Executive Summary to Volume IV

Candidate Electric Energy Technologies for Future Application in the Railbelt Region of Alaska

Volume III

November 1982

Prepared for the Office of the Governor
State of Alaska
Division of Policy Development and Planning
and the Governor's Policy Review Committee
under Contract 2311204417

Battelle
Pacific Northwest Laboratories

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CANDIDATE ELECTRIC ENERGY TECHNOLOGIES FOR FUTURE APPLICATION IN THE RAILBELT REGION OF ALASKA

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Richland, Washington 99352

RAILBELT ELECTRIC POWER ALTERNATIVES STUDY

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INTRODUCTION

The State of Alaska commissioned Battelle, Pacific Northwest Laboratories in its Railbelt Electric Power Alternatives Study to investigate potential strategies for future electric power development in Alaska's Railbelt region. The results of the study will be used by the Office of the Governor to formulate recommendations for electric power development in the Railbelt.

The primary objective of the study is to develop and analyze several alternative long-range plans for electric energy development in the Railbelt region. Each plan is based on a general energy development strategy representing one or more policies that Alaska may wish to pursue. The analyses of the plans will produce a forecast of electric energy demand, a schedule for developing generation and conservation alternatives, an estimate of the cost of power, and a discussion of the environmental and socioeconomic characteristics for each plan.

In the development of these plans, 38 electric energy alternatives to be included as potential future Alaskan sources were identified (Table 1). Eight of these were identified to be inappropriate for further consideration either for technical or availability reasons. This report, Volume III of seventeen volumes (see page iii), summarizes the study findings on the 30 remaining energy alternatives. Except for solar electric power and load management, where the discussion of alternatives within these two categories has been consolidated, the summary of each alternative typically contains a discussion of the following areas: a general description of the alternative, possible Railbelt applications, commercial availability, conversion efficiency (or performance), estimated cost of power, resource availability, environmental consequences, and socioeconomic consequences.

The estimated cost of power for each alternative is presented as levelized lifetime costs for 1990 operation in 1980 dollars, using a 3% discount rate. Costs are adjusted for the Alaskan construction cost environment. Further technical detail for each alternative can be found in Volume IV of this report series. Additional information on fuel price is available in Appendix B in Volume IV and in Volume VII of this report series.

TABLE 1. Candidate Electric Energy Alternatives

Baseload Generating Alternatives	Candidate Electric Energy Alternative	Selection Criteria: Commercial Availability	Selection Criteria: Technical Feasibility
Coal-Fired Steam-Electric Generation	Yes	Available	Yes
Natural-Gas/Distillate-Fired Steam-Electric Generation	Yes	Available	Yes
Biomass-Fired Steam-Electric Generation	Yes	Available	Yes
Peat-Fired Steam-Electric Generation	Yes	Available	Yes
Combined-Cycle Plants	Yes	Available	Yes
Magnetohydrodynamic Generators	No[a]	2000-2005	Yes
Nuclear Light Water Reactors	Yes	Available	Yes
Fast Breeder Fission Reactors	No	2005-2025	Yes
Geothermal Generation	Yes	Available	Yes
Fusion Reactors	No	2025	Yes
Ocean Current Energy Systems	No	Beyond 2000	No (Resource Limited)
Salinity Gradient Energy Systems	No	Beyond 2000	No (Resource Limited)
Ocean Thermal Energy Conversion System	No	2000	No (Resource Limited)
Space Power Satellites	No	Beyond 2000	No (Resource Limited)
Baseload/Load-Following Generating Alternatives			
Combustion Turbines	Yes	Available	Yes
Diesel Generation	Yes	Available	Yes
Conventional Hydroelectric	Yes	Available	Yes
Small Hydroelectric and Microhydroelectric	Yes	Available	Yes
Fuel Cells	Yes	Available	Yes
Fuel-Saver (Intermittent) Generating Alternatives			
Ocean Wave Energy Systems	No	1990s	No (Resource Limited)
Tidal Power	Yes	Available	Yes
Large Wind Energy Systems	Yes	Available	Yes
Small Wind Energy Systems	Yes	Available	Yes
Solar Photovoltaic Systems and Solar Thermal or Control Receiver Systems	Yes	Available	Yes
Cogeneration	Yes	Available	Yes
Energy Storage Alterantives			
Pumped Hydroelectric	Yes	Available	Yes
Storage Batteries	Yes	Available	Yes
Compressed Air Energy Storage	Yes	Available	Yes
Load Management			
Direct Load Control	Yes	Available	Yes
Passive Load Control	Yes	Available	Yes
Incentive Pricing	Yes	Available	Yes
Education and Public Involvement	Yes	Available	Yes
Dispersed Thermal Energy Storage	Yes	Available	Yes
Electric Energy Conservation in Buildings	Yes	Available	Yes
Electric Energy Substitutes			
Passive Solar Space Heating	Yes	Available	Yes
Active Solar Space and Hot Water Heating	Yes	Available	Yes
Wood-Fired Space Heating	Yes	Available	Yes

(a) "No" indicates that this technology was not analyzed in the study.

COAL-FIRED STEAM-ELECTRIC GENERATION

A coal-fired steam-electric generating plant consists of a coal-fired furnace and boiler to generate steam, a steam turbine-generator unit for production of electric energy, and a condensor feedwater system to return process water to the boiler. Also required are a flue gas pollution control system to trap particulates and to control the emissions of sulfur oxides and coal handling facilities to receive, store, and prepare the coal for firing. Available plant sizes range from 20 to 1200 MW; 200-MW units appear to be appropriate for Railbelt applications.

POSSIBLE RAILBELT APPLICATIONS

Coal is currently available from Nenana field near Healy and is potentially available from the Beluga field east of Cool Inlet. Coal-fired generation shows promise as a major source of baseload power in the Railbelt region. Units are already operating in the region (Healy, Chena, University of Alaska). The size range of most interest in the Railbelt system is 20 to 200 MW. These units, as well as larger sizes, are commercially available. Mine-mouth generation would have the advantage of minimizing transportation and storage costs and impacts, but these gains would be partially offset by the requirement for longer transmission facilities.

COMMERCIAL AVAILABILITY

Coal plants and their associated pollution control equipment are commercially available. Some special provisions may have to be made for cold weather operation of coal handling and scrubber equipment, but this is not considered a major complication. A coal plant can be constructed in 7 years, including time to obtain necessary permits. A plant could be on line by 1989 with a 1982 decision to build. A 20-MW unit could be constructed in a shorter time if the boiler were a package design and auxiliary equipment were skid mounted.

CONVERSION EFFICIENCY

The conversion efficiency of coal-fired plants varies with unit size and the scrubber system used. A range of efficiencies from 26 to 36% can be expected with units from 20 to 600 MW capacity, respectively.

ESTIMATED COST OF POWER

Estimated electric energy costs are shown below for 200-MW plants operating at a 29% conversion efficiency and a 65% capacity factor. Smaller plants would demonstrate higher costs. Some cost savings would be realized in plants larger than 200 MW.

The cost components are as follows:

	Coal-Fired Steam-Electric (mills/kWh)	
	Beluga	Nenanna
Capital	23	23
Fuel	27	30
Operating and Maintenance	7	7
Total Production Cost	57	60

Approximately 50% of the capital expenditures of a coal-fired plant would flow outside the Railbelt, but only 10% of the operating and maintenance costs would leave the region. Fuel would be purchased within the region.

ENVIRONMENTAL CONSEQUENCES

Coal-fired power plants generate large quantities of solid waste derived from the combustion process. These wastes include fly ash and bottom ash. The desulfurization of stack gases generates more solid wastes. All of these wastes require careful disposal to ensure the protection of water resources.

The combustion of large amounts of coal potentially leads to a significant deterioration of the local air quality. Therefore, siting of future plants using Nenana coal will probably be either to the north or south of these coal deposits to meet the Class 1 air-quality standards that apply in Denali National Park. Because Alaskan coal is generally very low in sulphur, Class 2 standards should not be difficult to meet with commercially available scrubbing equipment.

Because of the large land area needed for construction and operation, preemption or alteration of terrestrial biota habitat can be a significant environmental impact at some sites. These land requirements are generally greater than those for other types of fossil-fueled power plants.

Coal-fired plants will use the same, or less, water per unit of capacity than any other thermal plant except a combined-cycle facility. A 200-MW plant (a suitable plant size for the Railbelt) would require about 90,000 gpm for a once-through cooling system or 1,800 gpm for a recirculating system. Waste water from ash transport and flue gas desulfurization processes demand sophisticated treatment to reduce toxicity to aaceptable discharge levels. Zero discharge plant designs are available.

SOCIOECONOMIC CONSIDERATIONS

A 200-MW plant is estimated to require a construction work force of 600 and an operating work force of 85. For a 200-MW plant, any community other than Anchorage would experience a severe strain on community services, schools, and housing during the construction period.

NATURAL GAS AND DISTILLATE-FIRED STEAM-ELECTRIC GENERATION

Natural gas and oil-fired steam-electric plants are similar in concept to coal-fired steam-electric plants except natural gas or distillate fuel oil is used to fire the furnace to generate steam. Flue gas pollutant control systems and fuel and solid waste handling systems are typically less complex.

Available plant sizes range from 10 to 200 MW. The 200-MW units appear to be appropriate for Railbelt applications.

