bacteria (Roskoski 1975). Slash remaining on the forest floor reduces the rate of soil organic matter decomposition, and thus effectively reduces the leaching of nutrients into groundwater and streams. Slash also acts as a buffer to reduce the rate of sediment transport in surface water flow, although the significance of this effect is questionable (Smith 1962). By the time slash begins to decompose, the new stand is generally sufficiently established to retain a high percentage of the available nutrients. Slash also provides habitat for wildlife species such as rabbits and ground-nesting birds.

The vast majority of insects and fungi that feed on logging residues benefit the forest by decomposing slash and making its nutrient content available. Few of these species attack living trees (Smith 1962). However, some bark beetles and heart-rot fungi do thrive in cull logs and large branches and may establish populations that threaten the new or residual stand of trees.

Slash left in the forest can provide a fuel source which, if ignited, can speed the spread of forest fires and hinder the movement of fire-fighting efforts. Small branches and twigs can provide tinder ideal for starting wildfires but this material generally decomposes quickly following harvest. Slash is not perceived as a major fire menace in the Northeast, where precipitation is rather evenly dispersed throughout the year.

Slash represents a major aesthetic nuisance to many people, who may perceive it as a hazard, a sign of poor forest practices, or simply a mess. This problem can be mitigated by removing slash from highly visible areas.

The use of bole-only harvesting in the Northeast typically means that substantial quantities of tops, limbs, and branches are left in the forest. The employment of this harvest system would fail to demonstrate the commercial viability of whole-tree harvesting for the production of fuelwood, which would reduce the total amount of fuelwood available immediately. These events could slow the development of the use of wood to produce energy in New England. The disposal of slash in the forest represents both beneficial and harmful impacts as seen above. Continuation of this practice, as an alternative to the proposed system which would remove slash, however, could reduce the danger of long-term nutrient depletion of the forest (see Appendix D).

Alternative Residue Systems

Policy Statement

As an alternative to the proposed action, the U.S. Department of Energy could support a program to collect and utilize agricultural wastes for the production of energy in southern Maine.

Description

The characteristics and requirements of a facility designed to burn crop residues and animal manure, as either supplementary or primary fuels, are generally similar to those of the proposed wood-fired facility. An extensive collection network would be required to collect these residues, which are dispersed at a relatively low density over a wide area in southern Maine. Table 33 outlines the availability of these fuels in the counties that intersect the fifty-mile radius harvest region of the proposed plant.

TABLE 33: ANNUAL AVAILABILITY OF CROP RESIDUES AND ANIMAL MANURE

County	Crop Residues[1] (dry tons)	Animal Manure[2] (dry tons)
Maine		
Androscoggin	1,006	27
Cumberland	2,028	15
York	1,491	17
Kennebec	594	36
Lincoln	424	3
Oxford	2,675	13
Sagadahoc	0	2
New Hampshire		
Belknap	194	282
Carroll	166	144
Strafford	177	417
Total	8,755	956

1. *Includes all crop residues wasted and left in the field.*
2. *Includes only manure wasted, since residues used as feed, fuel, or fertilizer are not available for use at the biomass facility.*

Source: SRI 1976.

TABLE 34: ENERGY CONTENT OF AGRICULTURAL RESIDUES

Material	Energy Content (10^6 Btu/dry ton)
Chicken Manure[1]	4.39
Cattle Manure [1]	2.21
Corn Residues[2]	16.2
Wheat Residues[2]	15.7

1. *Anaerobically digested to produce a low-Btu gas.*
2. *Direct-fired.*

Source: SRI 1978.

While the crop residues could be chopped and dried to provide useful fuel, the animal manure would have to be converted to a gas before it is burned (SRI 1978). Table 34 describes the energy content of agricultural residue fuels after processing.

From this information, it is calculated that the total energy contribution from agricultural wastes could not exceed 2.4 percent of the gross energy input of the proposed power plant. The extremely limited availability of these fuels precludes further consideration of this alternative.

Alternative Transportation Systems

Policy Statement

As currently planned, most of the fuelwood will be transported as chips to the proposed wood-fired power plant, in large truck vans and railcars (see Appendix F). No transportation controls have been designed specifically for this project. There are three major types of alternatives to this proposed transportation system -- modal alternatives, implementation of transportation controls, and the implementation of harvesting controls. These alternatives are summarized in Table 35.

Description

Modal alternatives. There are two major modal alternatives to the present plan for transporting the wood chips to the proposed wood-fired power plant. Chips could be delivered to the plant by rail only or both by trailer-on-flatcar systems. Trailer-on-flatcar system would require construction of loading and unloading ramps for moving truck vans on and off the flatcars.

A rail-only transport system would actually have to rely on trucks to move wood from the harvest site to a central railcar loading station. Trucks could haul roundwood to be chipped at the station and blown into railcars. In this case, as much as 50 percent of the fuelwood value of harvested trees would be left in tops and branches in the forest (Hewett 1978). Alternatively, chip vans could transport chips from whole-tree harvesting operations to be reloaded into railcars at the rail landing. In

TABLE 35: MAJOR ALTERNATIVES TO PROPOSED TRANSPORTATION SYSTEM

Modal Alternatives	Description
Rail Only	Use rail for long-distance haul of fuel
Trailer-on-Flatcar	Use both truck and rail for long-distance haul of fuel
Transportation Controls	
Wood Unloading Schedule	Accept wood fuel at plant at specified times of the day and on specified days only
Routing	Use only pre-specified routes for truck travel
Vehicle Loads	Accept fuel only from trucks acceptably loaded
Vehicle Condition	Accept fuel only from vehicles meeting maintenance criteria
Harvesting Controls	
Geographic Distribution	Harvesting (or wood removal) in dispersed areas
Timing	Chip vans loaded at specified times

this case, expensive equipment suitable for unloading chip vans and reloading railcars would have to be provided at each landing (Adler, Blakey & Meyer 1978).

Transportation controls. A number of controls could be implemented to ease the impacts of trucking wood chips to the wood-fired power plant. Any facility accepting wood deliveries can establish unloading hours, which helps to minimize traffic impacts. If the truck fleet were owned by the power plant or managed under restrictive contract, routing controls could be instituted. These would ensure that the plant's truck traffic avoided sensitive neighborhoods, congested areas, or fragile streets and roads. A wood-fired power plant could also institute a strict policy of refusing to unload overweight trucks arriving at the woodyard, and could establish an inspection and permit program that ensured that chip vans delivering wood were maintained according to certain standards.

Harvesting controls. Harvesting policies also can affect the impacts of trucking. If harvesting were geographically dispersed, truck concentrations on any one route would be relatively small. Similarly, loading of wood chip vans could be timed so that the trucks would not travel during local peak traffic hours.

Economics

Using both rail and trucks for transporting fuel to the plant would add considerable capital expense to the facility. Truck-railcar transfer equipment for a single site, including a blower system, a dumper and hopper, and a conveyor, would cost approximately $500,000 (Adler, Blakey & Meyer 1978). Railcar unloading equipment would cost from $200,000 to $600,000, making the total cost of the rail-only system approximately $1 million (Adler, Blakey & Meyer 1978).

Other alternatives are not as capital intensive, but some will add to the operating costs of the plant. If truck routing is controlled, trips will probably be longer. Transportation costs are directly related to trip length. Total yearly transportation operating costs will be approximately $2 million (assuming the trucks are carrying 680,000 tons per year an average of 50 miles per trip at $.06 per ton-mile: assumptions from Milligan 1979a and Adler, Blakey, & Meyer 1978). Therefore, a rerouting scheme that increased trip lengths by 10 percent would increase costs by $200,000 per year. Other controls on transportation activities, such as establishing limited unloading schedules and refusing overloaded or poorly maintained trucks, are likely to have some effect on rate negotiations with haulers. A resulting increase of, for example, $.005 per ton-mile would add approximately $170,000 to the plant's yearly costs. The actual increase in operating costs will, of course, depend on the extent of the controls. Minor restrictions on routing, scheduling, and loading would result in cost impacts less severe than those cited above.

Environmental Impacts

A trailer-on-flatcar or rail-only delivery system could reduce or eliminate the volume of chip van traffic arriving at the wood-fired power plant and thus could reduce or eliminate the potential for adverse impacts in the area. These impacts are described in Appendix F. In either case, truck traffic would affect the fuelwood harvest region, since trucks would have to deliver wood from the harvest site to the rail loading site. If the rail loading system concentrated shipments (i.e., if the number of loading sites were less than the number of harvest sites, which would almost certainly be the case), inappropriate location of these loading sites could exacerbate truck-related impacts. For example, if a loading site were located near a highway intersection with inadequate capacity, the truck traffic could add to the congestion at the intersection. Other impacts of increased reliance on rail transportation are negligible (see Appendix F).

Table 36 summarizes the effects of the transportation controls alternatives. These alternatives have benefits that at least partially offset their cost, as discussed earlier. Generally, these alternatives could be instituted when or if it became necessary to reduce congestion, noise, air quality deterioration, or highway damage.

Traffic impacts. Of the different impact types, reduction of traffic congestion is the most straightforward. As discussed in Appendix F, traffic congestion arises due to concentration of vehicles in time and in space. Deliveries of wood to the power plant would be distributed in a relatively uniform way over time. Deliveries that occurred during Westbrook's peak commuting hours would have the most adverse traffic impact. An extremely effective strategy to control this impact would be to use an unloading schedule that directed wood deliveries away from these peak hours. A measure of this type would significantly reduce the traffic-related impacts of truck deliveries.

Where traffic problems occurred only in certain geographic areas, delivery trucks could be directed to avoid routes passing through those areas. Control over truck routing, however, is difficult to establish, especially over only a particular category of trucks. Special institutional arrangements would be necessary to implement such controls (see Table 36).

The general effect of trucks in the traffic stream is strongly influenced by the condition of the vehicles and in particular by the vehicles' horsepower-to-weight ratio. Poor acceleration at intersections and performance on grades directly affect traffic flow (AASHO 1965). By controlling the condition and design of vehicles, this impact can be minimized (Whiteside et al. 1973).

Noise impacts. The impact of truck-related noise depends both on the magnitude of noise and on the proximity to sensitve land uses. In some cases, timing is also a significant factor; trucks operating early in the morning or late at night when general traffic volumes are low may be more noticeable and bothersome. Adherence to an operating schedule could reduce this noise nuisance (Galloway, Clark & Kerrick 1969). Use of only specified routes could similarly reduce the extent to which power plant trucks impacted sensitive areas (Galloway, Clark & Kerrick 1969). As mentioned earlier, however, control over truck routing is somewhat more difficult to exercise than other controls. While considerable effort has been made to reduce truck noise through

TABLE 36: EFFECTS AND IMPLEMENTATION OF TRANSPORTATION CONTROL ALTERNATIVES

Control	Impact Reduction	Implementation Requirements
Wood Unloading Schedule	Congestion Noise Air quality	Adherence to strict unloading schedule
Routing	Congestion Noise Air quality Bridge maintenance	Full fleet control: i.e., fleet owned by power plant or managed under restrictive contract
Vehicle Loads	Highway maintenance Bridge maintenance Congestion	Weighing at power plant, rejection of overloaded vehicles
Vehicle Condition	Noise Air quality Congestion	Inspection/permit program managed by power plant operator

mechanical improvements and muffling, further improvements in vehicle design will lead to quieter trucks (Kugler & Piersol 1973) also, careful maintenance of the vehicles reduces truck noise emissions (Kugler & Piersol 1973).

Air quality impacts. Air quality problems that occurred at particular times of day (e.g., high carbon monoxide concentrations) or in particular geographic areas could be reduced through schedule and routing control. Use of newer, properly maintained vehicles would result in overall reductions in truck emissions.

Highway and bridge maintenance impacts. It was assumed that trucks would not use bridges posted with limits lower than their gross weights. Strict controls over truck routing could assure conformance with bridge limitations. In addition, a policy to control vehicle gross weights by refusing delivery from violators would reduce possible bridge and highway impacts. Damage to highway surfaces is exponentially related to axle loads (Chastain et al. 1965). Thus, the potential for roadway or bridge damage can be significantly reduced by a strict policy of refusing to unload overweight trucks.

Summary of long-term impacts. A variety of wood transportation alternatives could reduce the impacts of the chip hauling activity. Use of rail transport as a substitute for trucks would require increased investment in loading/unloading equipment but could significantly reduce most impacts of wood hauling. Less expensive transportation and harvesting controls could reduce all categories of impacts due to truck transport. Many of these controls could be quite readily instituted if the impacts of wood chip delivery became unacceptably adverse.

ALTERNATIVE SITES

Process of Site Selection

To ensure selection of a site that would best meet all criteria for location of a wood-fired power plant, the Department of Energy's contractor (Rust Engineering Company for Wheelabrator Cleanfuels Corporation) assessed locations in the three northern New England states. Because of high fuel costs, substantial local interest and a relative abundance of low-quality wood and wood residue, Maine was chosen for detailed investigation. Twenty-two sites in Maine, each adjacent to a large-scale industrial steam customer, were assessed. These locations were analyzed to ensure that the maximum energy-conserving benefits of congeneration could be obtained. Of these sites, five were selected on the basis of engineering and economic potential for final evaluation.

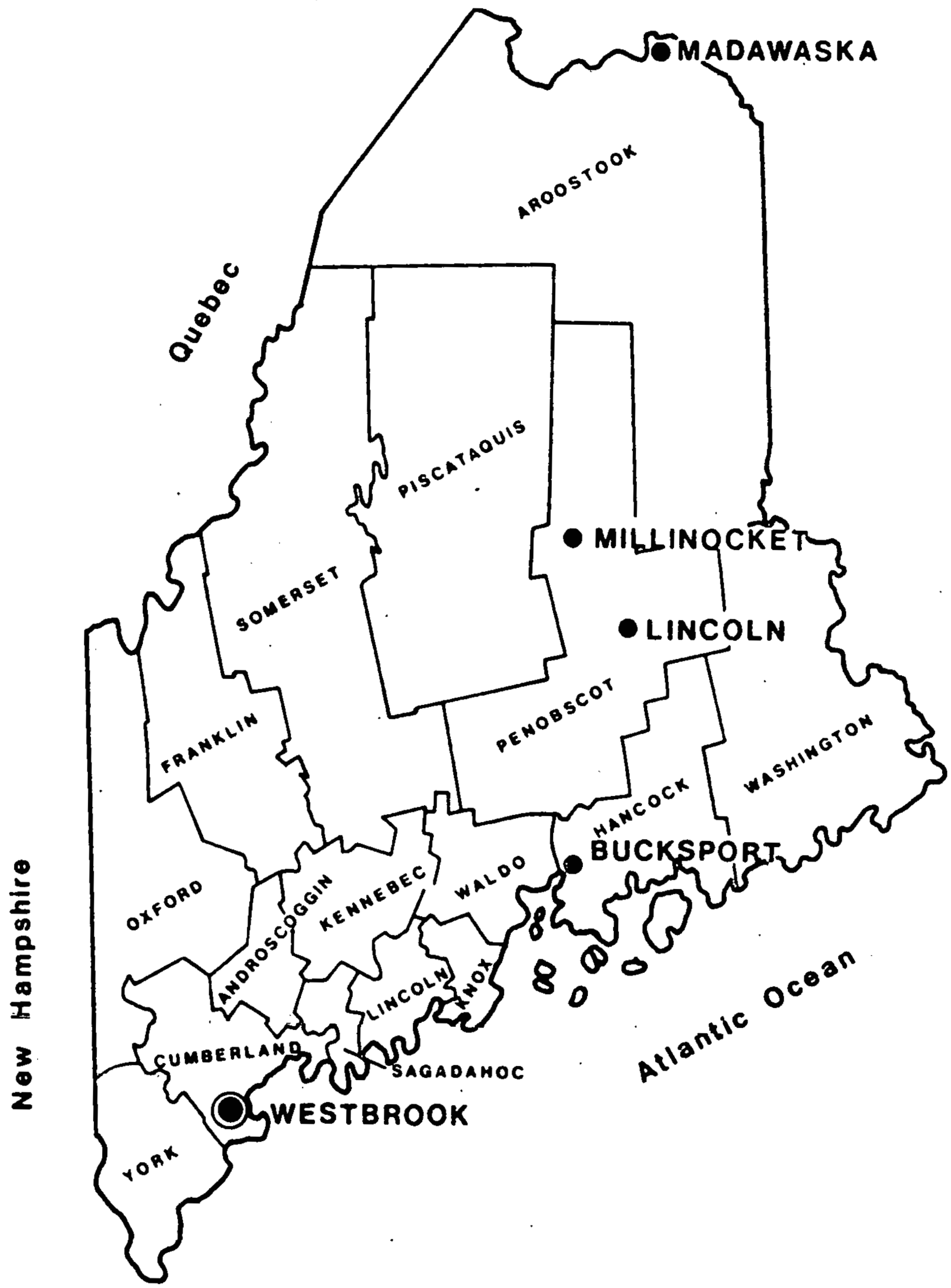
The sites selected for final assessment were Madawaska, in Aroostook County; East Millinocket, in Penobscot County; Lincoln, in Penobscot County; Bucksport, in Penobscot County; and Westbrook, in Cumberland County (see Figure 3). Westbrook, the site finally selected, is the subject of this environmental impact report; the evaluation of the four alternative sites follows. The plant specifications for the alternative sites are assumed to be the same as those for the Westbrook site; however, because the cogeneration requirements differ at each site, the actual plant specifications would probably differ slightly. The environmental impacts of the proposed plant at the alternative sites are described here only to the extent that they differ from those at the Westbrook site. Otherwise, the impacts may be assumed to be similar.

Characteristics of Alternative Sites

Madawaska

Location. The power plant site considered would be located on reclaimed land owned by the Bangor and Aroostook Railroad adjacent to Fraser Paper Limited's American paper mill. The site is

FIGURE 3: FIVE MAINE SITES EVALUATED AS LOCATIONS FOR WOOD-FIRED POWER PLANT



bounded by the Saint John River, U.S. Route 1, and Bridge Street, the access to the international bridge to Edmunston, New Brunswick (see Figure 4).