POSSIBLE RAILBELT APPLICATION

Oil-fired steam-electric plants may be fueled with either distillate (#2) or residual (#6) fuel oil. Residual fuel oil is typically less expensive but often requires use of flue gas desulfurization equipment.

The present sources of fuel oil in the Railbelt are confined to the refineries of Kenai and Fairbanks. Petroleum pipelines carry imported refined products from the port at Whittier to Anchorage. Because the fuel refining or pipeline transmission systems are already in place, these areas are prime sites for plant construction. Gas-fired units can be located near wells or gas pipelines. The Anchorage, Cook Inlet, and Kenai regions are well suited in this respect.

COMMERCIAL AVAILABILITY

Natural gas and distillate-fired steam-electric plants are a commercially available mature technology. The Powerplant and Industrial Fuel Act of 1978 (PIFUA), however, prohibits the use of oil or natural gas for continuous duty generating units exceeding 10-MW capacity. Exemptions under PIFUA may be granted only when a utility can show that no reasonable alternatives exist. The possibility exists that synthetic or gaseous fuels may be derived from coal in the future (these fuels would be exempt from the restrictions of PIFUA).

CONVERSION EFFICIENCY

Units of this type exhibit a conversion efficiency that ranges from 28 to 30%.

ESTIMATED COST OF POWER

The cost of power is a function of both the size of installation and fuel type. Distillate fuel-fired plants require more storage and pollution control equipment than do the gas-fired plants. Estimated costs for 200-MW distillate fuel oil and natural gas-fired steam-electric plants operating at 31 and 30% conversion efficiencies, respectively, and a 65% capacity factor are as follows:

	Distillate Oil (mills/kWh)	Natural Gas (mills/kWh)
Capital	13	9
Fuel	103	48
Operating and Maintenance	4	4
Total Production Cost	120	61

An estimated 70% of the plant capital costs and 16% of operation and maintenance costs would be spent outside of Alaska. Fuel would be purchased within the region.

ENVIRONMENTAL CONSEQUENCES

A 200-MW capacity distillate plant would require 20 acres compared to 13 acres for gas, respectively. The difference is due to the distillate tank storage facilities. Water requirements are about the same as those for other thermal plants of the same size.

Of all combustion processes, air pollution problems are the least when gas is burned. If residual fuels are used, stack scrubbers may have to be installed to remove sulphur dioxide. Nitrogen oxide emissions may be significant enough to require control techniques such as two-stage combustion.

The impacts on aquatic species caused by cooling water intake and discharge systems will be about the same as any other comparably sized combustion steam generating plant. A minimal impact on terrestrial biota can be expected from the loss of habitat.

SOCIOECONOMIC CONSIDERATIONS

A 200-MW plant is estimated to require a peak construction force of 580 and an operating force of 70. These work forces could strain facilities, particularly housing, in many of the small communities along distribution pipelines.

BIOMASS-FIRED STEAM-ELECTRIC GENERATION

Biomass fuels available in the Railbelt region for power generation include sawmill wood waste and fuel derived from municipal waste. Small quantities of waste oil are also available. Wood waste has been used as an energy source for many years, particularly in the timber industry. Use of refuse-derived fuel is a more recent concept and is less well developed in the United States.

POSSIBLE RAILBELT APPLICATIONS

In the Railbelt region, biomass power plants using municipal refuse supplemented by wood residue and coal potentially may contribute up to 5% of future power needs. These units would be central station plants serving single load centers or connected to a Railbelt power grid. Relatively small plants at Anchorage and Fairbanks may be feasible, making full use of the municipal refuse, waste oil, wood residue, and supplemental coal available in the respective areas.

COMMERCIAL AVAILABILITY

Direct-fired steam-electric plants that are designed to use biomass fuels as the primary feed material or that have the capability to be supplemented by fossil fuels are commercially operating. Processes for converting biomass to a gas as fuel for power heat and power generation could be available in five years. Wood-to-methanol (wood alcohol) plants are commercially available, while herbage-to-methanol processes remain to be demonstrated.

CONVERSION EFFICIENCY

The typically high moisture content of biomass fuels and small scales of operation introduce thermal inefficiencies into a biomass-fueled power plant. Heat rates can range between 20,000 Btu/kWh and 14,000 Btu/kWh for rated capacities of 5 and 50 MW, respectively. (This compares to heat rates of 9,000 Btu/kWh for many coal-fired plants.) Operated as base-loaded units, biomass facilities have demonstrated high reliability.

ESTIMATED COST OF POWER

The power costs of dual, direct-fired refuse/coal electric-generating plants of 25-MW rated capacity and 24% conversion efficiency in Anchorage and 20-MW rated capacity in Fairbanks are estimated to be 67 and 78 mills/kWh, respectively. The cost components are as follows:

	Biomass-Fired Anchorage (mills/kWh)	Steam-Electric Fairbanks (mills/kWh)
Capital	32	36
Fuel	0	7
Operations and Maintenance	35	35
Total Production Cost	67	78

The high construction costs of small-scale biomass power plants are a major factor in the relatively high power costs of this option. Coal is used as a supplement to refuse-derived fuel, with the latter proportion increasing over the life of the facility. The capacity factor used in estimating costs for these units is 65%.

RESOURCE AVAILABILITY

Potential sources of biomass fuels in the Railbelt region include mill residue (bark chips, slabs, sawdust and planer shavings) from saw mills in the area and municipal waste from Fairbanks and Anchorage. A major consideration of using biomass for power generation is its availability near (within approximately 50 miles) the power plant. The high moisture content and low bulk density of most biomass material make shipping it long distances for fuel use economically prohibitive.

ENVIRONMENTAL CONSEQUENCES

Water resource impacts of biomass-fired power plants are not expected to be significant because of the small plant capacities that are considered likely. Proper siting and design of intake and discharge should minimize withdrawal and discharge impacts. The burning of biomass could significantly impact ambient air quality. Facilities of approximately 5-MW capacity or more will require an air pollution control system that meets federal New Source Performance Standards. Land requirements for biomass-fired plants are expected to be similar to coal-fired plants. Because of the relatively small plant capacities involved, the impact on the terrestrial biota is expected to be minimized through the plant siting process.

SOCIOECONOMIC CONSIDERATIONS

A relatively small labor force is required to construct and operate biomass-fired facilities. For 15- to 30-MW plants, a construction and operating staff would be approximately 65 and 25, respectively. The effect of plant construction and operation in the Anchorage, Fairbanks, and Soldotna areas would be minimal, while the impact on smaller communities, such as Nenana, could be significant.

NUCLEAR LIGHT WATER REACTORS

Nuclear steam-electric generation converts heat generated in the fissioning of uranium atoms into steam. The steam is used to drive turbine generators, which generate electricity. Nuclear steam-electric generation has two basic design concepts: the boiling water reactor (BWR) and pressurized water reactor (PWR). Both concepts employ designs based on the use of natural water ("light water") as the reactor coolant. In the BWR design, cooling water circulates through the reactor core where it is heated to steam that is used directly to drive the turbogenerator. In the PWR concept, water is heated under high pressure in the reactor core. Steam used to drive the turbogenerator is generated in a secondary heat exchanger in this concept.

POSSIBLE RAILBELT APPLICATION

Nuclear steam-electric generation is not considered applicable to the Railbelt region, primarily because the available sizes of nuclear plants are too large for forecasted Railbelt loads. Because of the large economies of scale in nuclear technology, plant sizes are large. These plants are designed for baseload operation and are available from domestic vendors in the 800 to 1200 MW range. Because the forecasted Railbelt interconnected load in 2010 would require a capacity of only 1800 MWe, even the smallest nuclear plant would contribute about 50% of the total capacity requirement. Because of reliability and reserve considerations, a plant exceeding 20% of the system total capacity is not recommended.

In addition to the technical/economic considerations impacting the use of nuclear power in Alaska, current State statutes specifically exclude nuclear energy production from the definition of power projects that can be funded through the Power Development Fund (see Power Authority Act as amended 4483.230(4)).

COMMERCIAL AVAILABILITY

Nuclear technology is well developed. Nuclear steam supply systems are commercially available from four different vendors. Due to protracted licensing and construction requirements, 12 years currently are required from the decision time to bringing a nuclear plant on-line. Therefore, the earliest on-line date would be 1994, assuming a 1982 decison.

CONVERSION EFFICIENCY

The light water nuclear plants considered here demonstrate a conversion efficiency of 32.5% and a capacity factor of 65%.

ESTIMATED COST OF POWER

The estimated cost of power from a 1000-MW nuclear plant constructed in the Railbelt region is 31 mills/kWh. The cost components are as follows:

	Nuclear Steam-Electric (mills/kWh)
Capital	19
Fuel Cycle	8
Operating and Maintenance	4
Total Production Cost	31

About 60% of the capital expenditures would be outside the Railbelt and most of the labor would be imported from the lower 48 states.

RESOURCE AVAILABILITY

The available nuclear capacity is essentially unlimited from the standpoint of resources. By the time U.S. low-cost uranium resources are exhausted, the fast breeder reactor (FBR), whose costs are insensitive to uranium supply, is anticipated to be commercially available.

ENVIRONMENTAL CONSEQUENCES

Nuclear plants typically require 250 to 2,000 acres of land for the plant site and exclusion area. Less than 50 acres of terrestrial biota habitat is usually lost. As with all large thermal generation plants, significant quantities of cooling water are required. For a 1000 MWe-plant, 310,000 gpm is needed for a once-through system or 6,200 gpm for a recirculating system. The withdrawal and discharge of water quantities of this magnitude cause some impact on aquatic species. Routine radioactive releases present a minimal environmental impact. A major reactor accident that would release enough radioactivity to contaminate the surrounding area is an extremely small possibility. This type of accident did not occur, for example, even in the case of the Three-Mile Island accident. With nuclear plants the radioactive waste and air pollution problems are minor compared to combustion thermal plants.

SOCIOECONOMIC CONSIDERATIONS

Construction of a nuclear plant can have adverse affects on nearby small communities. Housing, public services, and facilities would be potentially strained. The migration of skilled construction workers and their families would require an expansion of community services for the 7- to 10-year construction period. Only within the vicinity of Anchorage could a nuclear facility be constructed without major socioeconomic impact. Communities of 5000 or less population would experience severe impacts.

GEOTHERMAL GENERATION

The design of a geothermal electric plant depends highly on the characteristics of the particular geothermal resource used. Three basic generating technologies currently are available: 1) dry steam, in which the geothermal reservoir produces high-quality steam that can be used directly in turbines; 2) flashed steam, in which the hot pressurized water from the reservoir is flashed to steam for use in turbines; and 3) binary cycle, in which the low temperature of the geothermal water is used to heat a secondary working fluid with a low boiling temperature (such as freon or isobutane). This fluid is used to drive special turbines. Combinations of these basic designs also have been proposed. The cooled geothermal fluids are generally reinjected into the underground reservoirs.

Techniques are being developed for extracting energy from "hot dry rock" geothermal resources. Although this concept shows promise, it is probably 15 to 20 years away from commercial availability.

POSSIBLE RAILBELT APPLICATIONS

The power plant must be located near the geothermal reservoir. Only hot dry rock and low-temperature, liquid-dominated hydrothermal resources have been identified near the Railbelt. Known hydrothermal resources are too low temperature to be suitable for generation. Hot dry rock technology is as yet unproven and the resources are remotely located. Because of the presence of active igneous systems in the Railbelt region, further exploration for geothermal resources suitable for electrical development appears to be warranted.

COMMERCIAL AVAILABILITY

The dry-steam and flashed-steam plant technologies are well developed and commercially available. Both binary cycle and combined-cycle techniques are currently in the development stage. As just stated, commercial recovery of energy from hot dry rocks appears to be 15 to 20 years away.

CONVERSION EFFICIENCY

A plant operating on dry steam has a conversion efficiency of about 16%. Depending on the resource temperature, binary cycle designs may operate in a range of 5 to 10% conversion efficiency.

ESTIMATED COST OF POWER

The cost of geothermal electric energy is highly dependent on the resource's characteristics. High-temperature dry steam found at shallow depths can be used to generate electricity at about one fifth the cost of low-temperature water. The costs for three types of 50-MW geothermal energy sources operating at 10% conversion efficiency and a 65% capacity factor are as follows:

	Vapor-Dominated Hydrothermal (mills/kWh)	Binary Cycle (mills/kWh)	Hot Dry Rock (mills/kWh)
Capital	9	16	31
Fuel	0	0	0
Operating and Maintenance	26	26	26
Total Production Cost	35	42	57

An estimated 55% of the capital expenditures for a geothermal plant would be spent outside the Railbelt region. About 12% of the operating and maintenance expenditures would go outside the Railbelt.

RESOURCE AVAILABILITY

Low-temperature liquid-dominated resources have been discovered near Fairbanks where they have been used for space heating. Exploratory drilling has located another low-temperatue (170^{o}F) resource in the Willow area. Other more remote resources have been located in the Wrangell and Chigmit Mountains. Currently, geothermal electric generation in the Railbelt seems to be resource limited.

ENVIRONMENTAL CONSEQUENCES

The biggest impact to terrestrial biota from geothermal electric generation is the effects of drilling numerous production/reinjection wells. Some loss of habitat from the plant and the reservoir system would occur. If air emissions (H_2S, radon, methane) are not controlled, they can be hazardous to both humans and various biota.

Aquatic species can be affected by the accidental release of geothermal fluids. (Heavy metals and boron are particularly hazardous.) In normal operation, however, most of the hazardous compounds are reinjected into the ground. As long as the reinjected material is confined to the geothermal reservoir, little impact would occur on other water resources. Cooling water demands per unit of capacity are unusually high for geothermal plants because of their low conversion efficiencies.

SOCIOECONOMIC CONSIDERATIONS

A 50-MW geothermal electric plant is estimated to require a construction work force of 90. Because of the remoteness of the areas where the resources are found, construction camps for the workers probably would be necessary.

PEAT-FIRED STEAM-ELECTRIC GENERATION

Peat consists of partially decomposed plant matter and inorganic minerals that, over time, have accumulated in a water-saturated environment. Peat can be burned directly to fire a steam-electric plant or can be converted to a gas for use in a combustion turbine unit. Extensive experience has been gained using peat burned directly in a steam-electric power plant.

POSSIBLE RAILBELT APPLICATIONS

The Matanuska-Susitna Valley and Kenai Peninsula appear to have peat bogs that could possibly be suitable for energy production. One site, at Nancy Lake East, could provide fuel for a 30-MW cogeneration plant for about 15 years. However, significant peat use for power purposes most likely will not occur in the Railbelt in this decade for two reasons. First, the most known Alaskan peat has higher than desired ash content. Secondly, more site-specific resource availability and plant siting information needs to be obtained.

COMMERCIAL AVAILABILITY

The technology for using peat for a fuel in a steam-electric generating plant has been well demonstrated. Large plants in the 440-MW to 1000-MW range are operating or under construction in Ireland, Northern Europe and the Soviet Union. Little peat has been used in the United States. Boilers ranging from 20 to 300 MW of thermal output to handle peat are commercially available from European manufacturers. Peat gasifiers are currently under advanced research and development in the United States and elsewhere.

CONVERSION EFFICIENCY

Peat, because of its inherent high moisture content, introduces thermal inefficiencies into the combustion process. However, efficiencies improve with plant size. The heat rate for peat-fired plants of 50 MW is approximately 14,000 Btu/kWh. This rate compares to a heat rate of about 9000 Btu/kWh for a comparable coal-fired plant.

ESTIMATED COST OF POWER

The estimated cost of energy for a peat-fired steam-electric power plant of 30-MW rated capacity and operating at a 24% conversion efficiency is 79 mills/kWh. The cost components are as follows:

	Peat-Based Steam-Electric (mills/kWh)
Capital	11
Fuel	32
Operating and Maintenance	36
Total Production Cost	79

This estimate compares favorably with a 40-MW peat-fired power plant scheduled to be built in New Brunswick, where power costs are estimated to be about 55 mills/kWh.

RESOURCE AVAILABILITY

Although the quantity of peat resources is not well defined, significant fuel peat resources exist. The high ash content of much of Alaska peat could limit it use, however. Use of peat for power generation will require a careful matching of peat quality and quantity to power needs on a site-specific basis. Further resource assessment is necessary before the potential of peat or a power source alternative in the Railbelt can be fully evaluated.

ENVIRONMENTAL CONSEQUENCES

The use of peat as an energy resource will impact the region's air, water, and land resource. A careful matching of power plant location and peat processing, energy conversion, and emission control methods will be necessary to minimize environmental impacts.

SOCIOECONOMIC CONSIDERATIONS

A construction force of 65 and an operating staff of up to 25 would be required for a 15- to 30-MW plant. If the power plant is located at a "bog site" and construction and operation is associated with bog preparation and peat harvesting operations, additional staff would be required. Construction and operation of a facility in a remote location, such as Matanuska-Susitna Valley, could have significant impact on the small communities (Houston, Willow, and Knick) located nearby.

COMBUSTION TURBINES

Combustion turbines can burn natural gas, #2 fuel oil, or coal-derived fuels. Incoming air is compressed in the first stage of the turbine and fuel is injected into the combustor stage. The hot gases are expanded through the power turbine, which drives the compressor and the generator. The hot gases then are exhausted to the atmosphere. Considerable waste energy in the exhaust gases can be recovered by using alternative cycles. These cycles will be discussed under combined-cycle and cogeneration technologies.

POSSIBLE RAILBELT APPLICATION

Gas turbine plants are commercially available in sizes ranging from 0.5 MW to over 100 MW. Because they require no cooling water, that siting restriction is removed. If the plants are near a pipeline or refinery, they are ideally suited to the Railbelt application. Although gas turbines are designed for peaking operation, they can be used for intermediate or even baseload operation. Due to their low conversion efficiency, however, they are not normally used for baseload operation. Regenerative cycles that preheat the incoming air can enhance combustion turbine efficiency.

Although future installation of oil or gas-fired electrical generating equipment of over 10-MW capacity is banned by the Fuels Use Act (PIFUA), Alaska may be able to obtain exemptions because of its unique situation. Since many of the turbine components are shipped assembled, a plant that burns gas probably can be on-line 2 years after the decision to build is made. A Railbelt plant could be operating by 1984 if a decision were made in 1982.

COMMERCIAL AVAILABILITY

As mentioned earlier, gas turbines are commercially available in a variety of sizes.

CONVERSION EFFICIENCY

Depending on size and design, conversion efficiencies of gas turbines range from 28 to 34%.