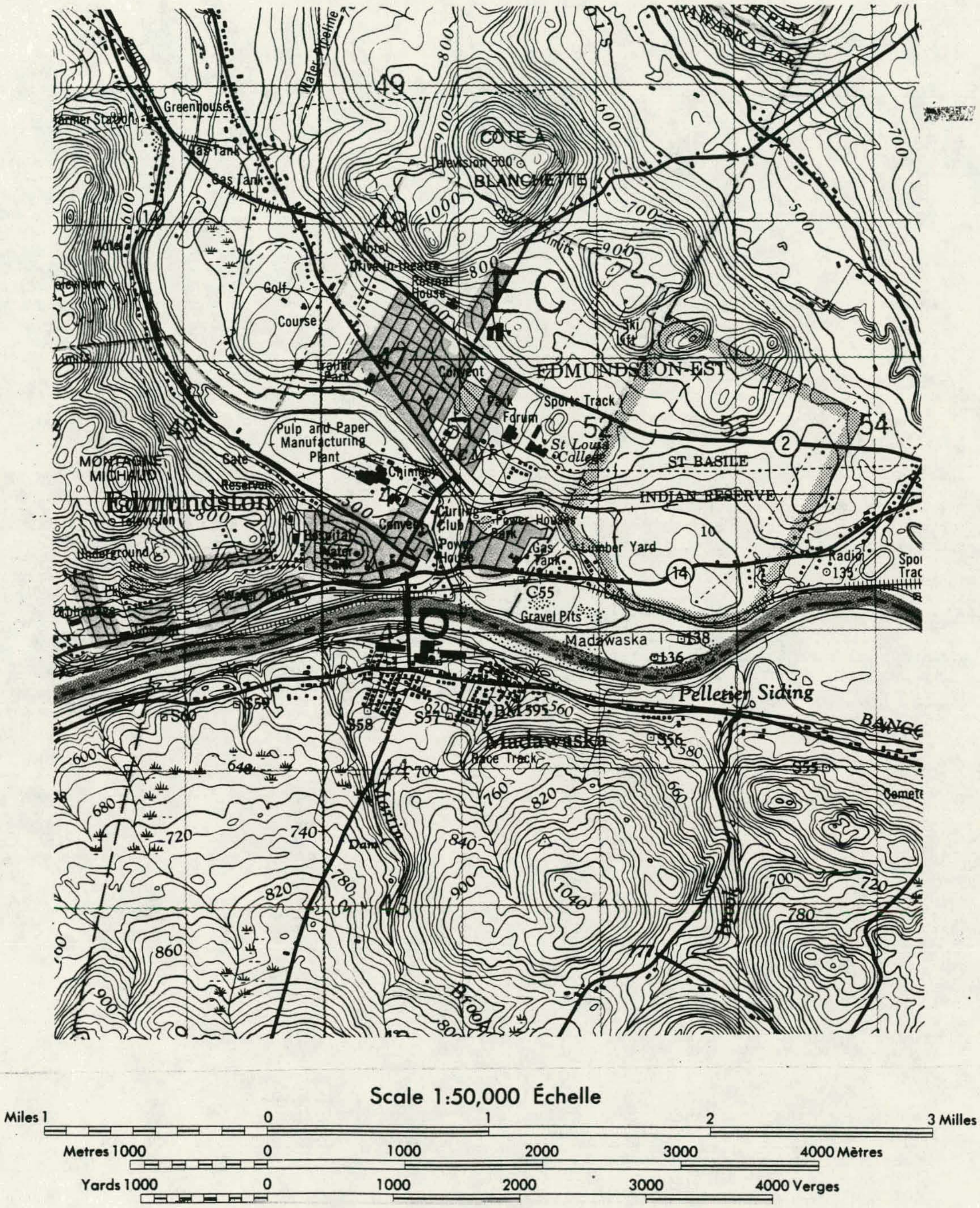
Site characteristics. The site has sufficient land available only for the power plant buildings. This land is reclaimed and comprised mainly of coal ashfill (Hale 1978). Steam transmission and electric transmission lines would be contained on the property of Fraser Paper Limited, the proposed steam customer. Truck access to the site is from Mill and Bridge Street; rail sidings are located on the property. No land is available nearby for wood storage; it would be necessary to acquire land along the valley close to Route 1 for a chip storage area. However, much of the suitable land close to Route 1 and the railroad is flood-prone and zoned for resource protection.

Use of power by customer. Fraser Paper Limited has stated that it would use the proposed plant to replace existing oil-fired boilers that it presently operates (Hale 1978). Many impacts of the plant would be reduced in significance because of the elimination of impacts associated with existing oil boiler combustion.

Transport routes and traffic problems. From harvesting areas in Maine, chip vans would haul fuelwood to the plant on U.S. Route 1, the only major highway into Madawaska from other parts of the state. Route 1, which is also Main Street in Madawaska, currently suffers significant congestion, which would be made worse by the chip van traffic associated with this project. If significant quantities of wood were supplied from Canada, severe congestion would also result at the only border crossing, the International Bridge, which is currently served by two small customers stations at a constricted access point.

Air quality impacts. Madawaska and the proposed plant site are situated deep in the valley of the St. John River, which flows from west to east. The valley floor lies approximately 500 feet below the mountains to the south, and the walls are moderately steep (see Figure 4). Although there are no reliable climatic data available for Madawaska, this site appears to have poor air

FIGURE 4: MADAWASKA SITE



O *Proposed site*

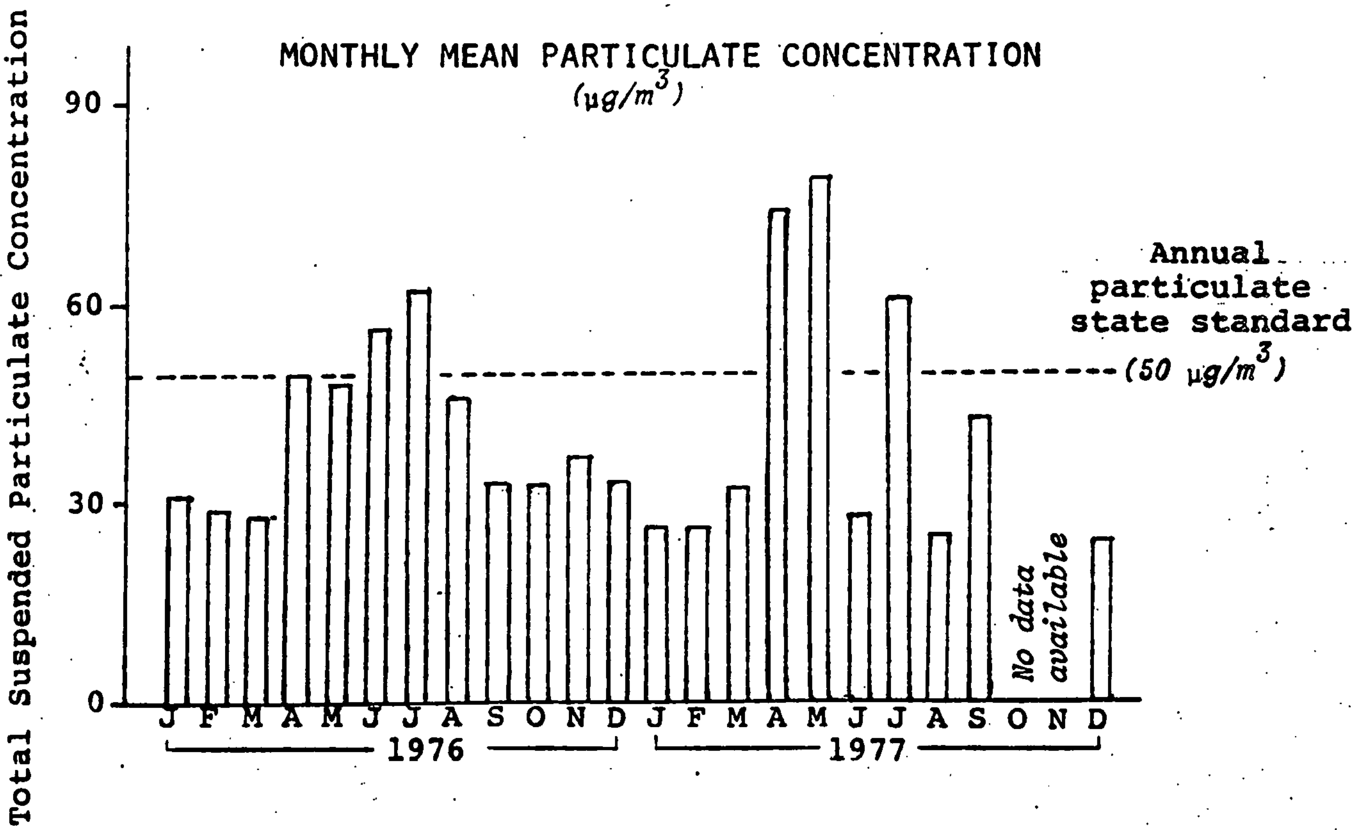
dispersion characteristics relative to the other sites because of its deeply enclosed location.

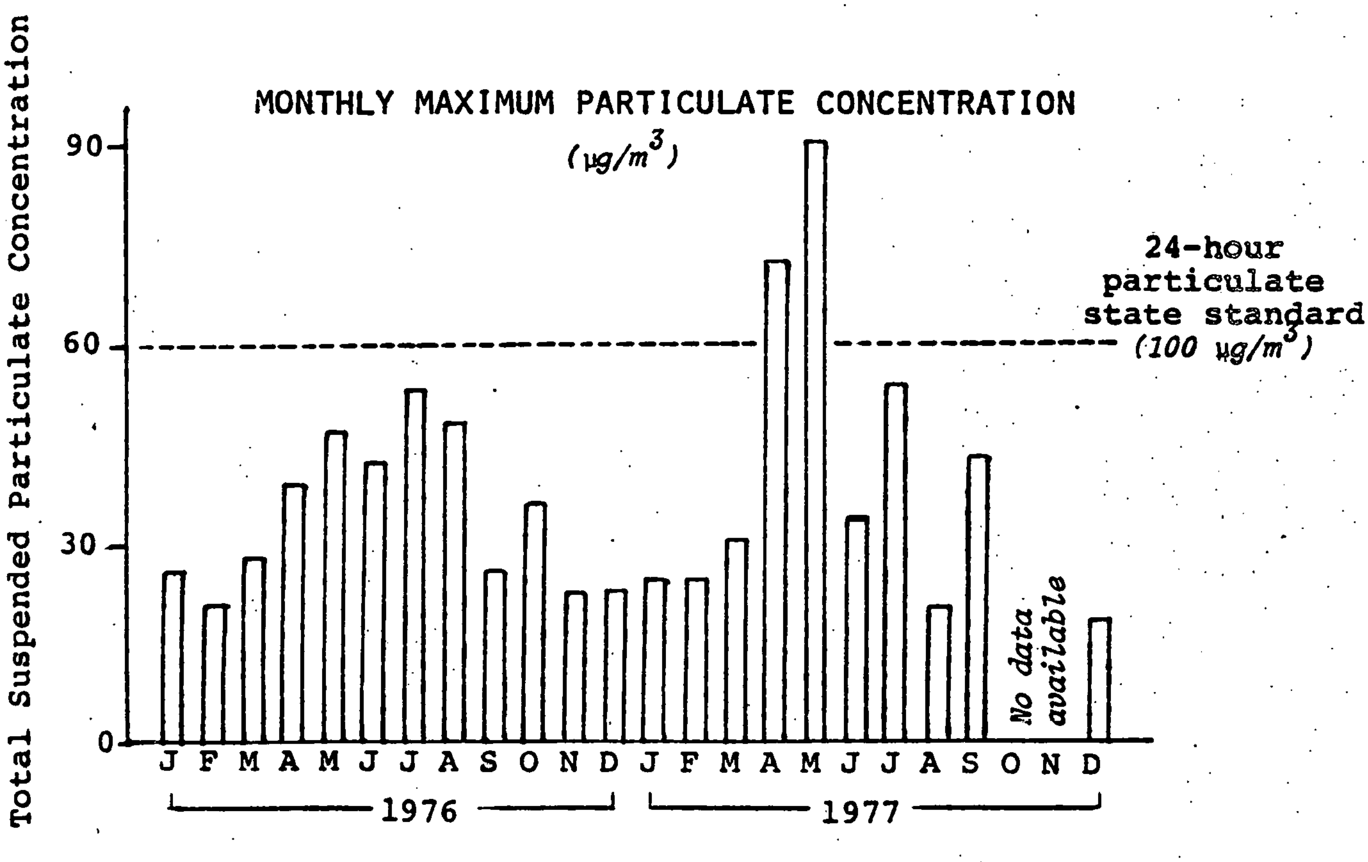
As the plant would replace existing high-sulfur, oil-fired boilers, sulfur dioxide pollution would be reduced but particulate emissions would increase. Recent measurement of the ambient particulate pollution levels indicated a number of violations of the state's 24-hour particulate standard (see Figure 5). Examination of the ratios between particulates and sulfur dioxide on days of high particulate pollution suggests that the high particulate levels may be attributed partially to fugitive dust or secondary sources at the recording site rather than plume impaction from the stacks at Fraser Paper Limited. Figure 6 shows ambient concentrations of sulphur dioxide in the area.

Because of the existence of multiple sources of particulates in the Madawaska-Edmunston area, the extent to which a wood-fired power plant would contribute to particulate levels cannot be determined without intensive modeling analysis. A preliminary assessment of the air quality impacts of the plant was made using the VALLEY air pollution impact model (see Appendix B for a description of the model). The input parameters for the model are given in Table 37. The source of the emissions was assumed to be adjacent to the Fraser Paper Company Mill and the source elevation was 520 feet above sea level. The output of the model for particulates and sulfur dioxide is given in Table 38. This table indicates the worst case impacts under a variety of conditions and operating assumptions for the four alternative sites.

In general, for Madawaska, maximum impacts of the proposed plant would occur under stable (Class 6) conditions with low wind speeds from the northwest and southeast. Highest levels of both particulates and sulfur would occur under these conditions and affect the valley walls to the south-southeast and northwest of the plant. Sulfur dioxide concentrations would be highest when the proposed plant was operating on Number 6 fuel oil in the back-up mode. Particulate impacts would be highest when wood fuel was being burned with wood drying in operation.

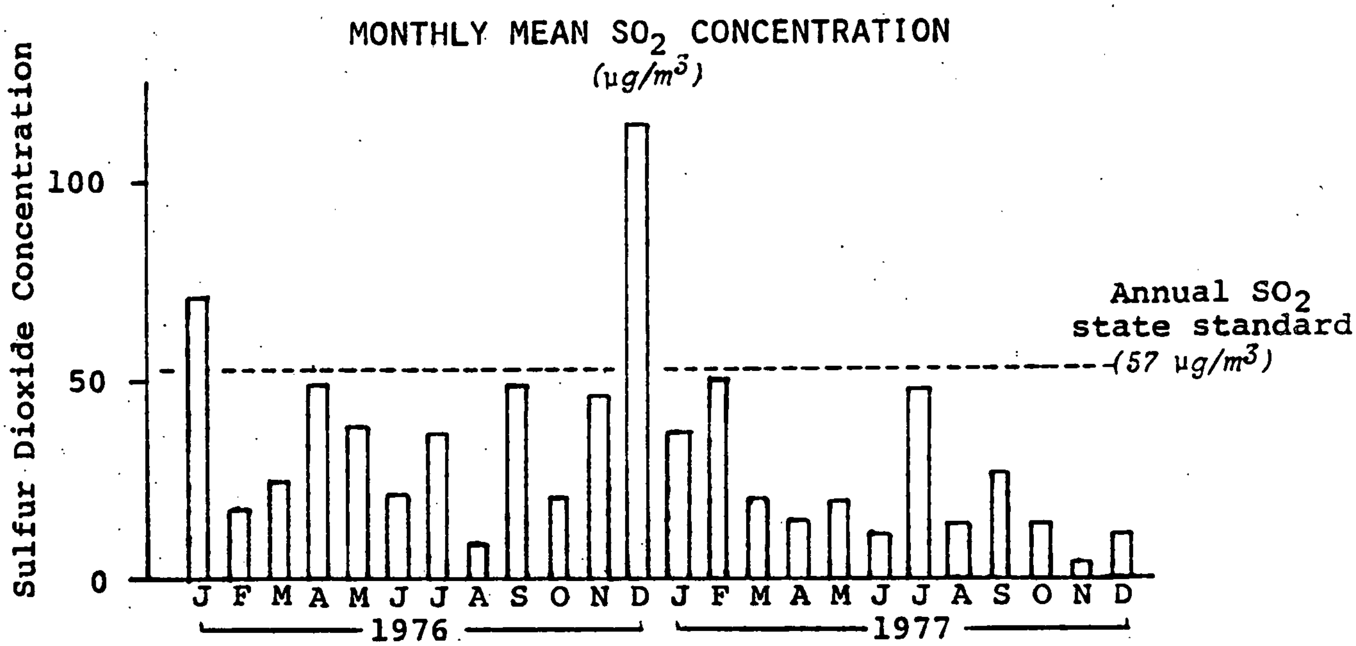
FIGURE 5: PARTICULATE CONCENTRATIONS - MADAWASKA