ESTIMATED COST OF POWER

Overall power costs from 70-MW gas turbines are estimated at a 65% capacity factor and a conversion efficiency of 28%. The cost components are as follows:

	Natural Gas (mills/kWh)	#2 Fuel Oil (mills/kWh)
Capital	7	7
Fuel	44	111
Operation and Maintenance	7	7
Total Production Cost	58	125

Because most of the plant is preassembled, about 80% of the capital expenditures would be spent outside the Railbelt.

RESOURCE AVAILABILITY

Although supplies of natural gas and distillates suitable for use in turbines exist in the Railbelt, their future use is uncertain because of the present version of the Fuel Use Act. After 1990 the use of natural gas for electrical generation is prohibited, unless an exception can be obtained. Combustion turbine plants, however, will be allowed to operate on fuels derived from coal, biomass products, or distillate oil.

ENVIRONMENTAL CONSEQUENCES

Because combustion turbines do not require the use of water cooling, aquatic species should not experience any significant impacts.

Air pollution problems also should be minimal, particularly if natural gas is used to fire the turbines. Due to the relatively low firing temperature, nitrogen oxides are easily controlled. Sulphur emissions are no problem with natural gas; they can be controlled in distillate firing by controlling the fuel's sulphur content.

Land losses are only 3 acres for a 170-MW plant; therefore, the loss of habitat should be small. Probably the most serious impact on both terrestrial biota and humans is the "noise pollution" caused by turbines. Even with baffling, these plants tend to give off an offensive high decibel, high pitch sound.

SOCIOECONOMIC EFFECTS

Because combustion turbine plants can be built with a relatively small work force, 30 construction workers for a 170-MW plant, the socioeconomic impacts will be minimal. The siting restrictions are few, so construction near the very small towns that would have difficulty in absorbing even 30 workers should be able to be avoided.

COMBINED-CYCLE POWER PLANTS

A combined-cycle power plant uses two thermodynamic cycles to generate electricity. The prime mover is a combustion turbine that drives a conventional combustion turbogenerator. The exhaust from the turbine is used in a heat recovery boiler to generate steam that drives a steam turbine. Combustion turbines may be retrofitted to convert them to combined-cycle generation. Likewise, the steam boilers can be bypassed in a combined cycle and operate only on the combustion turbine cycle. This mode of operation allows considerable flexibility both in constructing new capacity and in operating existing capacity.

The combined-cycle power plant should not be confused with the various cogeneration designs in which waste heat from the electrical generation is used for process and/or space heat applications.

POSSIBLE RAILBELT APPLICATIONS

Combined-cycle plants currently are operating in Fairbanks and Anchorage. Further construction of this type of plant will be restricted by the Fuel Use Act, which limits the construction of new generating capacity burning gas or oil after 1990, unless an exemption can be obtained. If coal gasification plants were built in the Railbelt, then large combined-cycle plants could be built to operate on the coal-derived gas. The combined-cycle plants operating on coal-derived gas can operate as intermediate duty or baseload capacity and would have no restrictions under the Fuel Use Act.

COMMERCIAL AVAILABILITY

Combined-cycle plants currently are available in a wide range of sizes. Assuming an exemption for a natural-gas-fired design, a 200-MW plant could be installed in about three years and therefore could be on-line in 1985 with a 1982 decision. Coal gasifier - combined-cycle plants are not yet commercially available. The earliest such a plant could be on-line in the Railbelt is estimated to be 1991.

CONVERSION EFFICIENCY

The conversion efficiency of a combined-cycle plant is approximately 40%.

ESTIMATED COST OF POWER

The capital costs of combined-cycle plants are markedly higher than the combustion turbines, but because of higher efficiency, their operating costs are considerably less. A 200-MW combined-cycle plant operating at a 40% conversion efficiency and a capacity factor of 15% could generate electricity in the Railbelt at the estimated costs shown below:

	Natural Gas (mills/kWh)	#2 Fuel Oil (mills/kWh)
Capital	10	10
Fuel	33	79
Operation and Maintenance	6	6
Total Production Cost	49	95

Approximately 70% of the capital costs would be spent in the lower 48 states.

ENVIRONMENTAL CONSEQUENCES

Combined-cycle plants are expected to have the same environmental impacts as those of a combustion turbine. Air emissions would consist of some carbon monoxide and nitrogen oxides, but ample control technology is available to keep these emissions within standards. The steam turbine requires cooling water for the condensers, although much less than a comparably sized plant operating only on the steam cycle. Loss of habitat will affect terrestrial biota. About 12 acres of land are needed by a 200-MW plant when fuel storage is included.

SOCIOECONOMIC CONSIDERATIONS

The construction of a 200-MW combined-cycle plant requires a work force of 45 for about two years. Severe socioeconomic impacts would be expected only in small communities where the infrastructure is insufficient to meet new demands. Because operating and maintenance can be performed with 15 people, few impacts should result.

DIESEL GENERATION

A diesel generating plant uses an internal combustion engine operating on a diesel cycle to drive an electric generator. These units are commonly used for standby or peaking capacity. Some 36 MW of utility capacity and 17 MW of military capacity presently are installed in the Railbelt. Diesel units are reliable, with forced outage rates of 10% or less. Also, they can operate efficiently at less than full load.

POSSIBLE RAILBELT APPLICATION

Diesel generation presently accounts for about 5% of Railbelt generation. Station sizes typically range from 2 to 18 MW in the Railbelt, although 30 MW units are available. Few siting constraints exist. Because cooling systems are usually closed, a constant water supply is not required. Diesel units require a weatherproof structure that is designed to suppress noise and also require access to a fuel supply via barge, rail, or truck. Diesels can start up rapidly under most weather conditions. Thus, they are useful for emergency power, peaking, and supplemental (to wind or tidal power) applications.

COMMERCIAL AVAILABILITY

Diesel units are readily available in a wide variety of sizes. Since they are largely prefabricated, they can be installed in a short time. Including permits, a 12-MW unit could be on-line in two years or less. Therefore, a diesel unit could be generating power by 1984 with a 1982 decision.

CONVERSION EFFICIENCY

The conversion efficiency of diesels is sensitive to both design and size. Typically, diesels in the Railbelt exhibit efficiencies of about 33%. Very small units have conversion efficiencies as low as 30%, whereas large, slow-speed units are as high as 40%. The diesel has excellent load-following characteristics because the efficiency of a 900 kW unit changes only 7.5% over the entire load range of 400 to 900 kW. A comparable combustion turbine unit changes more than 100% over the same range.

ESTIMATED COST OF POWER

The estimated costs of power from a 12-MW diesel unit constructed in the Railbelt and operating at 65% capacity factor and 38% conversion efficiency are as follows:

	Distillate Oil (mills/kWh)
Capital	7
Fuel	87
Operation and Maintenance	6
Total Production Cost	100

About 80% of the capital cost of a diesel unit would be spent outside of Alaska because these units largely are factory assembled and require a minimum of site labor.

RESOURCE AVAILABILITY

Diesel units can be fueled by a variety of liquid and gaseous hydrocarbons, but most Alaskan units are presently fueled by distillate oils. Synthetic fuels, such as low and medium Btu gas from coal and biomass, and methanol, also have been proposed for diesel units. Ample fuel should be available from one or more of these sources.

ENVIRONMENTAL CONSEQUENCES

Diesel units should cause very small environmental impacts because they do not require continuous sources of cooling water and because they have a small land requirement (usually less than 5 acres including tank storage).

Air emissions are mostly carbon monoxide (controlled with catalytic converters) and particles. Except in the nonattainment areas of Fairbanks and

Anchorage, siting approval should not be difficult. Noise pollution is a problem that can be controlled by noise-suppressing housing for the units.

SOCIOECONOMIC CONSIDERATIONS

Socioeconomic impacts should be minimal because of these units' small size and because few siting constraints exist. A large diesel generator (12 MW) would require a construction crew of about 25 workers for a year. Much of this force could be made up of local laborers, so the impact on even small communities should be easy to absorb.

CONVENTIONAL HYDROELECTRIC

Hydroelectric plants convert the potential and kinetic energy of water into electrical energy. The two basic types of hydro plants are conventional and low head. By definition, conventional plants have a head of 20 meters (65 ft) or more. Conventional hydroelectric plants use a dam to store water and to establish a hydraulic head, a penstock to convey the water from the reservoir to the turbines, hydroelectric turbines to generate the electricity, a tailrace into which the water is discharged after leaving the turbines, and a spillway over which water not needed for the turbines can be released. Fish passage equipment may also be required.

Low-head hydroelectric installations have little or no reservoir storage capacity. They operate essentially as run-of-river generation. They often use propeller type hydroelectric generators.

POSSIBLE RAILBELT APPLICATION

Over 700 potential hydropower sites have been identified by the Federal Power Commission, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Geological Survey, and the State of Alaska. The sites were assessed based on economic environmental characteristics. The 16 most promising sites in the Railbelt were selected on this basis. Added to this list are the two Upper Susitna Sites (Devil Canyon and Watana) plus two other Railbelt sites (Bradley Lake and Grant Lake), which are being seriously considered for development. The location of these sites are shown in Figure 1. The estimated annual energy generation of these 20 dams is over 14,000 GWh, which is greater than five times the current Railbelt energy demand. Because these sites would be high-head dams with storage capacity, they are capable of supplying either peaking or baseload capacity.