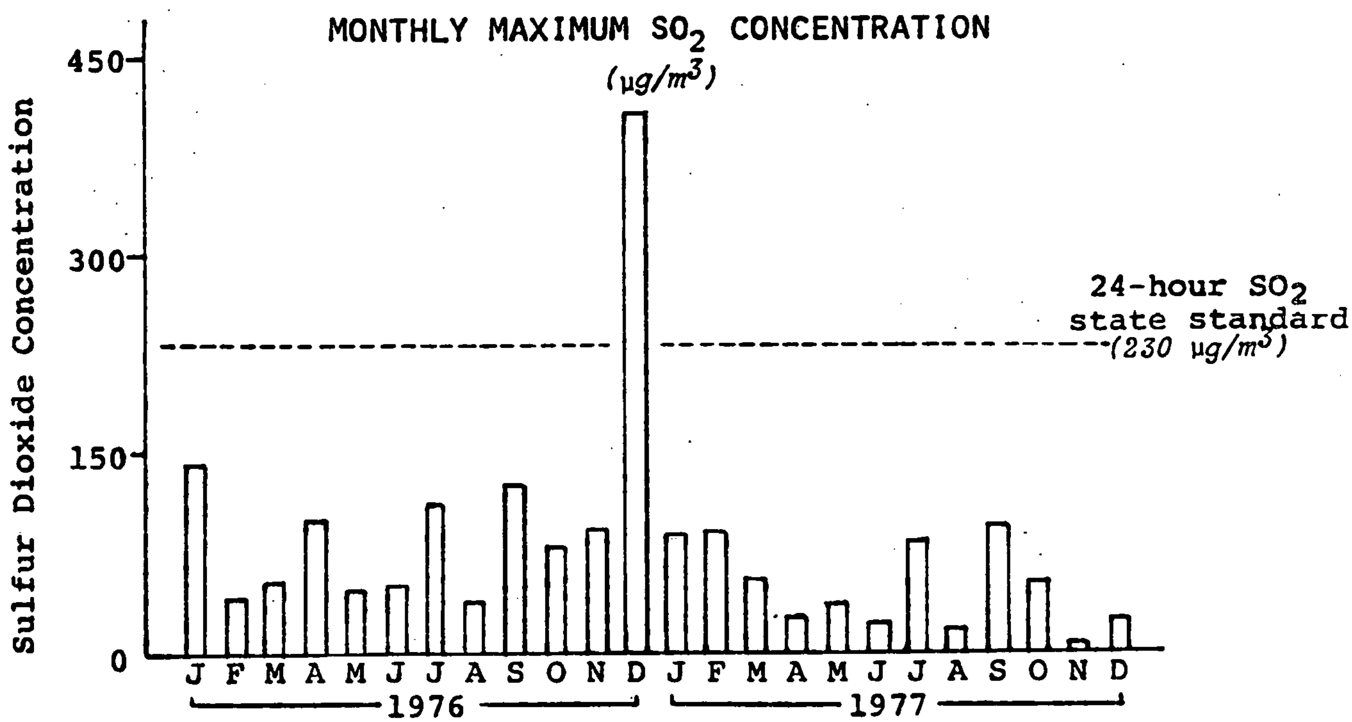




Data Source: MBAQC 1978

FIGURE 6: SULFUR DIOXIDE CONCENTRATION - MADAWASKA





Data Source: MBAQC 1978

TABLE 37: VALLEY MODEL INPUT AND PROGRAM PARAMETERS USED TO ASSESS IMPACTS OF WOOD-FIRED PLANT AT ALTERNATIVE SITES

Input Parameters

	Stack Gas Temperature	Stack Gas Volume Flow *(cu ft/minute)*	Source Strengths *(grams/second)* Particulates	Sulfur dioxide
Normal Operation: no wood drying	350°F	330,000	9.5[1]	11.0
Normal Operation: full wood drying	200°F	270,000	9.5[1]	11.0
Emergency Oil-Only operation	350°F	184,000	0.05[2]	51.1[3]

1. *Emissions estimates supplied by Rust Engineering Company of 56 lbs/hour would correspond to 7.1 grams/second. The more conservative EPA New Source Performance Standard for an oil boiler emitting 0.1 lb/10^6 Btu.*
2. *Computed from EPA 1976.*
3. *Computed from sulfur content of oil (0.7% when in emergency mode) and EPA 1976.*

PROGRAM PARAMETERS

Stack height: 300 feet above ground level
Stack inside diameter; 8'6"
Units of concentration: μg/cu m
Environment: Rural
Pollutant half-life: Infinite
Concentration averaging time: 24 hours

TABLE 38: VALLEY MODEL OUTPUT - WORST CASE AIR QUALITY IMPACTS OF THE WOOD-FIRED PLANT AT THE FOUR ALTERNATIVE SITES[1]

Site	Atmospheric Stability[2]	Wind Speed (meters/Second)	Concentrations (µg/cu m) Particulates[3]	Sulfur dioxide[4]
Madawaska	6	1	35	190
	6	2	18	91
East Millinocket	1	1	8.7	47
	1	2	5.2	27
Lincoln	1	1	9.0	48
	1	4	5.8	29
Bucksport	6	2	23	110
	6	3	20	100

1. *Data rounded to two significant figures. Highest and second highest concentrations for each site shown.*
2. *Atmospheric stability is rated 1 through 6, 1 indicating highly unstable, 4 indicating neutral, and 6 indicating highly stable.*
3. *Assumes plant operating under normal conditions, 98.5% wood and 1.5% oil with full wood drying.*
4. *Assumes plant is operating under emergency oil-only conditions, using oil with 0.7% sulfur content.*

The current existence of some violations, a high background particulate level, and the probability of poor dispersion with plume impact on the valley wall indicate that air quality impacts of the proposed plant at this site could pose a problem. The substitution of a wood-fired power plant for the present oil-burning facility would, however, improve the sulfur dioxide level in the air.

Water availability. The St. John River would provide water for the proposed plant. At Fort Kent, approximately twenty-two miles upriver from Madawaska, the St. John has a mean discharge of 9,961 cubic feet per second (cfs), and a recorded low flow of 596 cfs based on ten years of records (see Table 39). The plant's water requirements would represent 2 percent of the low flow figure. Thus, the water supply is adequate. In any case, the plant would replace an existing oil-fired facility, which currently draws comparable amounts of water from the river.

Water quality impacts. The St. John River is classified by the state of Maine as a cold water fishery. Therefore, heated water discharged into the river is not allowed to raise the river water temperataure above 68^{o}F. As the river naturally exceeds the allowable 68^{o}F maximum (Groves 1978), no further temperature increase will be permitted. Cooling towers or ponds would ensure that this standard could be met.

Landfill availability. A seventy-five acre state-approved landfill site operated by the town of Madawaska is available sixteen miles from the site.

Zoning. The probable power plant location on the Fraser Paper Company property is zoned for industry. The wood storage area has not been specified, but there is a shortage of suitable land zoned for industrial use near the Fraser site. Much of the undeveloped land along the St. John River is flood plain land and has been zoned for resource protection.

Socioeconomic impacts. Madawaska, a town of 5,594 persons (MSPO 1977) is located in Aroostook County on the Canadian border. Madawaska had an average labor force of 2,308 in the period from March of 1978 to January of 1979, with 151 persons unemployed

TABLE 39: DISCHARGE OF THE ST. JOHN RIVER AT FORT KENT

(cfs)

Month	Mean[1]	Minimum[2]
Oct	6,657	596
Nov	6,989	1,210
Dec	5,601	1,370
Jan	3,300	1,440
Feb	3,145	1,070
Mar	3,786	1,260
Apr	23,018	1,500
May	43,631	4,570
Jun	9,309	1,820
Jul	4,105	1,610
Aug	4,252	848
Sep	5,199	651
Annual[3]	9,961	651

1. *Mean = Mean discharge of each month averaged over 10-year period.*
2. *Minimum = Minimum discharge recorded during each month over 10-year period.*
3. *Annual mean = Mean of 12 monthly means. Annual minimum = Minimum discharge recorded over entire time period specified.*

Source: USGS 1967-1977.

(MDMA 1979). Because of the small local labor force, construction workers would come from outside the immediate area. This temporary increase in population would tighten local housing markets and strain retail and community services. Some impact would also occur in the Canadian town of Edmunston.

School enrollments declined from 1,929 pupils in 1970 to 1.681 in the 1977-1978 school year (Houghton 1979); consequently, the town would be able to cope with the increased school population.

The labor force of about 32 workers needed to run the boiler would be composed, in part, of those who had run the oil boilers at Fraser Paper Limited. No net change in local employment or expenditures would be expected to result from the operation of the new boiler and no change in indirect employment or income would occur (see Appendix E).

The total assessed property value of Madawaska is $99,843, 390, with a property tax rate of $25 per $1,000 at 56 percent assessment (Madawaska 1979). To obtain the same amount of revenue, the local property tax rate could be lowered to $16 per $1,000 if the plant were constructed or a wider variety of community services could be obtained at the current tax rate.

If the plant were located at Madawaska, some wood would undoubtedly be harvested in Canada. Thus, Maine would share the direct and indirect economic benefits of harvesting with that country. While these benefits would be shared in rough proportion to the amount of wood harvested on either side of the border, it is also likely that some Canadian loggers would find harvesting employment in Maine. Hence, the direct and indirect socioeconomic benefits from harvesting described in Appendix E would be smaller for the state of Maine if the proposed plant were located in Madawaska. Similarly, the costs to the state for social services and road maintenance needs resulting from this project would also be somewhat lower.

Fuelwood supply impacts. Although fuelwood harvesting areas have not been located in detail, the wood supply from Maine would come mainly from the west and southwest of Madawaska as the region to the south and southeast is dominated by agriculture. The harvesting impacts in this area would probably not be significantly different from those in the Millinocket, Lincoln, or Bucksport regions although over half of the area within a fifty mile radius of the proposed Madawaska site lies in Canada. The established pulpwood supply areas for the Edmunston-Madawaska mill complex are mainly in Canada.

The forests of northern Maine are dominated by spruce/fir stands, which are under increasing pressure for pulpwood production. The forest lands are mainly held in large ownerships by companies producing commercial sawlogs and pulpwood. Within the spruce/fir stands are smaller but significant amounts of northern hardwoods, which at present are of poor quality and of less economic value to the pulp and paper industry than the spruce and fir. Harvesting wood for energy production would almost certainly involve both hardwood and softwood forest types and may involve integrated operations with pulp and timber harvesting that would lead to more complete utilization of the wood from existing logging operations. In the spruce/fir forests even-age management and clearcutting are frequently the preferred managment practice for pulpwood production.

The impacts of harvesting fuelwood in these areas will depend on the management practices adopted. It seems likely that the creation of a new market for low-quality wood in this region will result in increased use of clearcutting as part of a management strategy to convert hardwood stands to spruce, which would increase the use of even-aged management and single-species stands. In some instances, the market for low-quality wood created by this project would also stimulate increased timber stand improvement in both hardwood and softwood stands. With both clearcutting and timber stand improvement operations, increased mechanization and more complete wood removal from the forest would ensue. Improperly conducted, both techniques could lead to increased soil erosion, larger volumes of water runoff, severe water quality impacts, and aesthetic deterioration. These impacts are typically more adverse with clearcutting procedures though well-designed harvest operations minimize their severity (see Appendix D).

Potential harvesting impacts in Canada have not been assessed; however, they will be generally similar to those in Maine.

Large supplies of bark and wood residue are available in the area; their use in this plant would reduce current landfill problems and the use of open bark burners (cone burners) which cause high levels of particulate air pollution.

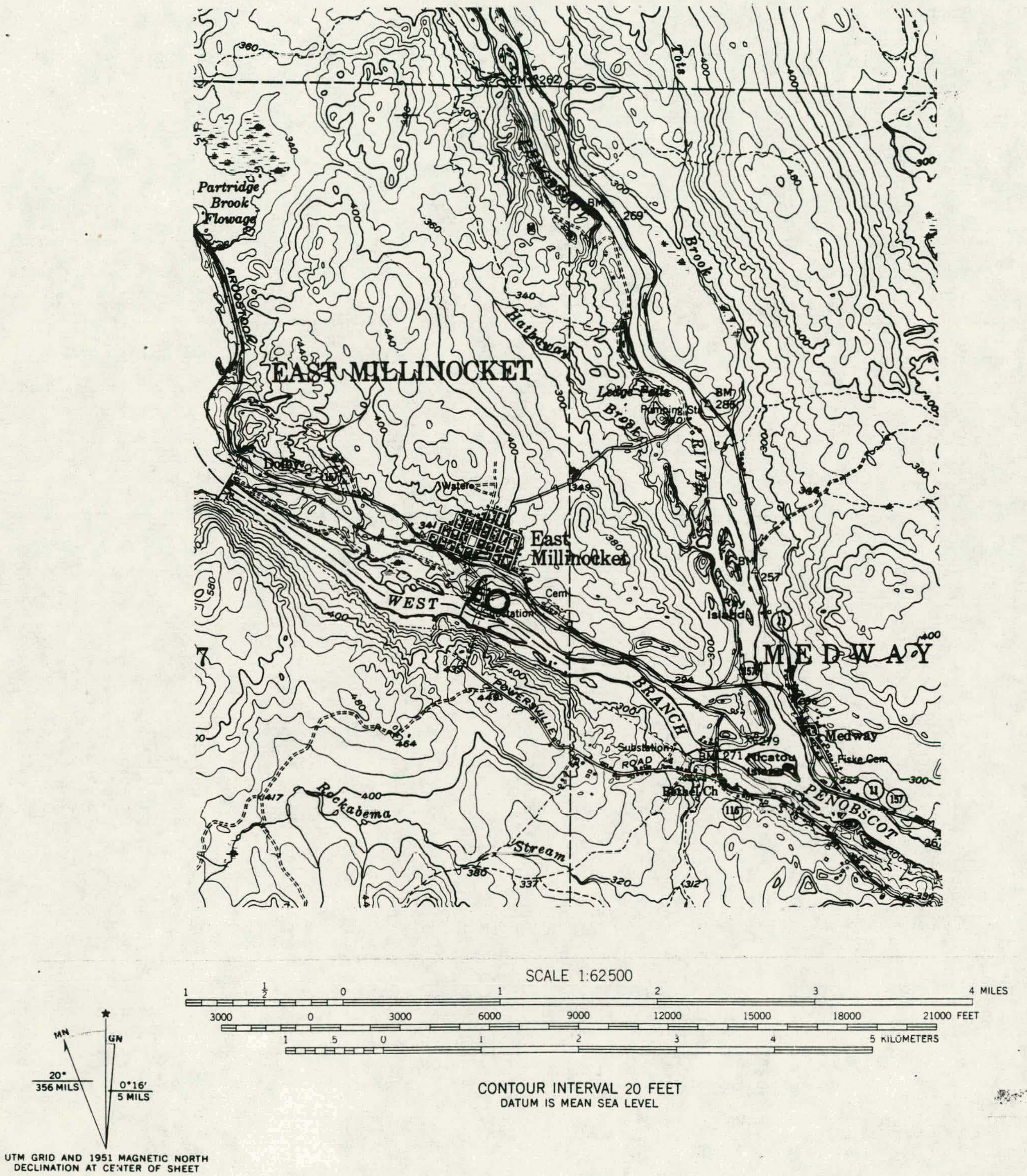
Summary. The difficulty of finding a location near Fraser Paper Company for wood storage would create a severe problem at this site. The suitability of a coal ash landfill area for the power plant site is also open to question and would require additional detailed analysis. The poor dispersion characteristics of the valley, could also pose air pollution complications. Traffic congestion in Madawaska, on Route 1 and across the International Bridge would be sufficiently serious to cause public concern.

East Millinocket

Location. The site considered would be adjacent to the Great Northern Paper Company Mill #2 in East Millinocket. The site is bounded by Route 11 and the West Branch of the Penobscot (see Figure 7).

Site characteristics. The site lies in the valley of the West Branch of the Penobscot River; it is immediately adjacent to the present Great Northern oil-fired boiler on its north side and approximately 2,000 feet from Route 11. The area at present is used as a parking lot. Minor rerouting of private plant driveways and relocation of another small parking lot would be necessary to accommodate the proposed plant, although no demolition of buildings would be required. At present, no vegetation exists on the site, which is used entirely for industrial purposes. Wood chip storage would be located at the northern end of the Great Northern yard in an area currently used for cordwood storage. Access to the chip storage area would be from Main Street (Route 11), via the present plant entrance (Mill Road). Steam and electric power lines could be contained on the Great Northern site.

FIGURE 7: MILLINOCKET SITE



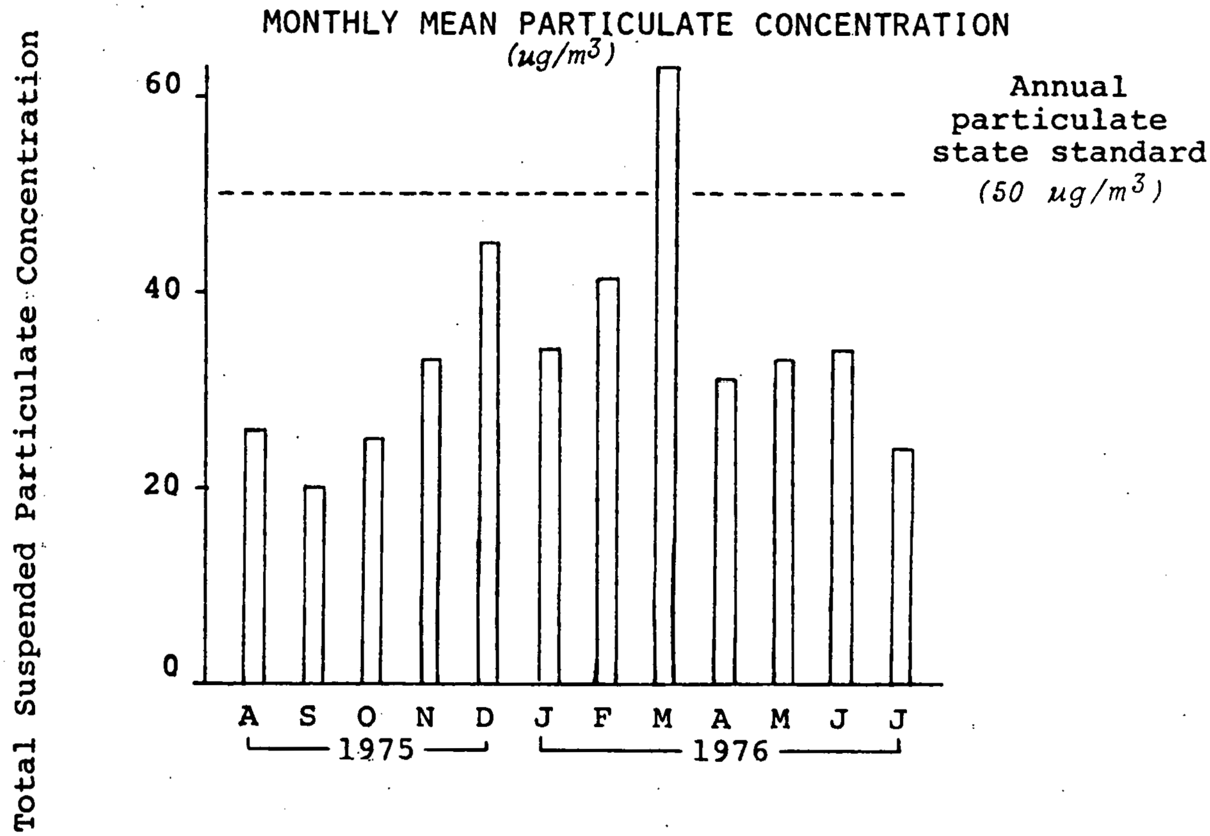
O *Proposed site*

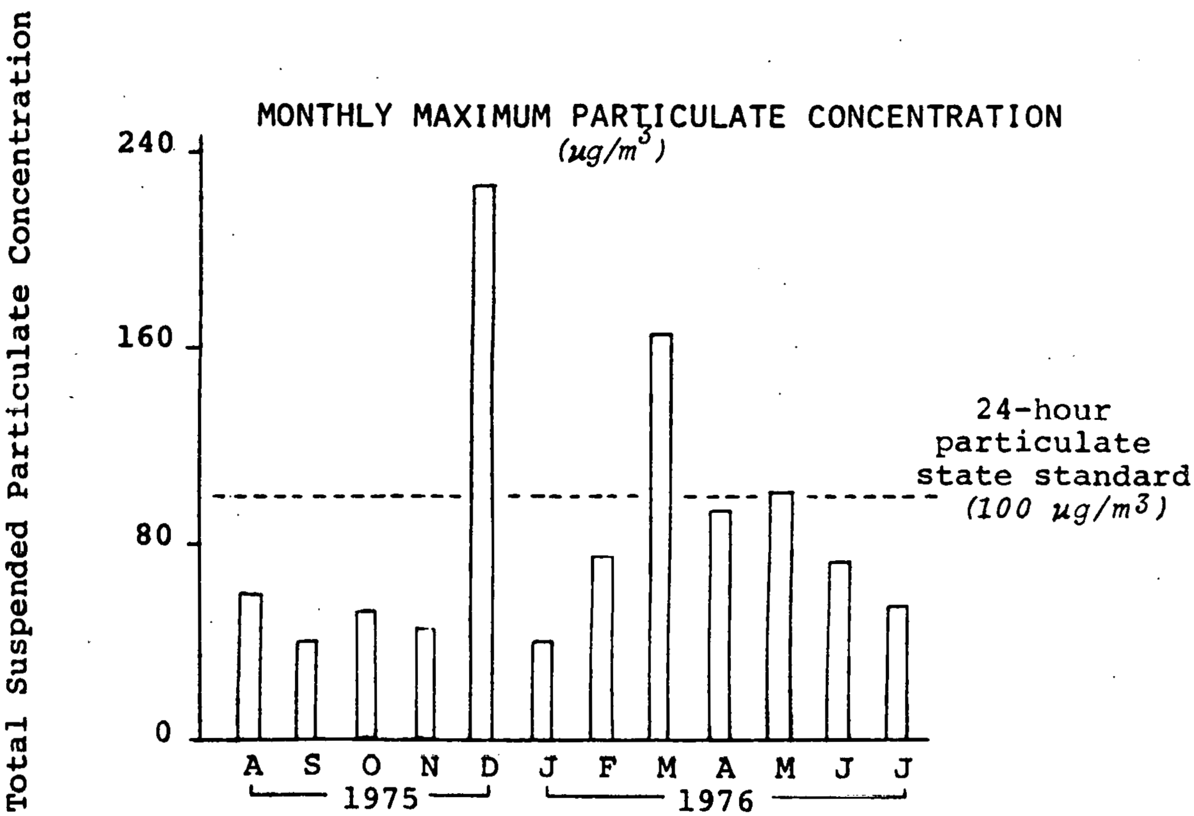
Use of power by customer. Great Northern has indicted that it would to use the steam and electric power generated by the plant to replace existing oil-fired boilers that they currently operation (Reardon 1978). No expansion of the paper company's manufacturing capacity is planned in conjunction with this project. The impacts of the wood-fired power plant would be offset by the removal of impacts associated with the operation of oil-fired boilers that will be shut down.

Transport routes and traffic problems. Fuel would arrive at the plant from all directions: from the west on Route 11, the north and south on Interstate 95 via Route 11, and the east on Route 157. All traffic would converge on Main Street (Routes 11 and 157) for access to the plant site (see Figure 7). The town of East Millinocket is situated primarily to the north of Route 11, and therefore would not be significantly impacted by trucks on route to the plant. The only area where serious traffic problems might occur is in the town of Millinocket, where traffic from the private haul road of Great Northern is routed through the center of town on Route 15. This route, however, would probably accommodate no more than one-quarter of the total truck traffic, depending on harvesting plans. Traffic problems should be relatively minor at this site.

Air quality impacts. Air quality Region 109 and East Millinocket are legal attainment areas for particulates, sulfur dioxide, carbon monoxide, and nitrous oxides, but exceed primary standards for photochemical oxidants (ozone). In this respect, however, East Millinocket is in the same position as all the other sites. Monitoring of particulates and sulfur dioxides in 1975 and 1976 (see Figures 8 and 9) shows that the town meets annual ambient air quality standards. There have been three occasions on which the maximum 24-hour particulate standards have been exceeded, however, and one on which the 24-hour sulfur dioxide standard was exceeded. The generally open topography of the Penobscsot Valley at East Millinocket provides good air dispersion. The substitution of wood for oil as an energy source would reduce ambient

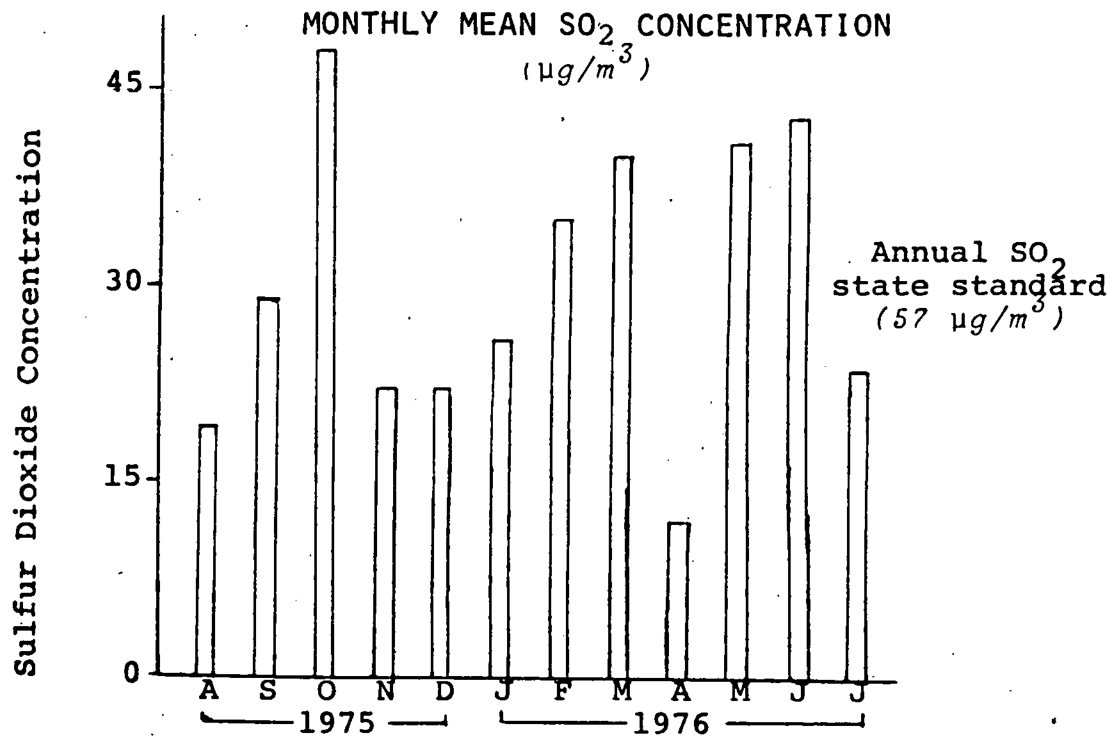
FIGURE 8: PARTICULATE CONCENTRATION - E. MILLINOCKET

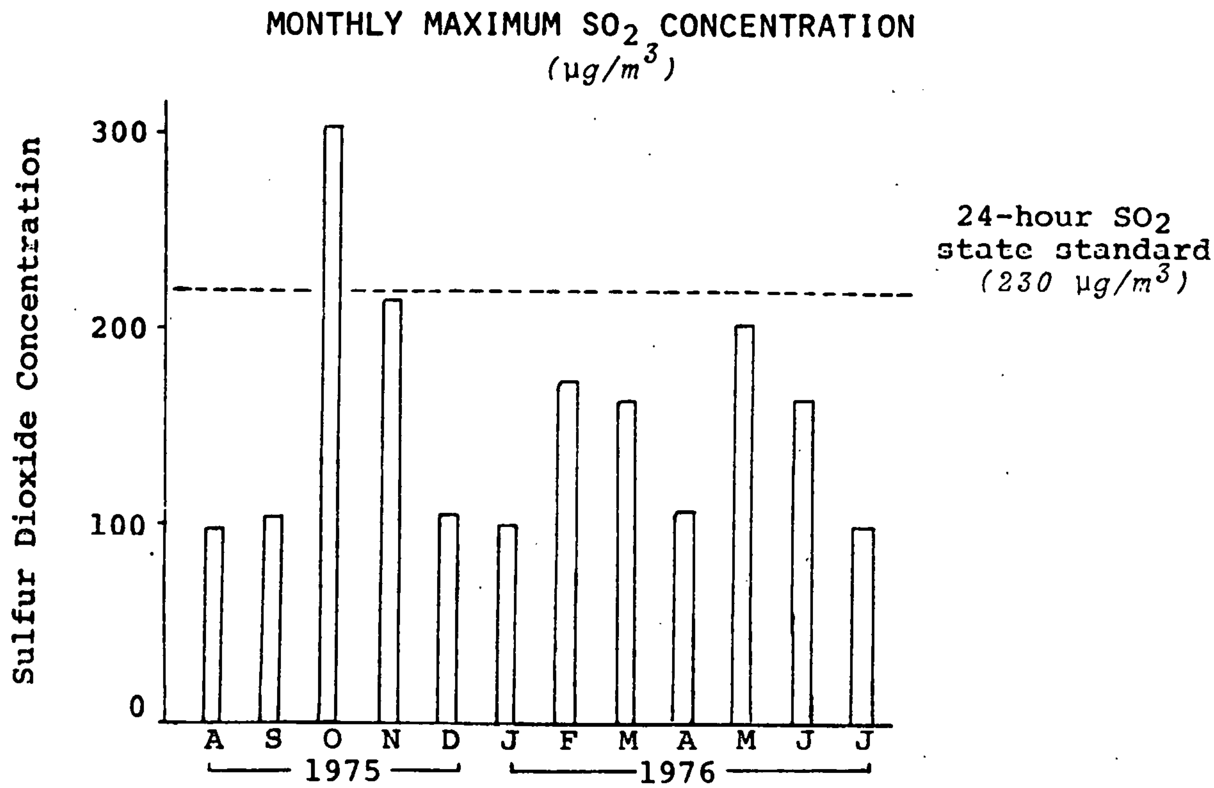




Data Source: Welch 1978

FIGURE 9: SULFUR DIOXIDE CONCENTRATION - E. MILLINOCKET





Data Source: Welch 1978

sulfur dioxide levels although it would increase particulate pollution.

A preliminary assessment of the air quality impacts of the proposed plant was made using the VALLEY air pollution impact model. (See Appendix B for a description of the model); the input parameters for the model for all alternative sites were given in Table 37. For East Millinocket the source of the expected emissions was assumed to be adjacent to the Great Northern Paper Company mill #2; the source elevation was 300 feet above sea level. The worst case impacts predicted by the model for particulates and sulfur dioxide at East Millinocket were shown in Table 38. In general, for East Millinocket, maximum impacts occur under highly unstable (Class 1) conditions, with low wind speeds. Highest levels of both particulates and sulfur dioxide would occur under these conditions and impact the area to the south-southwest and north of the plant. Sulfur dioxide concentrations are highest when the plant is operating on number 6 fuel oil in the back-up mode. Particulate concentrations are highest when wood fuel alone is being burned.

Water availability. The water source for this site is the West Branch of the Penobscot River, the flow of which is controlled year-round by an extensive series of upstream dams owned and operated by Great Northern. The average daily flow is 2,800 to 2,900 cubic feet per second (Welch 1978). As the flow is carefully controlled, the flow seldom drops below this level; no low-flow information was available for a site on the West Branch. However, a U.S. Geological Survey gauging station on the Penobscot downstream at Mattawamkeag reported the minimum daily flow for the last ten-year period to be 2,000 cubic feet per second (see Table 40). This flow also includes the volume of the East Branch. Based on the relative sizes of the East and West Branch watersheds, the ten-year minimum flow on the West Branch at East Millinocket is estimated to be approximately 1,500 to 1,800 cfs. The wood-fired power plant's water requirements equal .6 to .8 percent of this flow. As the wood-fired power plant will replace existing oil-fired boilers of roughly the same capacity, no signi-

TABLE 40: DISCHARGE OF THE PENOBSCOT RIVER AT MATTAWAMKEAG

(cfs)

Month	Mean[1]	Minimum[2]
Oct	4,199	2,740
Nov	4,988	2,970
Dec	5,485	2,380
Jan	4,409	2,200
Feb	4,852	2,500
Mar	5,307	2,000
Apr	9,939	3,260
May	13,993	3,940
Jun	6,455	3,050
Jul	5,083	2,300
Aug	4,633	2,800
Sep	4,575	2,600
Annual[3]	6,160	2,000

1. Mean = Mean discharge of each month averaged over 10-year period.
2. Minimum = Minimum discharge recorded during each month over 10-year period.
3. Annual mean = Mean of 12 monthly means. Annual minimum = Minimum discharge recorded over entire time period specified.

Source: USGS 1967-1977.

ficant additional drain on the waters of the West Branch will occur.

Water quality impacts. The Penobscot River at this point is classified as a cold water fishery (Groves 1978) and therefore state regulations prohibit artificially raising the temperataure above 68° F. No water temperature data is available at this site. Several design options would enable the facility to meet required standards.

Landfill availability. A state-licensed landfill owned by Great Northern is available two miles from this site. Great Northern dumps one hundred dry tons per day at present, and the landfull could accommodate an additional ten tons per day (Reardon 1978).

Zoning. This site is zoned for industry.

Socioeconomic impacts. The impacts on the local community would be shared by the towns of East Millinocket and Millinocket, both of which have experienced substantial construction acitivity in recent years. The labor force in East Millinocket averaged 1,021 during the period from March of 1978 to January of 1979, with 511 persons unemployed (MDMA 1979). The 240 construction workers needed would for the most part come from other areas of the state.

If construction worker availabiliity were low in the Penobscot County area at the time of construction and workers were not available within commuting distance, some sort of temporary housing facility would have to be established. The towns of East Millinocket and Millinocket would not be able to supply enough temporary housing. A temporary increase in population would create a strain on existing community services. Educational services should be least affected since schools experienced declining enrollments from 1,444 in 1970 to 1,325 in 1979 (Savage 1979). Construction probably would cause a temporary boom-town effect.

Most of the positions created by the proposed wood facility would be filled by workers who had previously run oil boilers at Great Northern. The number of those employed in jobs indirectly created by the operation of the boiler is small and should come from the immediate area.

A significant impact associated with the operation phase would be the increase in total assessed property value of the town by about $60 million. East Millinocket currently has a total assessed property valuation of $80,128,820 with a property tax rate of $20 per $1,000 at 100 percent assessment rate (E. Millinocket 1979). The proposed power plant would allow the town to lower the property tax rate to $12 per $1,000 and still receive the same revenue.

Within a fifty-mile radius from East Millinocket and Lincoln are portions of Hancock, Penobscot, Piscataquis, Aroostook, and Washington Counties. There are over 350 logging firms in the area (MDC undated). Some of the harvesters needed for this plant's operation would be currently unemployed persons in the area; others would be Canadian bonded or visa workers; others would be persons presently in other occupations, particularly heavy equipment operators. Any immigration to fill these positions would be dispersed over a wide area (over 7,800 square miles) and would have a minimal impact on population. Indirectly created jobs, approximately seventy, should also be primarily filled by persons in the area, as would the jobs in trucking.

Fuelwood supply impacts. East Millinocket lies in the middle of the northeast's largest forested region, an area dominated by spruce/fir forests and consisting almost entirely of large landownerships held by companies interested in marketing timber products. Currently, no significant market for low-grade hardwood produced in this region exists. The impacts of harvesting in this region would be generally similar to those described for Madawaska except wood is not expected to be harvested in Canada. Large amounts of bark and wood residue are available in this region; their use would constitute an important environmental benefit by alleviating the need for landfills and open cone burners.

Summary. Impacts associated with the operation and harvesting for the proposed plant, if it were located at East Millinocket, would be relatively minor. Some traffic congestion could occur in Millinocket from the transport of fuelwood through that town. Construction impacts could be somewhat disruptive and cause a temporary housing shortage and boom-town atmosphere.

Lincoln

Location. The site considered would be located on the property of Lincoln Pulp and Paper Company, the potential steam customer, between Lincoln Village and the Penobscot River (see Figure 10).