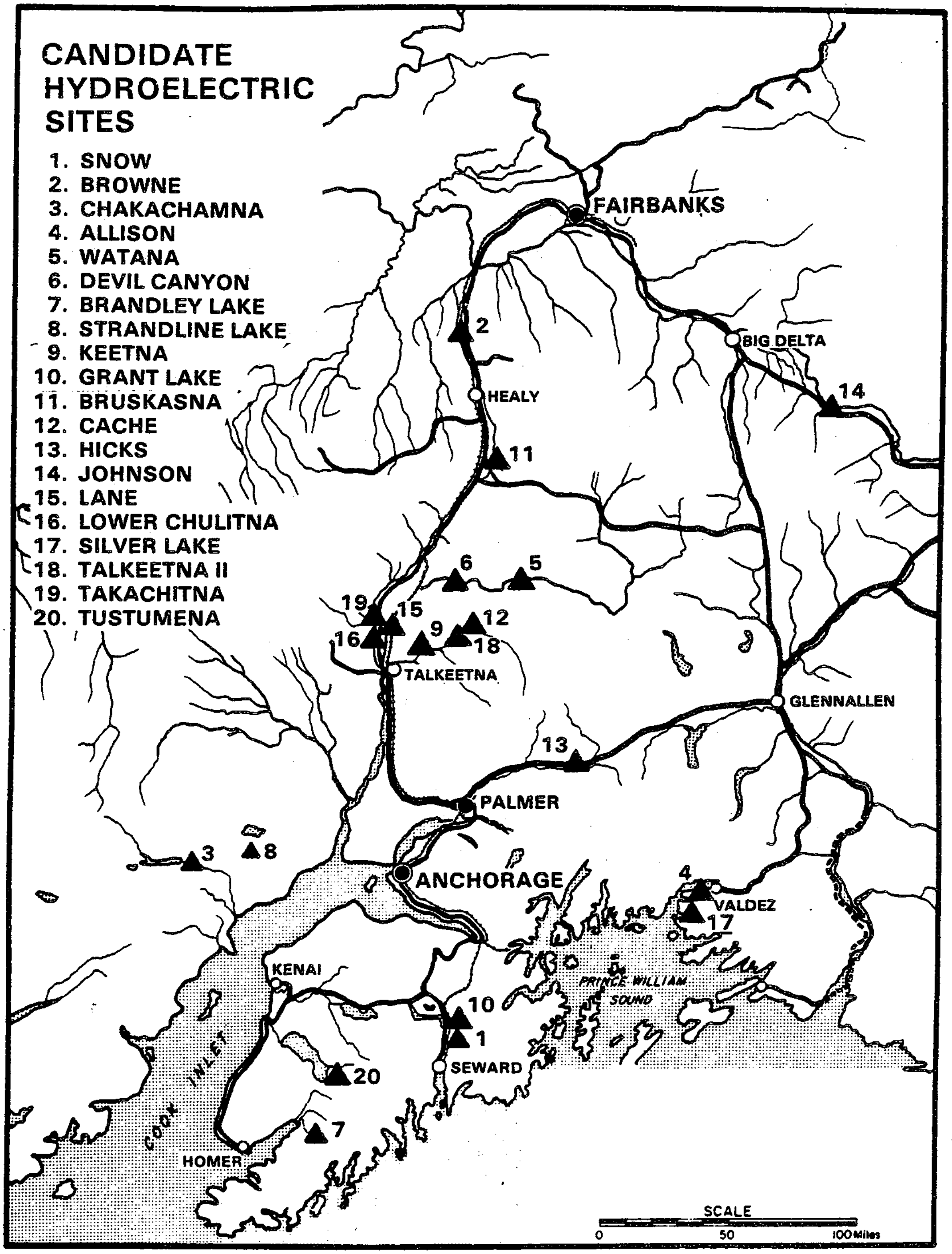

FIGURE 1. Candidate Hydroelectric Sites

COMMERCIAL AVAILABILITY

Hydroelectric generation is a well developed technology; the first plant in the U.S. was put into service in 1882. Two significant hydro plants are currently operational in the Railbelt. One is at Ekultna (30 MW) near Anchorage and the other is at Cooper Lake (15 MW) on the Kenai Peninsula. Solomon Gulch (19 MW) near Valdez is under construction. The type of conventional hydro plants considered here requires 5 to 10 years to construct. An estimated 3 to 5 years must be added to construction time for preconstruction field studies, licensing and design. Therefore, a hydro plant might be available from 8 to 15 years after a decision to proceed. With a 1982 decision date, a plant could be on-line from 1990 to 1997.

PERFORMANCE

Hydroelectric generators are very efficient - 90% or higher. A hydro plant will characteristically convert to electrical energy 80% or more of the energy in the water passing through the turbines. A more significant measure of a hydro project's contribution to a system is the average annual energy generation divided by the nameplate generator capability (the theoretical maximum generation). This measure of efficiency (utilization or capacity factor) takes into account the upstream water storage capacity, the necessity to spill water during the spring runoff and other factors that affect the energy delivered to the system. Hydro projects typically demonstrate a utilization factor of 45 to 60%.

ESTIMATED COST OF POWER

The cost of power from a hydro project is highly dependent on the specific site. Major cost variables are type, size head, and location of the project. An ideal site is located reasonably close to a labor center in a narrow, deep canyon with a minimum of excavation needed to reach bedrock. Low-head hydro development requires relatively less expenditure for dams and spillways than do the conventional high head developments. Estimates have been made of the 20 promising Railbelt sites shown in Figure 1. These costs are shown in the last three columns of Table 2, which summarizes the characteristics of these sites. An estimated 65% of the costs of a large hydro project would be spent in the Railbelt. For a small hydro project, only about 35% of the expenditures would be made in the Railbelt.

ENVIRONMENTAL CONSEQUENCES

The most obvious environmental impact of a hydro project is the loss of land caused by the impoundment. Conversely, if the river on which the project is located is subject to flooding, the dam can enhance the usage of downstream property by controlling the runoff. The reservoir created for a hydro project causes a fundamental change in the hydrologic system from a flowing-water to a still-water environment. Evaporation losses and groundwater seepage are then increased. In the low runoff regions of the northern Railbelt, these losses, if substantial, could cause significant impacts by reducing downstream flow.

The operation of the dam can have adverse ecological impacts. When the hydro project is used for peaking generation, large diurnal fluctuations in river flow result. These fluctuations can impact both the aquatic and terrestrial biota. They can also be hazardous to recreationists. Conversely, when designed with adequate storage capacity, the dams attenuate flood flow. They can improve water quality and aquatic habitat by augmenting low river flow. This flow regulation can be a large positive impact in the Railbelt region where many rivers exhibit wide variations in natural flow.

Water quality is affected by reservoir operation. The large still-water areas of the reservoir cause stratification during the summer months. Under these conditions the surface layer is heated to a higher temperature than would be found under natural free-flowing conditions. Lower layers are not aerated as much as they would be under free-flow conditions; therefore, a low dissolved oxygen (DO) content results. Both of these effects (high water temperature and low DO) can have adverse impacts on aquatic biota, especially cold water fish. These impacts can be minimized by designing the reservoir intake structure to take water from several different levels.

TABLE 2. Summary of More Favorable Potential Intermediate and Large-Scale Hydroelectric Sites in the Railbelt Region[a]

Site	Big Game Present	Waterfowl, Raptors Endangered Species	Anadromous Fisheries	Agricultural Potential	Wilderness Potential	Cultural, Recreational and Scientific Features	Estimated Capital Cost[b] ($/kW)	Estimated O&M Cost ($/kW/yr)[c]	Estimated Cost of Power (mills/kWh)
Bradley Lake	Black Bear Grizzly Bear	Peregrine Falcon	None	25-30% Marginal Soils High-Quality Forests	Good to High Quality Scenery	Boating	2,900[d]	58	49
Browne	Black Bear Grizzly Bear Moose Caribou (winter)	Low Density of Waterfowl	None	More than 50% Marginal Soils	None	Boating Potential	6,245	125	95
Bruskasna	Black Bear Grizzly Bear Moose Caribou (winter)	Low Density of Waterfowl, Nesting and Molting	None	None Identified	Good to High Quality Scenery	Boating Potential, Proposed Ecological Reserve	7,933	160	126
Cache	Black Bear Grizzly Bear Moose (winter) Caribou (winter)	None Identified	Spawning Area.	None Identified	Good to High Quality Scenery Primitive Lands	Boating Potential	11,275	225	179
Chakachamna	Black Bear Moose	Waterfowl Nesting and Molting	Present	Spruce and Hardwood Forest	Good to High Quality Scenery, Primitive and Natural Forest	Boating	2,997	60	48
Devil Canyon[f]	Black Bear Brown Bear Moose Caribou	Low Population of Waterfowl, Cliff Nesting Areas for Ravens and Raptors	Spawning Areas Downstream	Unknown	Wilderness Quality Lands	Hunting, Boating	1,890	38	23[g]
Hicks	Black Bear Grizzly Bear Caribou Moose (winter)	Waterfowl Nesting and Molting	Present Downstream	None Identified	Average Quality Scenery	Hunting	8,817	180	141
Johnson	Black Bear Grizzly Bear	Low Density Waterfowl Nesting and Molting Area	Spawning Area	25-50% Suitable Soils Spruce-Hardwood Forest	None Identified	Boating	Not Available	Not Available	120[e]

TABLE 2. (contd)