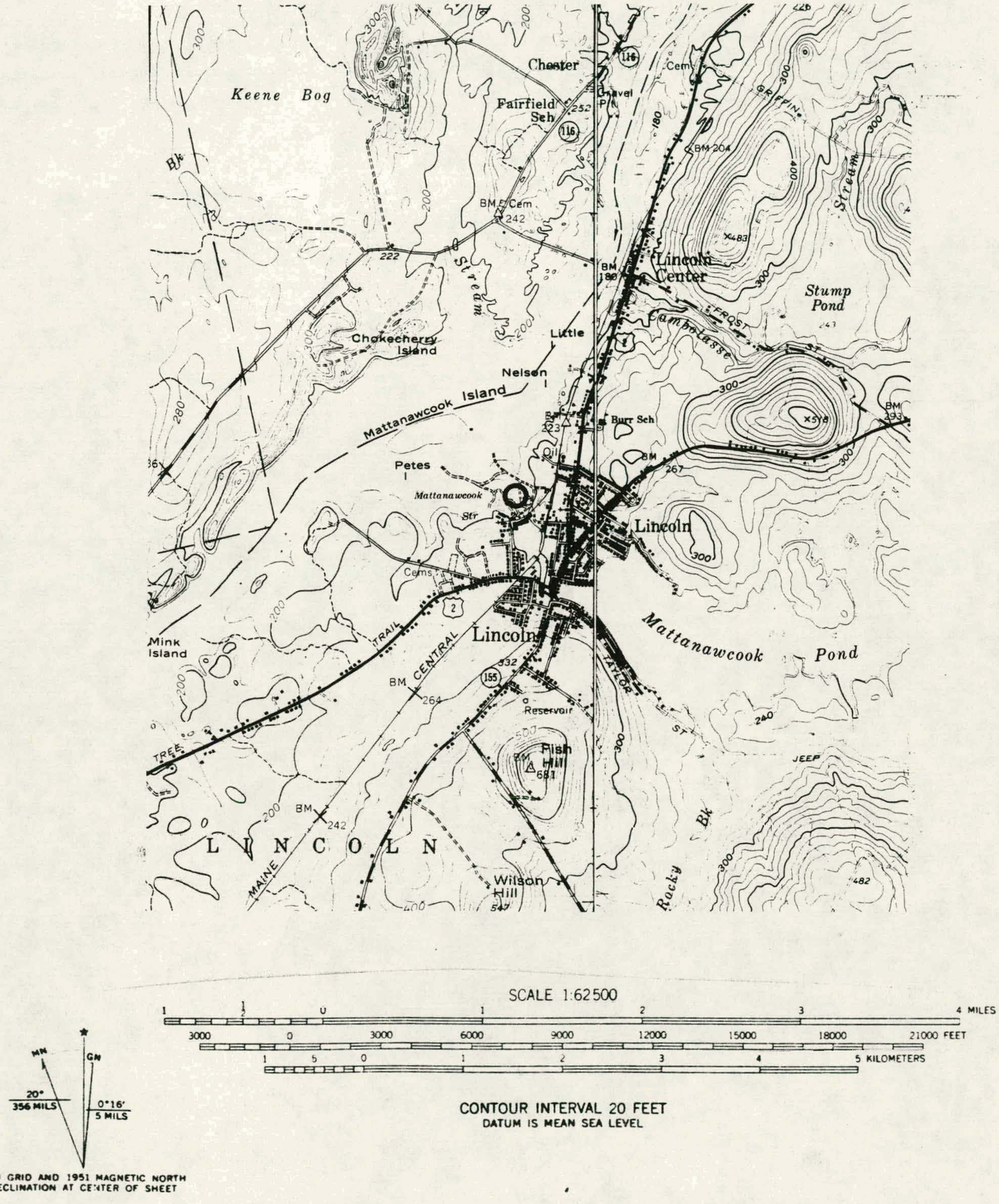
Site characteristics. Although the proposed location of the power plant would probably be close to the pulp mill, the exact sites for the boiler and chip storage piles have not been specified. There exists the possibility that the site would lie in the flood plain. Access to the site by road would probably be through existing entrances on Depot Street and on an access road off West Broadway (Route 2). Transmission lines for steam and electric power would be contained on the property of the Lincoln Pulp and Paper Company.

Use of power by customer. Lincoln Pulp and Paper Company would use the steam provided by the plant to expand its pulp and paper-making operations. It would not shut down existing boilers.

Transport routes and traffic problems. Lincoln is centrally located in a major forested area: wood supplies are expected to come from all directions. Fuelwood would arrive along from the north and south with connections to Interstate 95, and along Route 6 from the east and west. Truck traffic converging on Lincoln would cause traffic problems at a number of points. These include the intersections of Depot Street and Route 2, Fletcher Street and West Broadway (Route 2), Main Street and Lee Street (Route 6), and Main Street and West Broadway (see Figure 10). In many cases, these problems could be greatly reduced by minor road realignments, some of which are currently in progress. Truck scheduling to avoid Main Street would greatly reduce the traffic problems.

Air quality impacts. The topography surrounding the Lincoln site is gentle and air dispersion appears to be no worse than at the other valley sites considered. The ambient air quality in

FIGURE 10: LINCOLN SITE



O *Proposed site*

TABLE 41: PARTICULATES AND SULFUR DIOXIDE CONCENTRATIONS IN LINCOLN, MAINE

Location	Year	No. of Observations	Highest Value[1]	Highest of 2nd Highest Values[2]	Annual Mean[3]	No. Exceedences Federal Primary[4]	No. Exceedences 24-Hr Std Secondary[5]	No. Exceedences Maine 24-Hr Std[6]
				Particulates (μg/cu m)				
Mattanawcook Academy	1973	34	85	74	31*	0	0	0
	1974	58	135	131	36	0	0	4
	1975	57	110	104	34	0	0	2
	1976	56	162	101	35	0	1	2
	1977	40	119	115	26**	0	0	2
	1978	27	66	64	34*	0	0	0
Lincoln Vocational Educational Building	1977	18	119	75	35*	0	0	1
	1978	24	104	91	44*	0	0	1
Lincoln Post Office	1977	16	169	69	42*	0	1	1
	1978	26	105	100	53*	0	0	1
				SULFUR DIOXIDE (μg/cu m)				
Mattanawcook Academy	1973	34	28	28	11	0	0	0
	1974	61	63	38	12	0	0	0
	1975	56	118	40	10	0	0	0
1976	1976	59	106	68	12	0	0	0
	1977	42	64	46	8	0	0	0
	1978	20	32	31	9	0	0	0

1. *Highest concentration recorded over one year at any one of the locations for 24-hour averaging period.*
2. *Highest of the second-highest concentrations recorded over one year at any one of the locations for a 24-hour period.*
3. *Annual particulate standards are expressed as a geometric mean; sulfur dioxide standards are expressed as an arithmetic mean. * indicates data do not meet EPA guidelines for accuracy.*
4. *National primary standards determine the levels of air quality necessary, with an adequate margin of safety, to protect the public health. Federal primary 24-hour standard for particulates = 260 μg/cu m and for sulfur dioxide = 365 μg/cu m.*
5. *National secondary standards determine the levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. Federal Secondary 24-hour Standard for particulates = 150 μg/cu m. There is no federal secondary 24-hour standard for sulfur dioxide.*

Lincoln has been monitored for sulfur dioxide and total suspended particulates since 1973. In addition, ozone and nitrogen dioxide were monitored for four and three weeks each in the fall of 1978.

The air quality for particulates and sulfur dioxide in Lincoln is summarized in Table 41. Particulates present a problem in Lincoln. While the federal primary 24-hour standard has not been exceeded since 1973, the strict Maine 24-hour standard has been exceeded at least fifteen times in that period. Annual concentrations, however, are quite low. Sulfur dioxide levels are far below standards for any averaging time.

Ozone concentrations monitored during one week in August did violate the old national ambient air quality standards for ozone (160 micrograms per cubic meter:$\mu g/m^3$) for a total of thirteen hours (see Table 42). Unfortunately, an incorrect setting on the recorder prohibited recording values greater than 200 $\mu g/m^3$ (which were observed, and therefore it is unknown whether or not the new standard of 235 $\mu g/m^3$ would have been exceeded. In September, the single high hourly value was only 125 $\mu g/m^3$. As ozone levels have not been monitored during an entire summer, maximum concentrations are not known. Nitrogen dioxide concentrations as observed in September of 1978 only, averaged about 20 $\mu g/m^3$, or 20 percent of the annual mean nitrogen dioxide national ambient air quality standard.

The Maine Department of Environmental Protection has classified Lincoln as an attainment area for sulfur dioxide, nitrogen dioxide, particulates, and carbon monoxide, and as in a nonattainment area (the Downeast Air Quality Control Region) for ozone (DMEP 1979).

A preliminary assessment of the air quality impacts of the plant has made using the VALLEY air pollution impact model (see Appendix B for a description of the model). The input parameters for the model for all the alternative sites were given in Table 37. For Lincoln, the source of the emissions was assumed to be adjacent to the Lincoln Pulp and Paper Company Mill; the elevation of the plant is 220 feet above sea level. The worst-case impacts predicted by the model for sulfur dioxide and particulates

TABLE 42: OZONE AND NITROGEN DIOXIDE CONCENTRATIONS IN LINCOLN, MAINE[1]

Ozone
(µg/cu m)

Date	No. Days Observed	Mean[2]	Range[3]	Hours Exceeding Federal 24-Hour Std Old[4]	New[5]
Aug. 1978	6	80	0-200	13	0
Sept. 1978	21	35	0-125	0	0

Nitrogen Dioxide
(µg/cu m)

Date	No. Days Observed	Mean	Range
Sept. 1978	21	22	10- 70

1. *At Mattanawcook Academy location.*
2. *Arithmetic mean*
3. *Recorder setting precluded recording ozone concentrations higher than 200 µg/cu m.*
4. *Old standard (before January 1979) = 160 µg/cu m.*
5. *New standard = 235 µg/cu m.*

at Lincoln were shown in Table 38. In general, for Lincoln, maximum impacts occur under highly unstable (Class 1) conditions with low wind speeds. Highest levels of both particulate and sulfur dioxide concentrations occur under these conditions and impact the area immediately southwest of the plant. Sulfur dioxide concentrations are highest when the plant is operating on Number 6 fuel oil in the back-up mode. Particulate concentrations are highest when wood fuel alone is being burned with wood drying in operation. Maximum impacts of particulates from the wood-fired power plant are predicted to be weaker than those for any other alternative site. However, these impacts would be in addition to present levels, as existing boilers will continue to be used at this site.

Water availability. There are two potential sources of water at the Lincoln site: the mill pond on the Mattanawcook Stream and the Penobscot River. The mill pond is the present source of water for the Lincoln Pulp and Paper Company mill. The mean discharge of the Penobscot based upon data from Mattawamkeag is 6,160 cubic feet per second (cfs), and the recorded low flow is 2,000 cfs (see Table 40). The wood-fired power plant's water requirements would represent .6 percent of the recorded low flow. On this basis, an adequate supply of water is available.

Water quality impacts. The Penobscot River is classified by the State of Maine as a cold water fishery (Groves 1978), but its summer temperatures exceed the maximum acceptable level of 68°F or 20°C (see Table 43). Cooling ponds or towers will enable the standard to be met at this site.

Landfill availability. There is a landfill on the Lincoln Pulp and Paper Company site, but it is close to capacity (Linnell 1978) so another site would have to be found. There is no site available in the town of Lincoln at present, and a recent study showed that the closest possible site that meets state standards is in Hampden, over fifty miles away (Lincoln Conservation 1978).

Zoning. The proposed site is zoned for industry.

Socio-economic impacts. Lincoln had a combined labor force of 5,120 in June 1978 with an average labor force of 1,997 during

TABLE 43: TEMPERATURE OF THE PENOBSCOT RIVER AT WEST ENFIELD

(°C)

Month	Mean[1]	Maximum[2]
July	22.7	27.0
August	21.8	27.5
September	17.8	24.5

1. *Mean = Mean temperature of each month averaged over 10-year period.*
2. *Maximum = Maximum temperature recorded during each month over 10-year period.*

Source: USGS 1967-1977

the period from March of 1978 to January of 1979 with 126 persons unemployed (MDMA 1979). Construction workers in large part would have to come from other parts of the state. This temporary increase in population would create some stress on housing and local services, although Lincoln has experienced large construction operations in the recent past without serious problems. Lincoln would be able to accommodate increased school requirements because enrollments have declined from 1,678 pupils in 1970 to 1,613 in 1978. They are projected to drop to 1,598 by 1979 (Webster 1979).

Lincoln, unlike the other alternate sites, will not be closing down an oil boiler. Consequently, the persons required to run the wood boiler would be newly hired. It is likely that most would come from the Lincoln-Howell labor area, as would the small number of indirectly employed persons.

The socioeconomic impacts of harvesting would probably be similar to those described for East Millinocket.

Fuelwood supply impacts. Lincoln lies in the middle of the Northeast's largest forested area. It is a region primarily of large landownerships held by companies interested in marketing timber products. Currently, no significant market for low-grade hardwood produced in this region exists. A large amount of bark and wood residues is available in this area; their use would constitute an important environmental benefit by alleviating the need for landfills and cone burners.

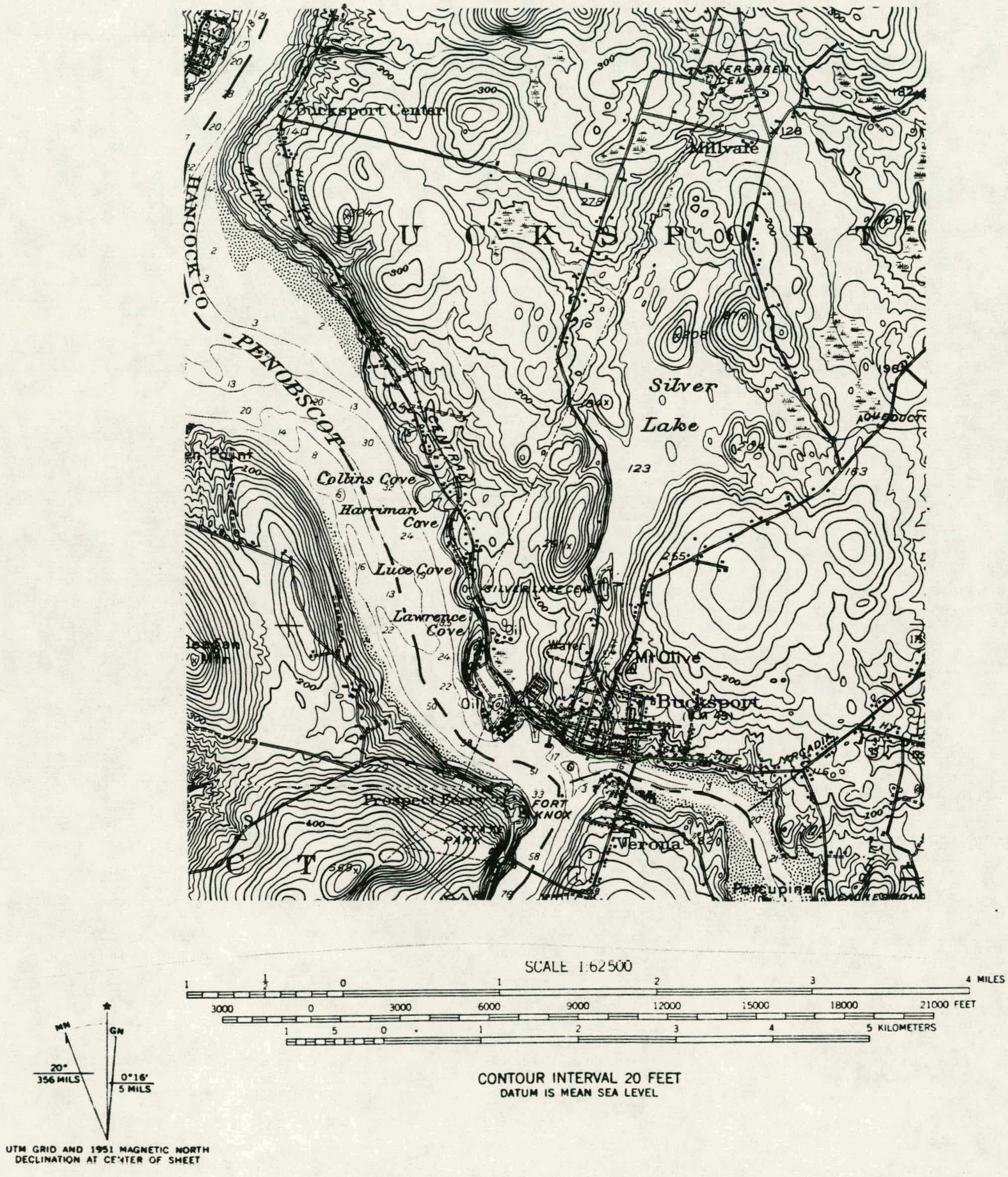
Summary. The major impacts at Lincoln would be air quality impacts, truck transport impacts, and socio-economic impacts during construction.

Bucksport

Location. A site for the wood-fired power plant has not been specified; it would probably be less than one and one-half miles north or northwest of the St. Regis Paper Company mill, the proposed steam customer (see Figure 11).

Site characteristics. As the site has not been chosen, the site characteristics cannot be assessed. The only undeveloped

FIGURE 11: BUCKSPORT SITE



Site undetermined

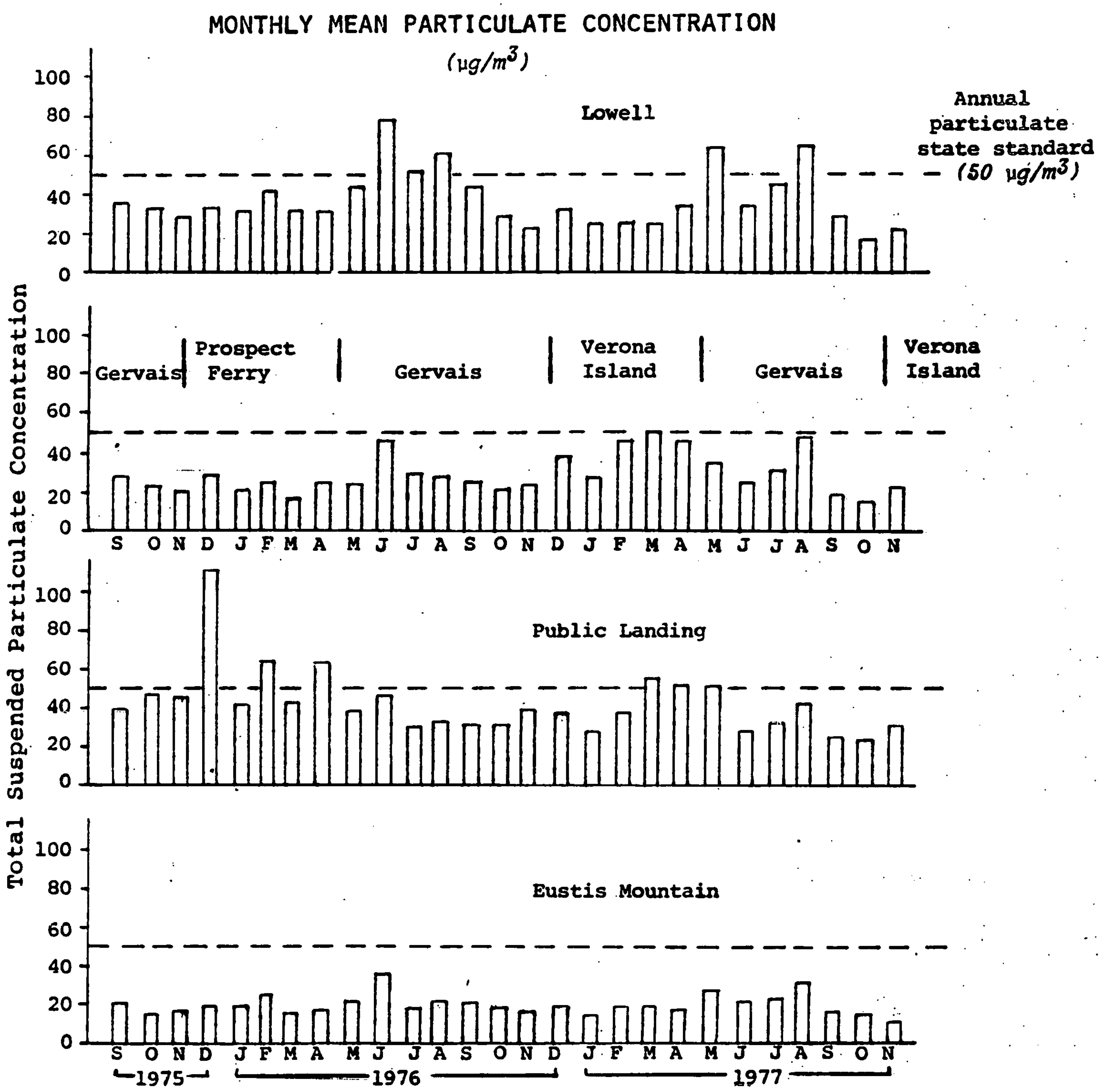
land within one and one-half miles of the paper mill is north of the plant and to the east of Route 15. This area is gently sloping and partly wooded. Several small residential developments and an oil tank farm close to Route 15 occupy adjacent sites. Depending on the choice of site, rights of way or easements for the steam and electric transmission lines would be required. These might have to pass through residential areas and the tank farm, and cross Route 15 and the Maine Central railroad tracks.

Use of power by customer. St. Regis Paper Company has indicated that it would use the steam from the proposed plant to replace existing oil-fired boilers and the electricity to replace electric power purchased from Central Maine Power Company. Many impacts of the plant would be offset by the elimination of the impacts associated with existing oil boiler combustion.

Transport routes and traffic problems. The wood supply areas for the proposed plant would be generally similar to those from which the St. Regis Paper Company mill obtains its pulpwood. Currently, most cordwood arrives in Bucksport via U.S. Route 1 from Washington and Hancock Counties. Some additional wood for a wood-fired power plant in Bucksport would undoubtedly come as residues or low-quality hardwood via state Route 15 from north of the Bangor area. All chip vans arriving from eastern Maine and most arriving from western Maine would reach the probable Bucksport site by traveling westbound on Main Street through the village of Bucksport. This narrow, small-town, commercial main street is severely congested during summer months when tourists frequent the village, and is moderately congested during the "off-season" (Lowell 1978; Bucksport Conservation 1978). The intersection of U.S. Route 1 and Route 15, where the only major supermarket in Bucksport is located, also experience serious congestion and traffic delays. Additional truck traffic associated with the proposed project would increase this congestion and could necessitate a bypass.

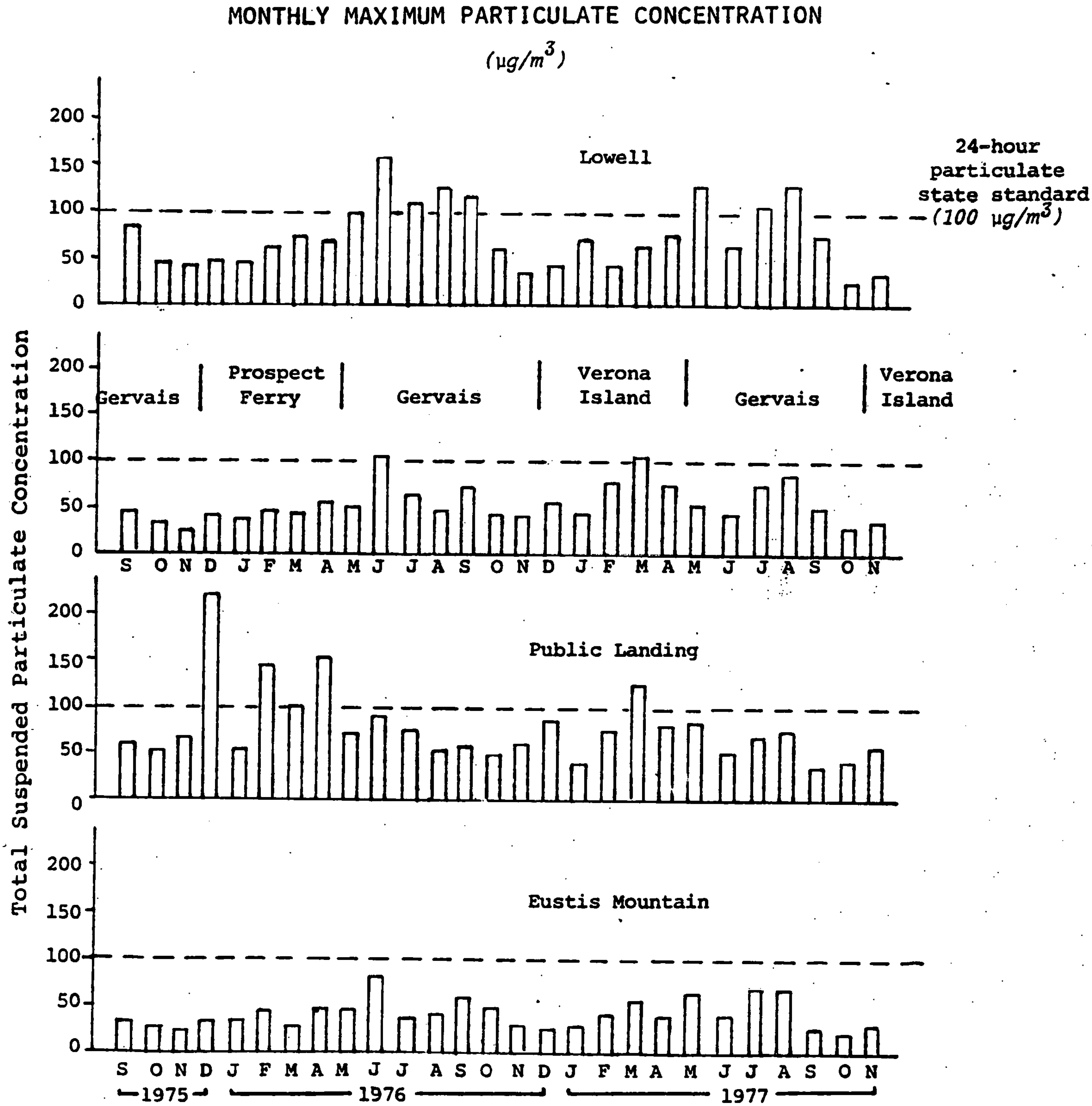
The impact of chip vans from Bangor and Brewer on Route 15, a narrow road that winds through several small towns, could also be adverse.

FIGURE 12: PARTICULATE CONCENTRATIONS - BUCKSPORT



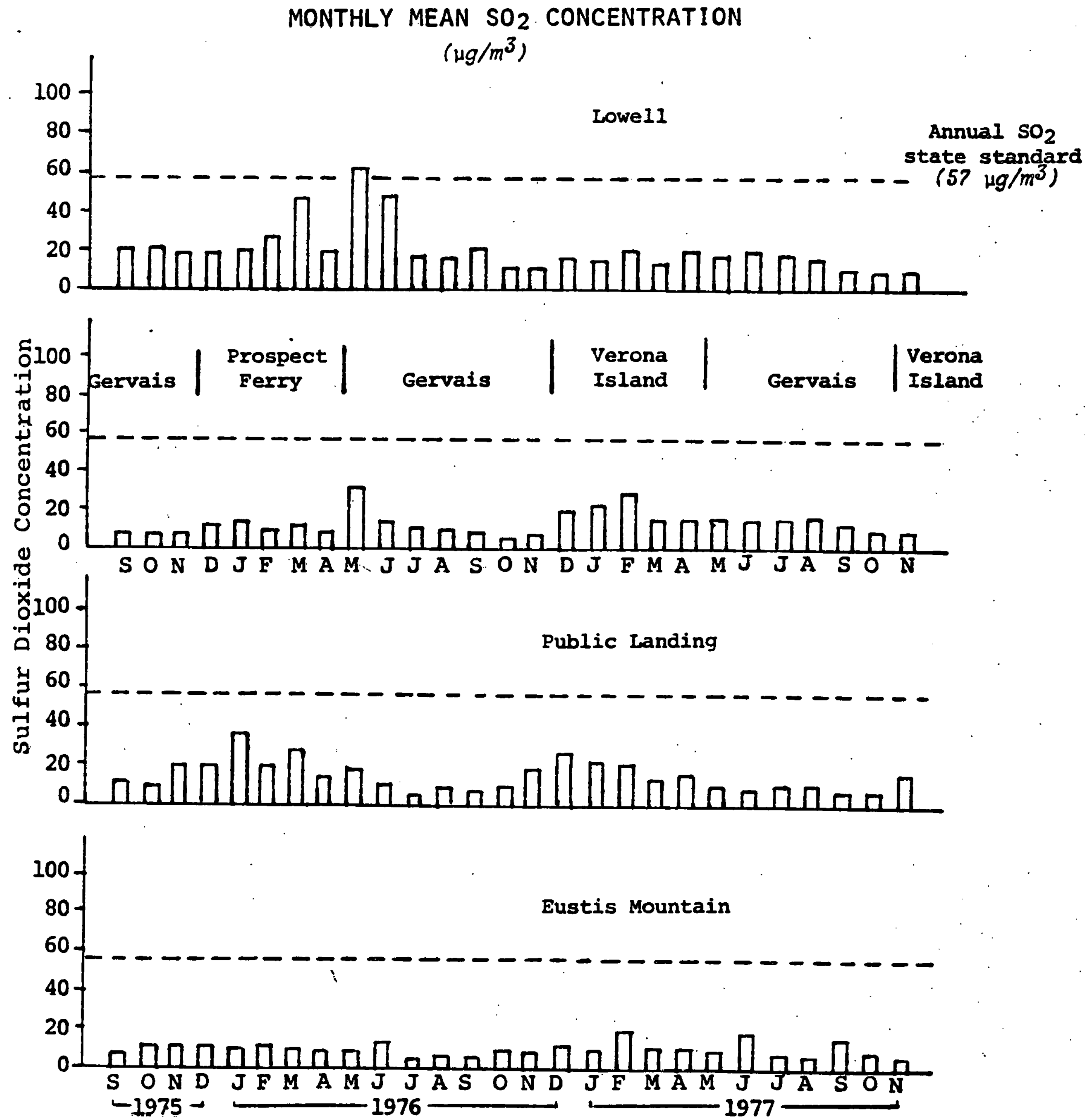
Data Source: St. Regis 1975-1977.

FIGURE 13: PARTICULATE CONCENTRATIONS - BUCKSPORT



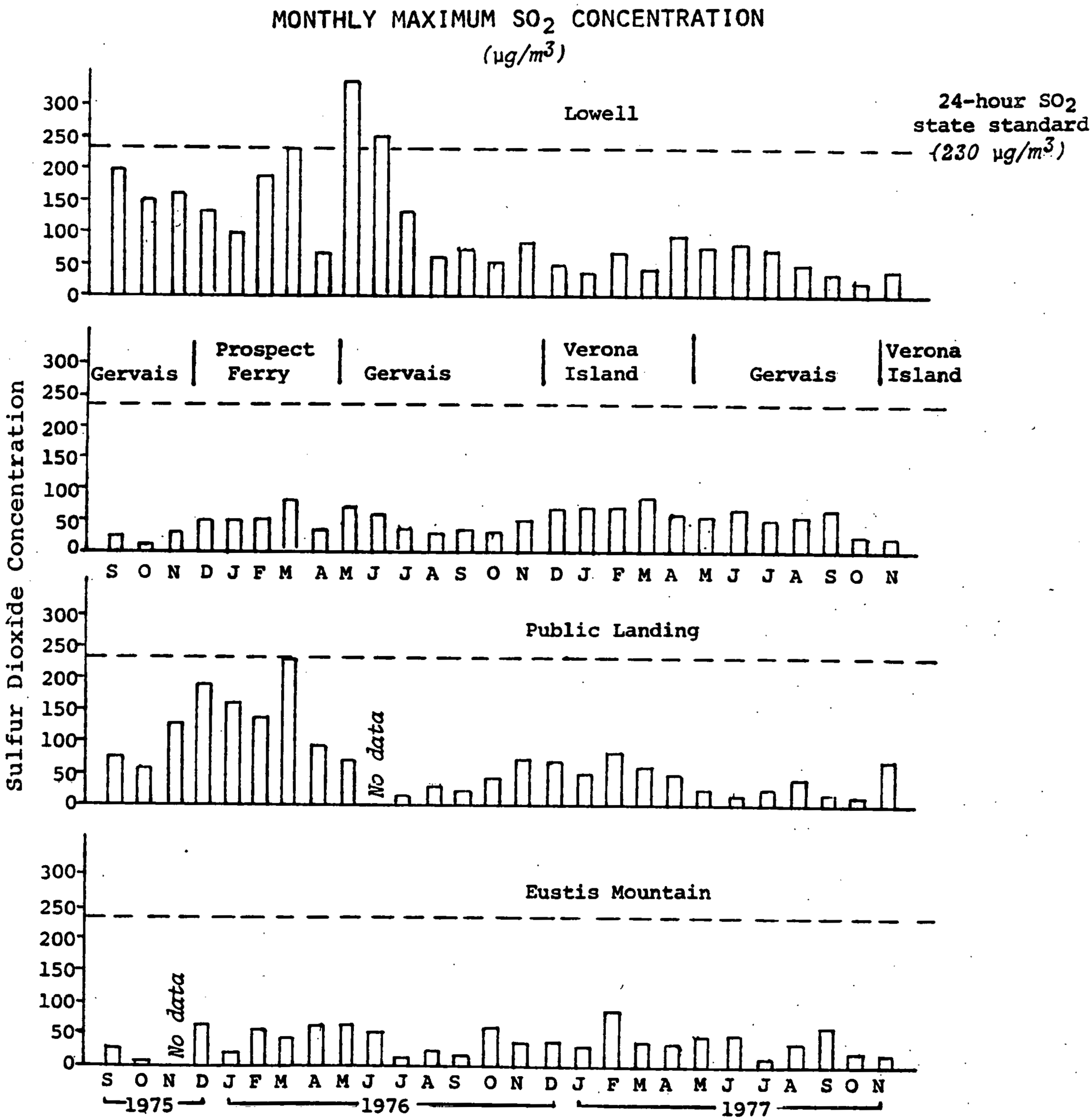
Data Source: St. Regis 1975-1977.

FIGURE 14: SULFUR DIOXIDE CONCENTRATIONS - BUCKSPORT



Data Source: St. Regis 1975-1977.

FIGURE 15: SULFUR DIOXIDE CONCENTRATIONS - BUCKSPORT



Data Source: St. Regis 1976-1977.

Air Quality impacts. The probable site at Bucksport is near the bottom of a moderately steep-sided valley, 300 to 500 feet deep, that runs north to south. The dispersion characteristics at Bucksport are less than ideal, but probably not greatly different from those at other valley sites considered. Examination of the ambient particulate and sulfur dioxide data collected during a detailed two-year aerometric monitoring program undertaken by St. Regis Paper Company indicates that an air pollution problem exists in the Bucksport area (see Figures 12-15). There have been several violations of the state particulate and sulfur dioxide standards during the past two years. Although conditions have improved, especially for sulfur dioxide, since the completion of St. Regis' tall stack in June of 1976, there have nevertheless been eight violations of the state 24-hour particulate standard since that date. Although some of these incidents might be attributable to fugitive dust, their occurrence at several sites and the high background levels indicate a problem.

Uncertainty with respect to how much oil-fired capacity would be closed down in response to the wood-fired power plant's output makes it difficult to determine the extent of likely air-quality trade-offs. Some reduction in sulfur dioxide levels could be expected by shutting down oil boilers, but net particulate emissions would increase. The proximity of elevated terrain nearby increases the possibility of localized air quality standard violations resulting from the plume impaction. A preliminary assessment of the air quality impacts of the proposed plant was made using the VALLEY air pollution impact model. (See Appendix B for a description of the model). The input parameters for the model for all the alternative sites were given in Table 37. For Bucksport, the source of the emissions was assumed to be adjacent to the St. Regis Paper Company Mill; the elevation of the plant assumed to be 20 feet above sea level. The worst-case impacts predicted by the model for particulates and sulfur dioxide at Bucksport were shown in Table 38. In general for Bucksport, maximum impacts occur under stable (Class 6) conditions with low wind speeds from the northeast. Highest concentrations of both particulates and sulfur dioxide occur under these conditions and affect the high land across the Penobscot River to the southwest of the plant. Sulfur dioxide concentrations are highest when the plant is operating on Number 6 fuel oil in the back-up mode. Particulate concentrations are highest when wood fuel alone is burned with fuelwood drying in operation.