Site	Big Game Present	Waterfowl, Raptors Endangered Species	Anadromous Fisheries	Agricultural Potential	Wilderness Potential	Cultural, Recreational and Scientific Features	Estimated Capital Cost[b] ($/kW)	Estimated O&M Cost ($/kW/yr)[c]	Estimated Cost of Energy (mills/kWh)
Keetna	Black Bear Grizzly Bear Caribou (winter) Moose (Fall & Winter)	None Identified	Spawning Area	None Identified	Good to High Quality Primitive Lands	High Boating Potential	4,767	95	77
Lane	Black Bear Moose Caribou	Low Density Waterfowl Nesting and Molting Area	Spawning Area	More than 50% Suitable Soils Spruce-Poplar Forest	None Identified	Boating Potential	Not Available	Not Available	65[e]
Lower Chulitna	Black Bear Grizzly Bear Caribou	Medium Density Waterfowl Nesting and Molting Area	Spawning in Vicinity	More than 50% Suitable Soils	Selected for Wilderness Consideration	Boating Potential	Not Available	Not Available	59[e]
Snow	Black Bear Dall Sheep Moose (winter)	Nesting and Molting Area	None	None Identified	None Identified	Chugach N.F. Proposed Biological Reserve	5,092	100	738
Strandline Lake	Black Bear Grizzly Bear Moose	Nesting and Molting Area	None	25-50% Marginal Soils	Good to High Quality Scenery, Primitive Lands	None Identified	6,300	130	94
Talkeetna II	Black Bear Grizzly Bear Moose (fall & winter) Caribou (winter)	None Identified	Spawning Area	None Identified	Good to High Quality Scenery, Primitive Lands	Boating Potential	9,993	200	158
Tokachitna	Black Bear Moose Caribou	Medium Density Waterfowl Nesting and Molting Area	Spawning in Vicinity	50% of Upland Soils Suitable	Nearby Primitive Area	Boating Potential	Not Available	Not Available	64[e]
Tustumena	Black Bear Dall Sheep	None Identified	None Identified	None Identified	Selected for Wilderness Consideration Good to High Quality Scenery, Primitive Lands, Natural Features	None Identified	Not Available	Not Available	125[e]
Watana[f]	Black Bear Brown Bear Moose Caribou	Low Population of Waterfowl	Spawning Areas Downstream	Unknown	Wilderness Quality Lands	Hunting Boating	3,890 (I) 4,030 (II)	78 (I) 81 (II)	50 (I)[f] 80 (II)[f]

(a) Environmental and land-use characteristics and capital cost estimates taken from Acres American (1981b) unless otherwise noted.
(b) Costs are overnight construction costs in July 1980 dollars.
(c) 2% of capital costs used for all projects.
(d) Preferred alternative. Provided in a telephone conversation with John Denniger from the Alaska Power Administration, Juneau, Alaska.
(e) Power costs were determined using cost indices provided in APA (1980) with Chakachamna estimate as a base.
(f) Devil Canyon and Watana dams comprise the Upper Susitna project, which is planned to be constructed in three stages, Watana I (680 MW), Watana II (1020 MW), Devil Canyon (600 MW). Average cost of power following construction of all stages is 56 mills/kWh.
(g) Corps of Engineers (1980).

As water is spilled over the spillway (typically during the spring runoff), it entrains atmospheric gases (nitrogen and oxygen). When the gas levels reach the supersaturation point, they can cause death to fish. Similarly, the high velocity of water in the spillways and outlet structures can cause scouring of the dam structures and river banks. Both of these effects can be mitigated by proper spillway design.

Alteration of streamflow characteristics by hydroelectric projects can have a serious impact on aquatic biota. Of particular concern in the Railbelt region is the effect on the anadromous salmonids. Major impacts that are difficult to mitigate include the following: loss of spawning areas above and below the dam; loss of rearing habitat; reduction or elimination of upstream access to mitigating fish; increased mortalities of downstream migrants; and altered timing of downstream migration. An initial assessment of potential hydropower sites in Alaska indicates that major impacts on anadromous fish could be expected on such salmon streams as the Tanana, Beluga, Skwentna, Susitna, and Copper Rivers.

The major impact on terrestial biota is the inundation of large land areas of wildlife habitat. Big game animals can be affected by loss of seasonal ranges and interruption of migratory routes. Winter ranges are particularly critical. Flood control by dams may significantly reduce the extent of wetland habitats because of the elimination of seasonal inundation of large areas downstream of the dams. This action can be expected to adversely affect moose and other wetland species. Fish-eating raptors and bears could be affected by the loss of andromous fish if passage is reduced or eliminated by the dams.

Mitigative measures can be taken to reduce many of these impacts, except the loss of habitat. However, some new habitat, such as nesting islands, could be created by spoils or channels. Impacts on wildlife can be minimized by selecting only those sites where wildlife disturbances would be the least. Table 1 summarizes the environmental impacts that could be anticipated at the 20 most promising Railbelt hydro sites.

SOCIOECONOMIC CONSIDERATIONS

The combination of remote sites and a large number of construction workers can be expected to cause a boom/bust cycle for most conventional hydro projects in the Railbelt. These sites are located at or near communities with a population of 500 or less. The in-migration of the 250 to 100 workers required for a project in the range of 100 to 1000 MW would more than quadruple the present population. Table 3 shows the representative labor forces and construction periods for small and medium-sized projects. The installation of a construction camp would not mitigate the impacts on the social and economic structure of a community.

TABLE 3. Representative Manning Requirements for Hydroelectric Projects

Rated Capacity	Construction Period (years)[a]	Construction Personnel (number of persons)	Operation Personnel (number of persons)
Small Hydro (5 MW)	2	25 to 35	2 to 3
Conventional Hydro (100 MW)	5 to 10	200 to 400	10 to 12

(a) To first power.

FUEL CELLS

The fuel cell is a solid state device for producing electricity by electrochemically combining hydrogen and oxygen. The hydrogen is supplied by reforming a hydrocarbon fuel such as oil, natural gas, or low or medium Btu synthetic gas derived from coal or other biomass sources. The oxygen is obtained from the atmosphere. Two basic fuel cell designs are currently under development: a cell using phosphoric acid as an electrolyte and a more advanced cell using molten carbonate as an electrolyte. Current demonstration fuel cell plants range in size from 25 kW to 11 MW.

POSSIBLE RAILBELT APPLICATION

When commercially available, fuel cell power plants could potentially play a useful role in the Railbelt electric power system as peak power generating units. The superior heat rate of fuel cell power plants over traditional natural gas combustion turbines peaking units is largely responsible for this potential. In the Anchorage area, fuel cell stations in the 10- to 25-MW size range fueled by natural gas could serve in a peaking and intermediate load-following capacity. Similar-sized fuel cell units could be an appealing follow-on system to existing combustion turbine power plants in the Fairbanks area. Coal gasifier or natural gas fired - fuel cell - combined cycle plants also hold future promise in a baseload capacity role.

COMMERCIAL AVAILABILITY

Fuel cells are an emerging technology. No commercial units are currently operating, although several demonstration units in the commercial size range are currently being tested. Most demonstration plant experience has been achieved using phosphoric acid as the electrolyte. Several small plants (1 MW or less) using the phosphoric acid fuel cells have demonstrated satisfactory operation. Units incorporating this technology are expected to be commercially available in the mid 1980s. Fuel cell power stations incorporating molten carbonate electrolytes and combined-cycle technology are not expected to be commercially available until the late 1980s and early

1990s. Early introduction of fuel cell power plants could be constrained by technical problems, insufficient orders, and national fuel policy.

CONVERSION EFFICIENCY

Fuel cell efficiencies are typically better than conventional methods of converting thermal energy to mechanical energy for power generation. Stand-alone fuel cell stations should exhibit conversion efficiencies in the range of 38 to 47%. If fuel cell stations are operated in the combined-cycle mode, efficiencies should range from 48 to 60%.

ESTIMATED COST OF POWER

The estimated costs of power from dispersed fuel cell stations using phosphoric acid electrolyte and operating at a 38% conversion efficiency are estimated as follows:

	Distillate (mills/kWh)	Natural Gas (mills/kWh)
Capital	9	9
Fuel	81	32
Operation and Maintenance	7	8
Total Production Cost	97	49

These costs are for 10-MW units operating at a 65% capacity factor located in an urban area. Only rough estimates of coal gasifier and natural gas combined-cycle plants are available. Power costs for these plants are expected to be 45 and 31 mills/kWh, respectively.

RESOURCE AVAILABILITY

Fuel cells can be fueled by a variety of liquid and gaseous hydrocarbons. Synthetic fuels, such as low and medium Btu gas from coal and biomass, are also being evaluated. The most fully developed process uses naphtha and methane in phosphoric acid fuel cells. If current availability of competitively priced natural gas in the Railbelt region continues, fuel cell stations could serve well as peaking and intermediate load-following units.

In the 1990s coal deposits in the Railbelt area (e.g., Beluga, Nenana) could provide the fuel for gasifier - combined cycle - fuel cell plants operated as baseload stations.

ENVIRONMENTAL CONSEQUENCES

Fuel cell plants are not expected to have major environmental impacts. Because of the high efficiencies of fuel cells and ease of controlling potential pollutants, fuel cells represent a dramatic improvement in air-quality impacts over combustion technologies. Water is produced by fuel cells during normal operation, minimizing the need for water during operation. Additional cooling water may be required by fuel cells operated as combined-cycle plants, however. Appropriate water-wastewater management planning will assure that thermal discharges comply with receiving stream standards. Impact on the terrestrial ecosystem is expected controlled to acceptable levels by proper siting.