A plant in Bucksport, depending on construction schedules, might have to compete for the allowable regional particulate increment with a large coal-fired power plant planned for Sears Island by Central Maine Power Company. A major hydrocarbon source, such as a wood-burning plant, which proposed to locate in the vicinity of a large nitrous oxides source, such as the Sears Island coal-fired power plant, could cause excessive ozone formation where the plumes intersect.

Water availability. The St. Regis Paper Company mill uses water from Silver Lake, which is approximately three-quarters of a mile north of the plant. The lake could provide at least 20 million gallons per day: at present only 15 to 16 million gallons are used for boiler feed (Robinson 1978). The lake also supplies Bucksport's domestic water. The proposed wood-fired power plant could probably draw the 1.8 million gallons per day it needs from this source.

Water quality impacts. There are no discharge or temperature data available at Bucksport. At the gauging station at West Enfield, approximately sixty miles upstream, the mean annual discharge of the Penobscot is 13,166 cubic feet per second (cfs), and the minimum recorded flow is 3,200 cfs (see Table 44). At Bucksport, the flow is undoubtedly much greater. Because the volume of the Penobscot at this point surpasses those of the water sources at the other sites, thermal discharge from a once-through cooling system at Bucksport would probably be less significant than at the alternative locations. The Penobscot at Bucksport is tidal, however, adding to the complexity of determining the extent of the mixing zone. If cooling towers were used as at the proposed plant in Westbrook, thermal impact would definitely be in the acceptable range.

TABLE 44: DISCHARGE OF THE PENOBSCOT RIVER AT WEST ENFIELD

(cfs)

Month	Mean[1]	Minimum[2]
Oct	7,489	3,950
Nov	11,438	4,300
Dec	12,756	3,950
Jan	8,268	4,550
Feb	10,162	4,150
Mar	11,353	4,650
Apr	29,424	6,200
May	30,403	7,180
Jun	12,846	4,570
Jul	8,693	4,080
Aug	7,486	3,200
Sep	7,681	3,340
Annual[3]	13,166	3,200

1. *Mean = Mean discharge of each month averaged over 10-year period.*
2. *Minimum = Minimum discharge recorded during each month over 10-year period.*
3. *Annual mean = Mean of 12 monthly means. Annual minimum = Minimum discharge recorded over entire time period specified.*

Source: USGS 1967-1977.

Landfill availability. There are no suitable landfill sites in the Bucksport area. The St. Regis landfill is close to capacity, and the town of Bucksport, after searching for a closer site, now trucks its solid waste twenty miles to Hampden near Bangor.

Zoning. The town of Bucksport does not have zoning ordinances except for state mandatory shoreland zoning. Unless the plant were to be located on the waterfront, zoning would not apply.

Socioeconomic impacts. Bucksport is seventeen miles from the Bangor-Brewer area and twenty miles from the Ellsworth area. The average labor force in Bucksport during the period from March of 1978 to January of 1979 was 2,028, with 89 persons employed (MDMA 1979). Additional workers could commute from the Bangor-Brewer and Ellsworth areas. About one hundred construction workers would be expected to move temporarily into the area if the plant were built at Bucksport. This influx would place pressure on housing in the town, but workers should be able to find accommodations in the Bangor-Brewer or Ellsworth areas. School enrollments have declined slightly from 1,456 in 1972 to 1,451 in 1977 (Kinney 1979).

Construction would cause temporary increases in employment and income. These increases would be distributed throughout the Ellsworth and Bangor-Brewer areas and therefore would not cause the boom-town effects expected at Millinocket, Lincoln, and Madawaska.

Most of the thirty-two workers needed to run the proposed boiler would be the people who ran the oil boilers it replaced. The number of those indirectly employed would be small and should come from the immediate area.

The socioeconomic impacts associated with harvesting fuelwood for the plant at this site would be similar to those discussed for Lincoln and East Millinocket.

Fuelwood supply impacts. The area likely to be the major biomass supply area for a wood-fired power plant at Bucksport lies to the east and northeast of the town. It is a region primarily of large landownerships held by companies interested in marketing timber products. Currently, no significant market exists for low-grade hardwood produced in this region. The harvesting impacts for Bucksport are expected to be generally similar to those described for East Millinocket and Lincoln. The proportion of hardwoods in the Handcock county area is higher than in the other alternative sites' harvest areas. Landowners in the area are poisoning hardwoods at present to convert the forests to the more profitable spruce/fir type. The opening of a market for low-grade hardwoods would enable landowners to sell these hardwoods and could hasten the transition to spruce/fir forest. Large amounts of bark and wood residue are available in this area; their use could constitute an important environmental benefit by alleviating the need for landfills and cone burners.

Summary. Construction of the proposed plant at Bucksport would require the acquisition and development of a currently undistured site for boiler location. Additionally, steam and electric power transmission lines from the proposed plant to the steam and electric customers would involve the acquisition and development of right-of-ways. Truck traffic congestion, air pollution, and the lack of suitable landfill sites are other environmental problems that would be encountered at Bucksport.

REFERENCES

AASHO 1965 — American Association of State Highway Officials. A Policy on Geometric Design of Rural Highways, AASHO, Washington, DC (1965).

ACE 1977 — U.S. Army Corps of Engineers. Environmental Impact, Dickey-Lincoln School Lakes: Summary ACE, Waltham, MA (August 1977).

ADL 1976 — Arthur D. Little, Inc. Environmental Considerations of Selected Energy Conserving Manufacturing Process Options: Vol. 5 - Pulp and Paper Industry Report, ADL, Cambridge, MA (1976).

Adler, Blakey & Meyer 1978 — Adler, Thomas; Blakey, Margaret; and Meyer, Timothy. The Direct and Indirect Costs of Transporting Wood Chips to Supply a Wood-fired Power Plant, DSD #103-1, Resource Policy Center, Thayer School of Engineering, Hanover, NH (1978).

AEC 1974 — Atomic Energy Commission. Final Environmental Impact Statement: Proposed Seabrook Station, units 1 and 2, AEC, U.S. Department of Energy, Washington, DC (1974).

Allen 1978 — Allen, Neal, Executor, Regional Waste Systems, Greater Portland Council of Governments, Portland, ME. Telephone conversation (July 12, 1978).

Allison 1979 — Allison, Gary, Vice-President, Wheelabrator Cleanfuel Corporation, Washington, DC. Speech at New England Wood Energy Advisory Council meeting, Boston, MA (January 22, 1979).

Andrews & Dammann 1979 — Andrews, R. and Dammann, J.C. Marketing Fuelwood in New Hampshire, Resource Report 71, N.H. Agricultural Experiment Station, Durham, NH (1979).

API 1978a — American Paper Institute. Report to the Department of Energy on Energy Conservation, Progress of the Pulp, Paper, and Paperboard Industry in 1977, API, New York, NY (1978).

API 1978b — American Paper Institute. "U.S. Pulp, Paper, and Paperboard Estimated Fuel and Energy Use," API, New York, NY (1978).

Atlass 1978 — Atlass, Hadley, Director, Maine State Development Office, Augusta, ME. Letter (January 16, 1978).

Bell 1978 — Bell, Harold, Manager of Purchases and Stores, Bangor and Aroostook Railroad, Hermon, ME. Telephone conversation (December 1, 1978).

Bereny 1977 — Bereny, Justin A. Survey of the Emerging Solar Energy Industry, 1977 Edition, Solar Energy Informaiton Services, San Mateo, CA (1977).

Berger & Lohnes 1979 — Berger, Glenn J., and Lohnes, John. A Guide to Legal and Institutional Factor Affecting The Use of Industrial Wood Boilers in New England, DSD #132, Resource Policy Center, Thayer School of Engineering, Hanover, NH (February 1979).

Black 1976 — Black, Theodore W. "Megawatts from the Wind," Power Engineering, (March 1976).

Blackman 1978 — Blackman, T., "Bark Pellets are High Energy Fuel for Coal/Gas Applications," Forest Industries (February 1978).

BLM 1976 — Bureau of Land Management. Final Environmental Impact Statement: Proposed Kaiparowits Project, BLM, U.S. Department of the Interior, Washington, DC (1976).

Brady 1974 — Brady, N.C. The Nature and Property of Soils, 8th ed. (New York: Macmillan Publishing Co., 1974).

Brenemann 1978 — Brenemann, John. Biofuels: A Survey, EPRI ER-746-SR, Electric Power Research Institute, Palo Alto, CA (June 1978).

Broglio 1979 — Broglio, Ronald, Energy Systems Manager, Rust Engineering Company, Birmingham, AL. Telephone conversation (January 16, 1979).

Bronheim 1978 — Bronheim, H. Future Oil Supply to the Northeastern United States, National Center for Analysis of Energy Systems, Brookhaven National Laboratory, Upton, NY (1978).

BSRD 1978 — Bio-Solar Research and Development Corporation. Waste to Woodes: Annual Report, BSRD Corp., Eugene, OR (1978).

Bucksport Conservation 1978	Tilley, Mrs. Richard; Thurston, Betty; and Webb, Glenn. Bucksport Conservation Commission, Bucksport, ME. Meeting (March 15, 1978).
Chamberlain 1979	Chamberlain, L., Director of Sales, Woodex of Maine, Lincoln, ME. Telephone conversation (January 26, 1979).
Butcher & Buckley 1977	Butcher, Samuel S., and Buckley, Douglas I. "A Preliminary Study of Particulate Emissions From Small Wood Stoves," Journal of the Air Pollution Control Association 27 (4) (1977).
Cady 1979	Cady, E. Forester, Berkshire-Franklin Resource Conservation and Development Project. Telephone conversation (March 29, 1979).
CFR 1978	Code of Federal Regulations, Title 40, Part 60. (Amended July 1, 1977).
Chastian et al. 1965	Chastain, W.E., et al. "AASHO Road Tests Applied to Design," Highway Research Record #90, Highway Research Board, Washington, DC (1965).
Cheremisinoff & Morresi 1976	Cheremisinoff, P.N, and Morresi, A.C. Energy From Solid Waste (New York: Marcel Dekker, Inc. 1976).
CMP 1977	Central Maine Power Company. "Petition for Certificate of Public Convenience and Necessity to Erect Permanently Installed Power Generating Facility of More than 1,000 Kilowatts in the State of Maine," Items 9 and 10, docket no. U3238, CMP, Portland, ME (July 6, 1977).
Converse 1974	Converse, A.O. A Brief Review of Load Management Techniques, Technical Memo No. DVE-1M, Thayer School of Engineering, Dartmouth College, Hanover, NH (1974).
Cooper 1975	Cooper, H.B. "The Ultimate Disposal of Ash and Other Solids from Electric Power Generation," in Water Management by the Electric Power Industry, Water Resources Symposium No. 8, Center for Research in Water Resources, University of Texas, Austin, TX (1975).

Cover 1978	Cover, John, Staff Engineer, Rust Engineering Company, Birmingham, AL. Letter (May 24, 1978).
Detwyler 1978	Detwyler, Richard, Plant Manager, Noyes Tire Co., Westbrook, ME. Telephone conversation (November 30, 1978).
DPR 1978	Domestic Policy Review. Status Report on Solar Energy, public review copy, DPR Integration Group, Washington, DC (August 1978).
Duff 1978	Duff, G.F.D. "Tidal Power in the Bay of Fundy," Technology Review (November 1978).
Dvorak et al. 1977	Dvorak, A.J., et al. The Environmental Effects of Using Coal for Generating Electricity, Argonne National Laboratory, Argonne, IL (1977).
E. Millinocket 1979	Tibbets, Edith, Clerk, Town Office, East Millinocket, ME. Telephone conversation (April 3, 1979).
Edelston & Rubin	Edelston, B.S., and Rubin, E.S. Current and Future Use of Coal in the Northeast, National Center for Analysis of Energy Systems, Brookhaven National Laboratory, Upton, NY (1976).
EIA 1978	Energy Information Administration. Steam Electric Plant Construction Cost and Annual Production Expenses 1977, 30th supplement, U.S. Department of Energy, Washington, DC (1978).
Eldridge 1975	Eldridge, Frank R. Wind Machines, MITRE Corporation, (Washington: U.S. Government Printing Office, 1975).
EPA 1974	U.S. Environmental Protection Agency. An Assessment Methodology for the Environmental Impact of Water Resource Projects, EPA-600/5-74-016, EPA, Washington, DC (July 1974).
EPA 1976	U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors, 2nd edition, AP-42, EPA, Research Triangle Park, NC (1976).
EPA 1978	U.S. Environmental Protection Agency. Compilation of Air Emission Factors, 3rd ed., AP-42, Supplement 8, EPA, Research Triangle Park, NC (May 1978).

ERDA 1976 — U.S. Energy Research and Development Administration. A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices For the Future. Vol. 2: Program Implementation (Washington: U.S. Government Printing Office, 1976).

Finn 1979a — Finn, W.D., Project Engineer, Rust Engineering Company, Birmingham, AL. Letter (February 2, 1979).

Finn 1979b — Finn, W.D., Project Engineer, Rust Engineering Company, Birmingham, AL. Letter (March 20, 1979).

FPC 1977 — Federal Power Commission. "Hydroelectric Power Resources of the United States," FPC, Washington, D.C. (1977).

Galloway, Clark & Kerrick 1969 — Galloway, W.J.; Clark, W.E.; and Kerrick, G.S. Highway Noise: Measurement, Simulation, and Mixed Reactions, Report No. 78, National Cooperative Highway Research Program, Highway Research Board, Washington, DC (1969).

Gatslick 1977 — Gatslick, Harold B. "What Wood Could Do," Forest Notes No. 126, Society for the Protection of New Hampshire Forests, Concord, NH (Summer 1976).

GCHEE 1977 — Governor's Commission on Hydro-Electric Energy. Report on Hydro-Electric Energy in New Hampshire: Existing and Potential Development, Office of the Governor, Concord, NH (April 1977).

Geary & Jones 1977 — Geary, J., and Jones, W.J. "Solar Energy Conversion," Appendix F of Alternative Electrical Energy Sources for Maine, MIT-EL 77-010, M.I.T. Energy Laboratory, Cambridge, MA (December 1977).

Gerlach 1970 — Gerlach, A.C., ed. The National Atlas, U.S. Department of Interior, Geological Survey, Washington, DC (1970)

Gordian 1975 — Gordian Associates, Inc. The Data Base: The Potential for Energy Conservation in Nine Selected Industries, Vol. 8 - Selected Paper Products, Conservation Paper #16, Office of Industrial Programs, Federal Energy Administration, Washington, DC (1975).

GPCOG 1977 — Greater Portland Council of Governments. Areawide Water Quality Management Plan, vol. II, revised, GPCOG, Portland, ME (November 1977).

Graham 1978 — Graham, Foster, General Services Manager, Burlington Electric Company, Burlington, VT. Telephone conversation (July 31, 1978).

Groves 1978 — Groves, S. Bureau of Water Quality Control, Maine Department of Environmental Protection, Augusta, ME. Meeting (March 16, 1978).

Hale 1978 — Hale, Roger, Energy Specialist, Fraser Paper Limited, Madawaska, Me. Meeting (March 16, 1978).

Hall et al. 1976 — Hall, E.H., et al. Comparison of Fossil and Wood Fuels, Battelle-Columbus Laboratories, Columbus, OH (1976).

Harmon 1978 — Harmon, Donald, Plant Manager, Century Tire Co., Portland, ME. Telephone conversation (December 1, 1978).

Harvey 1978 — Harvey, Warren, Vice-President, Public Service Company of New Hampshire, Manchester, NH. Telephone conversation (August 18, 1978).

Hecht & Duvall 1975 — Hecht, N.L., and Duvall, D.S. Characterization and Utilization of Municipal and Utility Sludges and Ashes: Vol. 3 - Utility Coal Ash, EPA-670/2-75-033C, U.S. Environmental Protection Agency Office, Cincinnati, OH (1975).

Hein & Lower 1978 — Hein, G.M., and Lower, B.L. "Energy Requirements for Coated and Uncoated Papers," Journal of the American Pulp and Paper Institute, vol. 61, no. 5 (1978).

Heinrichs 1979 — Heinrichs, Jay. "T on Trial," American Forests, vol. 85, no. 2 (February 1979).

Hewett 1978 — Hewett, Charles. The Availability of Wood for a 50-Mw Wood-fired Power Plant in Northern Vermont, DSD#114, Resource Policy Center, Thayer School of Engineering, Hanover, NH (1978).

Hewett & High 1979 — Hewett, C.E., and High., C.J. Construction and Operation of Small, Dispersed, Wood-fired Power Plants, DSD #117A, Resource Policy Center, Thayer School of Engineering, Hanover, NH (1979).

High & Knight 1977	High, Colin, and Knight, Susan. Environmental Impacts of Harvesting Noncommercial Wood for Energy: Research Problems, DSD#101, Resource Policy Center, Thayer School of Engineering, Hanover, NH (1977).
Hobart 1978	Hobart, Ray, Plant Supervisor, Yudi Tire Co., Westbrook, ME. Telephone conversation (November 30, 1978).
Hoff 1976	Hoff, Einar B. "Handling of Forest Products Fuels," in Energy and the Wood Products Industry, Proceedings No. P-76-14, Forest Products Research Society, Madison, WI (1976).
Hokanson & Rowell 1977	Hokanson, A.E., and Rowell, R.M. Methanol from Wood Waste: A Technical and Economic Study, Forest Service General Technical Report FPL 12, Forest Products Laboratory, Madison, WI (1977).
Houghton 1979	Houghton, John A., Superintendent of Schools, Madawaska, ME. Telephone conversation (March 19, 1979).
Hughes & Denio 1978	Hughes, David, Vice President of Engineering, and Denio, Donald, Methods Engineer, Boston and Maine Railroad, Boston, MA. Telephone conversation (December 4, 1978).
Hunt 1938	Hunt, G.M. Wood Preservation (New York: McGraw-Hill, Inc., 1938).
Hunt & Babcock 1978	Hunt, Donald, Manager, Maine Rubber Manufacturing Co., Lewiston, ME., and Babcock, Donald, Manager of Wholesale Division, Snows Tire Co., Lewiston, ME. Telephone conversation (November 30, 1978).
Inman 1977	Inman, R.E. Silvicultural Biomass Farms: Volume I-Summary, Technical Report No. 7347, MITRE Corporation, Washinton, DC (1977).
Jahn & Preston 1976	Jahn, Edwin C., and Preston, Stephen B. "Timber: More Effective Utilization," Science vol. 191 (February 1976).
Johnston 1978	Johnston, Dale, Senior Staff Engineer, Rust Engineering Company, Birmingham, AL. Telephone conversation (December 4, 1978).