SOCIOECONOMIC CONSIDERATIONS

Because of the availability of fuel and the absence of major environmental effects, small-scale (10 MW) fuel cell plants would be located in or near load centers to minimize transmission losses. Construction of these plants would extend over a year and would involve a work force of 90 persons. A construction force of this size could have a significant impact on a small community but little on a large community. Construction of a larger combined-cycle fuel cell plant could have a relatively greater impact.

STORAGE TECHNOLOGIES

Energy-storage technologies provide a way to use baseload electrical generating capacity to meet peak power demands. Energy-storage technologies have three major applications: 1) storage of energy from baseload plants during off-peak hours for release during peak periods, 2) storage of energy from intermittent operating generating facilities, and 3) standby power supply in case of power station or transmission system failure.

PUMPED HYDROELECTRIC

A hydroelectric pumped-storage plant consists of an upper and a lower reservoir, a reversing turbogenerator, and interconnecting piping. Water is pumped from a lower reservoir to the upper reservoir during off-peak hours. During peak demand periods, the water is allowed to flow from the upper reservoir through turbines to the lower reservoir, generating power in the process.

Possible Railbelt Applications

No hydroelectric pumped-storage projects have been developed in the Railbelt region. Circumstances under which development of pumped storage and other energy-storage projects might be attractive in the Railbelt region include the following:

1. use of energy-storage projects in conjunction with natural-gas-fired combined-cycle baseload plants to meet peak loads
2. use of energy-storage projects in conjunction with coal-fired baseload plants to meet peak loads
3. use of energy-storage projects to retime output of the proposed Cook Inlet tidal power project
4. use of energy-storage projects in conjunction with dispersed smaller-scale intermittent power projects (solar or wind) to provide firm power
5. use of energy-storage projects to enhance system reliability.

Commercial Availability

Hydroelectric pumped-storage is a well-developed technology. Pumped-storage plants had their commercial origin in the United States in 1929. Commercially operating pumps/turbines have been built with capacities ranging from 1.5 to 400 MW, with larger units expected in the future.

Conversion Efficiency

The overall conversion efficiency of hydroelectric pumped-storage plants is about 72%.

Estimated Cost of Power

Estimated costs for pumped-storage installations are highly site specific. Costs can vary significantly. Electric energy costs with 20-mill baseload power is estimated to be 56 mills/kWh for a 100-MW plant facility operating at a 21% capacity factor. The cost components are as follows:

	Pumped Storage (mills/kWh)
Capital	23
Fuel	28
Operation and Maintenance	5
Total Production Cost	56

Resource Availability

Although pumped-storage sites have not been identified in the Railbelt region, the significant hydro potential in the region indicates that such future development is possible as fossil fuel availability, load, and alternative energy generating conditions permit.

Environmental Consequences

The impacts of a hydroelectric pumped-storage facility on water resources are significant and are similar to those of a conventional hydroelectric facility. The major impacts occur from basin flooding and alteration of the natural hydraulic regime of both surface water and groundwater. Biological impacts are also potentially significant and will require detailed evaluation to assure minimum impact. The impacts on the terrestrial ecology are primarily loss of natural habitat and wildlife disturbance from potential increased human intrusion. Overall, the environmental impact of pumped-storage facilities will be a major consideration in plant siting, and to a degree, in operations.

Socioeconomic Considerations

Construction of a pumped-storage plant is labor intensive, involving as many as 350 workers for a 100-MW plant and a construction period of 4 to 5 years. The impact from construction of a 100-MW plant would range from minimal to major, depending on site selection.

STORAGE BATTERIES

In periods of low demand, electricity can be converted from high-voltage AC into lower voltage DC and stored in batteries. During peak load periods the process can be reversed to carry part of the utility's load.

Possible Railbelt Application

Circumstances under which development of storage batteries might be attractive in the Railbelt region are the same as those listed under "Possible Railbelt Applications" for hydroelectric pumped storage.

Commercial Availability

Utility-scale use of storage batteries is an emerging technology. Development of advanced batteries systems specifically designed for load-leveling applications is under way at several companies. Commercial-scale systems are expected to become available for utility use in the 1988-1992 time period. Thus, any Railbelt application will be in the midterm to long term.

Performance

Station-equivalent annual availability is estimated to exceed 90%. A 30-year economic lifetime with several replacements of batteries is estimated.

Estimated Cost of Power

The incremental power costs for a variety of advanced storage batteries for 20-, 40-, and 80-mill baseload power costs are estimated to range between 38 and 130 mills/kWh. These are tentative costs because actual manufacturing, O&M costs and lifetimes are only rough estimates.

Environmental Considerations

Advanced battery facilities are designed to have minimum impact on their surroundings. Land area required for a 100-MW station would be only about one-half acre.

Socioeconomic Effects

The maximum construction force for a battery-storage facility would be 20 to 40 persons. Because a battery power would logically be located near a load center, the impact of construction would be small. Out-of-state capital spending is estimated to be 85%.

COMPRESSED AIR ENERGY STORAGE (CAES)

In compressed air energy storage during off-peak hours, surplus energy from a utility grid is used to compress air for storage underground in manmade or natural geologic structures. During peak-demand periods, the air is released from the storage area, reheated and then expanded in turbines to generate electricity.

Possible Railbelt Applications

Presently, the Railbelt region does not have a suitable baseload generating capacity to warrant consideration of CAES. Circumstances under which use of CAES systems may become feasible in the Railbelt region are the same as those listed under "Possible Railbelt Applications" hydroelectric pumped storage. (CAES would be less suited for dispersed system backup capacity.)

Commercial Availability

The first (and only) CAES plant started operation in West Germany in 1978. Operating results on this 290-MW facility have been excellent. In the

United States, several sites have been evaluated for possible CAES facilities. Although the cost effectiveness of these conceptual plants generally has been confirmed, no decision has been made to build a plant.

Performance

The electrical input/output ratio of a conventional (reheat) CAES plant is about 0.75:1.0.

Estimated Cost of Power

For 924-MW rated capacity hard rock CAES plant, the estimated incremental electric energy cost will be 54 mills/kWh. This cost assumes a 1990 startup date, 30-year economic life, Cook Inlet Natural Gas for reheat and a 20-mill/kWh baseload cost. The estimated cost components are as follows:

	Compressed Air Storage (mills/kWh)
Capital	21
Fuel	27
Operation and Maintenance	6
Total Production Cost	54

Resource Availability

Siting a CAES plant is a major task. Finding a suitable geologic structure requires the most effort. A variety of competitively priced fossil fuel resources are available in the Railbelt region to meet CAES reheat needs. However, before a CAES plant can be constructed, the baseload generating capacity in the region must be expanded and the CAES options must be reviewed in detail.

Environmental Consequences

The environmental impacts of a CAES plant depend upon the type of storage medium employed. The most serious impacts may result from the construction activities themselves. The excavated material from salt domes and hard rock cavern systems pose significant storage/disposal problems. Aquifer CAES systems' impact on groundwater quality will also have to be carefully assessed. Standard air-quality control measures will have to be incorporated to minimize impact from the fossil-fuel-fired reheat facility.

Socioeconomic Consequences

Construction of a large CAES plant is labor intensive. A construction force of 150 to 300 would be required over a five-year period. Significant impacts can be expected on small communities located near the construction. The operating staff for a CAES facility is very small and should not impact local communities.

COGENERATION

Cogeneration is the sumultaneous production of electricity and useful heat. The heat, in the form of steam or hot water, may be distributed to commercial or residential users in district heating systems or to industrial users for process heat applications.

Cogeneration systems can be classified into two thermodynamics cycles:

- topping cycle - High-temperature steam, gas or diesel power is used to generate electricity and the rejected energy is used for process heat or space heating.
- bottoming cycle - High-temperature steam is used for process heat and the rejected steam is used in a special saturated steam turbine to generate electricity.

POSSIBLE RAILBELT APPLICATIONS

Significant potential for cogeneration exists in the Railbelt. Because cogeneration must be located adjacent to industrial or large residential users, the refineries on the Kenai peninsula, and Fairbanks have the greatest potential. Other petroleum-related activities such as oil and gas pumping stations also have potential applications. If natural gas liquefaction (LNG) facilities are installed, they would have a high potential. Other industrial and military installations could use cogeneration designs. Hospitals, large apartment complexes and other institutions in the high population areas of the Railbelt also are potential users.

COMMERCIAL AVAILABILITY

A variety of cogeneration designs are commercially available. The time required to license and install a plant may be dictated more by process heat use than by the electrical generation. The possible combinations of prime energy source and process heat use are so numerous that estimating a date by which this type of capacity could be on-line would be difficult, but a range of 2 to 6 years after the date of decision probably would cover most applications.

CONVERSION EFFICIENCY

The best measure of the efficiency of cogeneration should be percent of heat use. The electrical generation part of the cycle will convert the thermal energy of the primary heat source to electrical energy at an efficiency that is characteristic of the particular generation design (steam, gas turbine, or diesel). In addition, the waste or reject heat will be further used. The overall efficiency is usually in the range of 65 to 85%.

COST OF POWER

The cost of power from cogeneration is hard to define precisely. For example, if a refinery generates surplus electricity, which it supplies to the grid, the value of that power is the price the utility will pay for it. Alternatively, the power costs can be calculated by assigning a value to the process heat and deriving power costs as a by-product. An estimated 60 to 70% of the capital expenses of such installations would be spent outside the Railbelt.