Jones et al. 1977	Jones, W.J.; Ruane, M.; Carpenter, P.; Raskin, S.; and Tabors, R. "Conservation," Appendix B of <u>Alternative Electrical Energy Sources for Maine</u>, MIT-EL 77-010, M.I.T. Energy Laboratory, Cambridge, MA (1977).
Jones & Ruane 1977	Jones, W.J. and Ruane, M. <u>Alternative Electrical Energy Sources for Maine: Summary Report</u> MIT-EL 77-010, M.I.T. Energy Laboratory, Cambridge, MA (1977).
KCIM 1976	Keystone Coal Industry Manual (New York: McGraw-Hill, 1976).
Kingsley 1976	Kingsley, Neal P. <u>The Forest Resources of New Hampshire</u>, Resource Bulletin NE-43, U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Broomall, PA (1976).
Kingsley & Birch 1977	Kingsley, Neal P., and Birch. T.W. <u>The Forest Landowners of New Hampshire and Vermont</u>, Resource Bulletin NE-51, U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Broomall, PA (1977).
Kinney 1979	Kinney, Kenneth, School Superintendent, Bucksport, ME. Telephone conversation (March 20, 1979).
Klumb & Brendel 1977	Klumb, D.L., and Brendel, P.R. "Resource Recovery from Solid Waste: The Story of Union Electric's Solid Waste Utilization System," Union Electric Company, St. Louis, MO (1977).
Koch 1976	Koch, Peter. "Material Balances and Energy Required for Manufacture of Ten Wood Commodities," in <u>Energy and The Wood Products Industry</u>, Proceedings No. P-76-14, Forest Products Research Society, Madison, WI (1976).
Kugler & Piersol 1973	Kugler, B.A., and Piersol, A.G. <u>Highway Noise: A Field Evaluation of Traffic Noise Reduction Measures</u>, Report No. 144, National Cooperative Highway Research Program, Highway Resource Board, Washington, DC (1973).

Laaspere 1974 — Laaspere, T. On European Approaches to Managing the Electric Load, Report No. DVE-2, Thayer School of Engineering, Dartmouth College, Hanover, NH (1974).

Labuszewski 1977 — Labuszewski, T. "Wind Energy Conversion," Appendix K of Alternative Electrical Energy Sources for Maine, MIT-EL 77-010, M.I.T. Energy Laboratory, Cambridge, MA (December 1977).

Lapikas 1979 — Lapikas, T., Fleet Maintenance Engineer, General American Transportation Co., Masury, OH. Telephone conversation (February 15, 1979).

Le, Rubin & Meier 1978 — Le, T.; Rubin, E.; and Meier, P. Coal Utilization in the Northeast: Vol. 8 - Solid Waste Management Issues and Impacts, National Center for Analysis of Energy Systems, Brookhaven National Laboratory, Upton, NY (1978).

Lincoln Conversation 1978 — Davis, G.; Moulton, N; and Gildeau, F. Lincoln Conservation Commission, Lincoln, ME. Meeting, (March 14, 1978).

Linnell 1978 — Linnell, William, Technical Director, Lincoln Pulp and Paper Co., Lincoln, ME. Meeting (March 16, 1978).

Lowery 1979 — Lowery, James, Financial Analyst, Maine Public Utilities Commission, Augusta, ME. Telephone conversation (February 28, 1979).

Lowell 1978 — Lowell, Vaughn, Bucksport Conservation Commission, Bucksport, ME. Meeting (March 15, 1978).

Madawaska 1979 — Genderau, Linda, Town Office, Madawaska, ME. Telephone conversation (April 3, 1979).

Magee et al. 1973 — Magee, E.M., et al. Potential Pollutants in Fossil Fuels, Esso Research and Engineering Co., Linden, NJ (1973).

Manar 1978 — Manar, Otis, Project Engineer, Rust Engineering Company, Birmingham, AL. Telephone conversation (August 14, 1978).

Manar 1979a — Manar, Otis, Progect Engineer, Rust Engineering Company, Birmingham, AL. Telephone conversation (February 26, 1979).

Manar 1979b — Manar, Otis, Project Engineer, Rust Engineering Co., Birmingham, AL. Telephone conversation (March 9, 1979).

Manar 1979c — Manar, Otis, Project Engineer, Rust Engineering Company, Birmingham, AL. Meeting (May 17, 1979).

Marlow 1978 — Marlow, J.C. "Certain Small Mill Projects Can Add Up to Large Energy Savings," Pulp and Paper (January 1978).

Marra 1979 — Marra, Alan, Professor, Department of Wood Technology, University of Massachusetts, Amherst, MA. Telephone conversation (March 29, 1979).

Mays 1977a — Mays, J. "Wave Energy Conversion," Appendix I of Alternative Electrical Energy Sources for Maine, MIT-EL 77-010, M.I.T. Energy Laboratory, Cambridge, MA (December 1977).

Mays 1977b — Mays, J. "Ocean and Riverine Current Energy Conversion," Appendix J of Alternative Electrical Energy sources for Maine, MIT-EL 77-010 M.I.T. Energy Laboratory, Cambridge, MA (December 1977).

MBAQC 1978 — Maine Department of Environmental Protection, Bureau of Air Quality Control, Air Monitoring Records, MBAQC, Augusta, ME (1978).

McBride et al. 1978 — McBride, J.P.; Moore, R.E.; Witherspoon, J.P.; and Blanco, R.E. "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants," Science, vol. 202, no. 4372 (1978).

MDC undated — Maine Department of Conservation, Forestry Bureau. List of logging firms in Maine by county, on file at MDC, Augusta, ME (undated).

MDEP 1979 — Maine Department of Environmental Protection. State Implementation Plan for Air Quality, draft proposed revision, MDEP, Augusta, ME (January 1979).

MDMA 1979 — Maine Department of Manpower Affairs. Computer file of employment and unemployment estimates, MDMA, Augusta, ME (1979).

Meffert 1978 — Meffert, D.P., Senior Staff Engineer, Rust Engineering Company, Birmingham, AL. Letter (October 26, 1978).

Milligan 1978 — Milligan, S.B. Project Manager, Rust Engineering Company, Birmingham, AL. Letter (December 20, 1978).

MITRE 1975 — MITRE Corporation. An Analysis of Constraints on Increased Coal Production, U.S. Department of the Interior, Washington, DC (1975).

MOER 1976 — Maine Office of Energy Resources. Maine Comprehensive Energy Plan, vol. I, MOER, Augusta, ME (1976).

MSPO 1977 — Maine State Planning Office. Population Projection Series PPS-2, MSPO, Augusta, ME (August 1977).

NEEC 1978 — New England Energy Congress. Preliminary Report for Public Review, NEEC, Tufts University, Medford, MA (1978).

NEFRC 1976 — New England Federal Regional Council, Energy Resource Development Task Force, Hydroelectric Facilities Workgroup. A Report on New England Hydroelectric Development Potential, NEFRC, Boston, MA (June 1976).

NEPOOL 1971 — New England Power Pool. Contract, amended version, NEPOOL, Westborough, MA (September 1, 1971).

NERBC 1979 — New England River Basin Commission. "Inventory of Low-head Dams," unpublished computer printout on file at NERBC, Boston, MA (1979).

Newkirk 1976 — Newkirk, H.W., ed. Environmental Effects of Energy Production and Utilization in the U.S., vol. I-III, Lawrence Livermore Laboratories, University of California, Livermore, CA (1976).

NOAA 1978 — National Oceanic and Atmospheric Administration. "Harnessing Tidal Energy," Current Issue Outline 78-2, U.S. Department of Commerce, Washington, DC (1978).

Noyes 1974 — New England Waste Treatment Company. Feasibility Study for Noyes Tire Company, H. Walker Noyes Tire Co., Westbrook, ME (September 1974).

Nuclear Industry 1979 — "U.S. Nuclear Power Plants: Construction Progess," Nuclear Industry, vol. 26, no. 1 (1979).

OWHM 1974 — U.S. Environmental Protection Agency, Office of Water and Hazardous Materials. Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category, EPA, Washington, DC (1974).

Paskert & Gallagher 1977 — Paskert, P.F., and Gallagher, J M. Escalation in the Costs of Manpower, Materials, and Equipment Needed for Energy Facilities, Research and Engineering Division, Bechtel Corp., San Francisco, CA (1977).

Peters 1978 — Peters, Bradley, Vice-President, Maine Central Railroad, Bangor, ME. Telephone conversation (December 6, 1978).

Popovich 1978 — Popovich, Luke. "Of Mice and Men: The Troubles of 2,4,5-T," Journal of Forestry, vol. 76, no. 12 (December 1978).

Reardon 1978 — Reardon, Robert, Assistant Power Systems Manager, Great Northern Paper Company, East Millinocket, ME. Meeting (March 9, 1978).

Reed & Bryant 1978 — Reed, Tom, and Bryant, Becky. Densified Biomass: A New Form or Solid Fuel, Solar Energy Research Institute, Golden, CO (July 1978).

Rich 1978 — Rich, J. Philip. "Identification of Sequential Harvesting Procedure," preliminary draft, J.P.R. Associates, Stowe, VT (1978).

Robinson 1978 — Robinson, Preston, Chief Project Engineer, St. Regis Paper Company, Bucksport, ME. Meeting (March 15, 1978).

Rodemann 1978 — Rodemann, U.W. "Load Management Pays for Itself," Public Power, vol. 36, no. 6 (1978).

Rolfe 1978	Rolfe, David, Plant Engineer, S.D. Warren Company, Westbrook, ME. Meeting (November 13, 1978).
Rolfe 1979a	Rolfe, David, Plant Engineer, S.D. Warren Company, Westbrook, ME. Telephone conversation (January 17, 1979).
Rolfe 1979b	Rolfe, David, Plant Engineer, S.D. Warren Company, Westbrook, ME. Letter (February 2, 1979).
Roskoski 1975	Roskoski, J.P. "Differential Nitrogen Fixation in Wood Litter," Bulletin of the Ecological Society of America 56 (12) (1975).
Ruane 1977a	Ruane, M. "Conversion of Solid Wastes," Appendix G of Alternative Electrical Energy Sources for Maine, MIT-EL 77-010, M.I.T. Energy Laboratory, Cambridge, MA (1977).
Ruane 1977b	Ruane, M. "Ocean Thermal Energy Conversion," Appendix D of Alternative Electrical Energy Sources for Maine, MIT-EL 77-010, M.I.T. Energy Laboratory, Cambridge, MA (1977).
Ruane 1977c	Ruane, M. "Storage of Energy," Appendix H of Alternative Electrical Energy Sources for Maine, MIT-El 77-010, M.I.T. Energy Laboratory, Cambridge, MA (1977).
Rubel 1974	Rubel, Fred N. Incineration of Solid Wastes, Noyes Data Corporation, Park Ridge, NJ (1974).
Saeman 1973	Saeman, Jerome F. "Solving Resource and Environmental Problems by the More Efficient Utilization of Timber," in Report of the President's Advisory Panel on Timber and the Environmental, President's Advisory Panel on Timber and the Environment, Arlington, VA (1973).
Saeman 1977a	Saeman, Jerome, F. "Energy and materials from the Forest Biomass," paper presented at Institute of Gas Technology Symposium on Clean Fuel from Biomass and Wastes, Forest Products Laboratory, Madison, WI (1977).

Saeman 1977b — Saeman, Jerome F. Strategies and Priorities in Using Wood to Alleviate Energy Shortages, Forest Products Laboratory, Madison, WI (1977).

Saeman & Youngs 1978 — Saeman, J.F. and Youngs, R.L. "Wood Utilization Priorities as Set by Energy and Materials Shortages" presented at Society of American Foresters Convention, St. Louis, MO (1978).

Savage 1979 — Savage, Edward, School Superintendent, East Millinocket, ME. Telephone conversation (March 20, 1979).

Sax 1975 — Sax, N. Irving. Dangerous Properties of Industrial Materials, 4th ed. (New York: Van Nostrand Reinhold Co., 1975).

S.D. Warren 1978 — S.D. Warren Company. "Application for Air Emission License," submitted to the Maine Department of Environmental Protection, Augusta, ME (1978).

Shelton 1976 — Shelton, J. The Woodburner's Encyclopedia: Wood as Energy. (Waitsfield, VT: Vermont Crossroads Press, 1976).

Shelton 1978 — Shelton, J. Williams College, Williamstown, MA. Telephone conversation (August 29, 1978).

Sherburne 1979 — Sherburne, Russ, System Planning Supervisor, Central Maine Power Company, Portland, ME. Telephone conversation (February 23, 1979).

Sherwood & Meadows 1978 — Sherwood, Larry, and Meadows, Dennis. The Fuel Requirements of a 50-Mw Wood-fired Electrical Generating Facility in Northern Vermont, DSD #106, Resource Policy Center, Thayer School of Engineering, Hanover, NH (1978).

Smith 1962 — Smith, D.M. The Practice of Silviculture, (New York: John Wiley & Sons, Inc., 1962).

SPPP 1975 — Science and Public Policy Program. Energy Alternatives: A Comparative Analysis (Washington, DC: U.S. Government Printing Office, 1975).

SRI 1976	Stanford Research Institute. Crop, Forestry, and Manure Residue Inventory: Continental United States, vol. 1. SRI, Menlo Park, CA (1976).
SRI 1978	Stanford Research Institute. Crop, Forestry, and Manure Residue Inventory: Continental United States, vol. 1, SRI, Menlo Park, CA (1976).
St. Regis 1975-1977	Equitable Environmental Health, Inc., St. Regis Paper Company Aerometic Monitoring Program, EEHI, Woodbury, NY (1977).
Stone 1977	Stone, R.N. "Are U.S. Wood Supplies Dependable and Adequate?" in Energy Efficiency in Wood Building Construction, proceedings no. P-77-18, Forest Products Research Society, Chicago, IL (1977).
Stribling 1973	Stribling, J.B. "A Solution to the Scrap Tyre Problem," European Rubber Journal (March 1973).
Stribling 1978	Stribling, J.B. Heenan Environmental Systems Ltd., Worcester, England, Letter (December 6, 1978).
Swain 1979	Swain, Elizabeth, Wood Fuel Program Director, Maine Audubon Society, Falmouth, ME. Telephone conversation (February 15, 1979).
Thomae 1978	Thomae, Sally, Senior Research Associate in Pharmacology, Dartmouth College, Hanover, NH. Meeting (December 1, 1978).
Thomae 1979	Thomae, Sally, Senior Research Associate in Pharmacology, Dartmouth College, Hanover, NH. Meeting (March 7, 1979).
Threshold 1977	Threshold to Maine Resources Conservation and Development Project. Goals and Objectives, Fiscal Year 1978: Program of Action Short-term Plant, Supplement #6. Threshold to Maine RC & D Project, Portland, ME (1977).
Turner 1979	Turner, Alan, Wood Energy Specialist, Vermont State Energy Office, Montpelier, VT. Telephone conversation (February 15, 1979).

UNH 1966 — University of New Hampshire Agricultural Experiment Station. An Economic Analysis of the Potentials of the Hardwood Industry in Northern New Hampshire, UNH Agricultural Experiment Station, Durham, NH (May 1966).

USFS 1974 — U.S. Department of Agriculture, Forest Service. The Outlook for Timber in the U.S., Forest Resource Report No. 20 (Washington: U.S. Government Printing Office, 1974).

USFS 1976 — U.S. Department of Agriculture, Forest Service. The Feasibility of Utilizing Forest Residues for Energy and Chemicals, PB-258-630, National Technical Information Service, Washington, DC (March 1976).

USGS 1967-1977 — U.S. Department of the Interior, Geological Survey. Water Resources Data for Maine, Water Years 1966-1976, Water Data Reports ME-66-1 through ME-76-1, USGS, Washington, DC (1967-1977).

Valley News 1978 — The Valley News, West Lebanon, NH (September 30, 1978).

Voss 1977 — Voss, George D. "Industrial Wood Energy Conversion," in Fuels and Energy from Renewable Resources, David Tillman, Kyosti Sarkanen, and Larry Anderson, eds. (New York: Academic Press, 1977).

Vumbaco 1978 — Vumbaco, J.A. "Conservation Brings Savings," Public Power, vol. 36, no. 6 (1978).

Waterflow 1977 — Waterflow, A. "Geothermal Energy Conversion," Appendix C of Alternative Electrical Energy Sources for Maine, MIT-El 77-010, M.I.T. Energy Laboratory, Cambridge, MA (December 1977).

Wayne 1979 — Wayne, Warner, Chief Hydraulic Engineer, Stone and Webster Engineering, Boston, MA. Telephone conversation (March 5, 1979).

Webster 1979 — Webster, Gaylord, Business Manager, Office of the Superintendent of Schools, Linclon, ME. Telephone conversation (March 19, 1979).

Welch 1978 — Welch, Patrick H., Environmental Protection Supervisor, Great Northern Paper Company, East Millinocket, ME. Meeting (March 9, 1978).

Whiteside et al. 1973 — Whiteside, R.E.; Chu, T.Y.: Cosby, J.C.; Whitaker, R.L.; and Winfrey, R. Weights and Dimensions: Some Economic Effects on Highways, National Cooperative Highway Research Report #141, Highway Research Board, Washington, DC (1973).

Wilczynski 1978 — Wilczynski, E.J. "How Do Environmental Regulations Affect Paper Industry Energy Use?", Pulp and Paper (May 1978).

Williams 1974 — Williams, J. Richard. Solar Energy, Technology and Applications (Ann Arbor: Ann Arbor Science Publishers, 1974).

Zerbe 1978 — Zerbe, John I. "The Many Forms of Wood as a Fuel," American Forests 84(10) (1978).