ENVIRONMENTAL CONSEQUENCES

A cogeneration facility should have the same environmental impact as a simple generating station of the same capacity and type. For example, a 12-MW diesel cogeneration facility would be expected to discharge the same air emissions as would a comparable diesel generating station. The land-use factor would be higher in cogeneration if the acreage used by the process heat part of the facility is included.

SOCIOECONOMIC CONSIDERATIONS

Work forces may vary from 25 to 250 for the construction of cogeneration plants. Since the plants would probably be built in large industrial zones, little socioeconomic impact should occur.

TIDAL POWER

Tidal power uses the ebb and flow of tidal movement in an estuary to drive turbogenerators. The estuary is dammed to convert the potential energy from this movement to electricity. Because the available head is limited by the tidal rise, the turbines are of a special low-head design. The design of the dam and associated equipment is specific to the site. Only two tidal facilities are operating in the world. One is the Rance Project (240 MW) in northwest France and the other is the Kislogubsk station (0.4 MW) on Kislaya Bay, USSR.

POSSIBLE RAILBELT APPLICATION

Tidal power is intermittent; the tidal cycle goes from peak to peak every 12.9 hours. Unless some auxiliary pumped-storage capacity is added, a tidal power facility is capable of generating electricity less than 12 hours per day.

Cook Inlet is one of the few sites in the world with a significant tidal power potential. Estimates indicate that up to 2600 MW may be available on the Knik and Turnagain Arms of Cook Inlet. Although tides are regular and predictable, the timing constantly changes. Therefore, tidal facilities deliver peak power approximately twice a day but at differing times. Peak generating capacity also changes with the seasonal tides. Because tidal power is intermittent, it is useful primarily as a supplementary source of energy unless storage capacity is provided to allow consistent energy production. In short, tidal power is a renewable source of energy, but without storage it presents unique system problems.

COMMERCIAL AVAILABILITY

The material, design and equipment required to construct a tidal power plant are currently available. Plants have been constructed in France and the Soviet Union and are currently in the planning stage in eastern Canada. A Cook Inlet tidal plant would require a lengthy construction period, from 15 to 20 years. Railbelt system demand would have to grow considerably before it could accommodate an intermittent source of power in the 700 to 1500 MW range that is characteristic of the Cook Inlet. Based on system considerations, the Railbelt would not be able to accommodate such a facility before 2000 and possibly not before 2025.

PERFORMANCE

A tidal power facility converts the potential energy of the rising and falling tides into electrical energy. Although hydrogenerators are very efficient, the change in generating efficiency as the head drops and the down time while the reservoir is filling must be considered. One measure of design efficiency is to compare the electrical energy actually generated in a year to the energy that would be converted if all generators were to operate at full capacity the entire year. Preliminary analyses show that from 32 to 36% of the nameplate generation (theoretical maximum output) will be realized.

ESTIMATED COST OF POWER

A rough estimated power cost from a tidal station on Cook Inlet ranges from 46 to 129 mills/kWh depending on the site chosen and assumptions made on the disposition of off-peak power.

ENVIRONMENTAL CONSEQUENCES

The largest effects of a tidal power plant probably would be felt by the marine ecology. Short-term impacts would arise from dredging some 30 million cubic yards of sediments to prepare the foundation. About 7 million cubic yards of fill rock would be needed. Long-term effects could be expected from the change in water circulation patterns and the movement of glacial sediments deposited during the summer runoff. Anadromous fish migrations would be affected, as would the smelt runs.

The terrestrial ecology would be affected by the construction of access roads, by the dumping of dredge materials, and by the acquisition of fill.

SOCIOECONOMIC CONSIDERATIONS

A tidal power station of the 700 to 1500 MW size envisioned for Cook Inlet would require 2000 to 3000 construction workers for a 7- to 12-year period. Most of this labor force would be based in Anchorage. This size labor force could put a severe strain on housing and community infrastructure if employment were already high at the time of peak construction.

LARGE WIND ENERGY SYSTEMS

Wind energy is converted into electrical energy in two steps. In the first step the kinetic energy of the wind is converted into rotational energy of the blades. In the second step, the rotational energy of the blades is used to drive an electrical generator. Small wind energy devices have been used for many years, but large systems (over 0.1 MW capacity) are still in the developmental stage.

Three basic configurations of wind machines exist. They are classified according to the axis of rotation relative to wind direction as horizontal axis, vertical axis, or cross-wind horizontal axis. Vertical axis machines are generally less efficient than horizontal axis ones, but because they do not require a tower, they have a lower capital cost. They have the added advantage of being insensitive to wind direction. Cross-wind horizontal axis machines do not represent an improvement over either of the other two types. At the current stage of development, horizontal axis designs probably will be preferred for megawatt-scale machines.

POSSIBLE RAILBELT APPLICATIONS

Wind energy conversion units from 0.1- to 5-MW capacity would be well suited to the Railbelt. The power generated is, however, intermittent and requires backup capacity. Isolated communities that have diesel or gas turbine generation might profit from supplementary wind power. In combination with a hydro or pumped-storage system, a wind energy farm could make a significant energy contribution because it could store energy.

COMMERCIAL AVAILABILITY

Large wind turbines in the range of 1 to 2.5 MW are commercially available. A MOD-1 turbine (2 MW) has operated at Boone, North Carolina, since 1979. Three MOD-2 (2.5 MW apiece) turbines went into operation in 1981 near Goldendale, Washington. These and other wind turbines are available, but the benefits of assembly line production have not yet been realized.

PERFORMANCE

Capacity factor is typically used as a measure of a wind turbine's efficiency. Capacity factor is the actual power generated in a year divided by the theoretical maximum that would be generated if the wind were to blow at the optimum speed all year long. Since the output of a wind turbine is sensitive to both the velocity and steadiness of the wind, the capacity factor is highly site dependent. For a good site a capacity factor of 30 to 40% can be expected.

ESTIMATED COST OF POWER

The estimated costs of power from a 2.5-MW wind turbine installed in the Railbelt are as follows:

	Large Wind Systems With 40% Capacity Factor (mills/kWh)	Large Wind Systems With 30% Capacity Factor (mills/kWh)
Capital	49	65
Fuel	0	0
Operation and Maintenance	5	7
Total Production Cost	54	72

Approximately 80% of the capital cost of a wind turbine installation would be spent outside Alaska.

ENVIRONMENTAL CONSEQUENCES

Since wind turbines extract energy from the atmosphere, they can be expected to have a small impact on the climate in the immediate vicinity. The affected zone would be limited to a distance equivalent to 5 rotor diameters, which is 1500 feet for a MOD-2 turbine.

Rotation of the turbine blades can interfere with television, radio, and microwave transmission. Low-frequency sound also has been detected downwind of some installations. This impact is potentially stressful on human and animal populations.

For maximum efficiency, a smooth, flat site is desirable. Any trees or shrubs that cause air turbulence may have to be removed. The large land areas required (particularly for multiturbine wind farms) could affect terrestrial biota through loss of habitat.

Shoreline development could affect both harbor seals and migratory birds. The effect of such installations on harbor seals, which use much of the coastline, is unknown. If the turbines are located in the flyways of migrating waterfowl, bald eagles, peregrine falcons, or other birds, collisions with the rotating blades would be possible.

SOCIOECONOMIC CONSIDERATIONS

Erection of a 1- to 2-MW wind turbine would require approximately 2 years for site selection, including time to procure fabricated components, and about 6 months for construction. A crew of 10 to 15 would be required during construction, but no permanent onsite operating force would be needed. Because of the small size of the construction force, the socioeconomic impacts on even the smallest community should be minimal.

The construction of a 100-MW wind farm is expected to require a work force of about 60 over a 2-year period. This size labor force could cause some strain on small communities.

SMALL WIND ENERGY SYSTEMS

Small wind energy conversion systems (SWECS) are wind turbines with rated capacities of 100 kW or less. Both horizontal and vertical axis machines exist. The horizontal machines have a higher efficiency but require a tower, which adds to capital costs. The vertical axis machines have the advantage of not being sensitive to wind direction. Machines may be equipped with either alternating current (AC) or direct current (DC) generators. Alternating current generators will allow the power from the turbines to be used at the installation or to feed a utility grid. Direct current generators are usually used to recharge at offgrid installations where batteries are provided for backup power during calm periods.

POSSIBLE RAILBELT APPLICATION

The small capacity of SWECS installations makes system additions convenient. SWECS is, however, an intermittent energy source. Unless it is used in conjunction with a hydro, pumped storage, or some other storage, it can be regarded only as a fuel saver.

Some Railbelt sites may have the necessary wind conditions to use SWECS. Macro wind energy surveys, however, indicate that the most promising areas are outside Railbelt population centers. It thus appears that SWECS have only a limited potential in the Railbelt.

COMMERCIAL AVAILABILITY

Currently, small wind turbines are available from over 50 manufacturers. A Railbelt dealership and a repair network is already in place.

CONVERSION EFFICIENCY

The electrical generation that can actually be realized over a year's time is of primary interest in evaluating a SWECS. That figure is a function of the wind turbine design, the installation site, and the equipment's reliability. If the SWECS electrical generation over a year is divided by the theoretical maximum output (the nameplate rating) the capacity factor ranges from 25 to 40%.

ESTIMATED COST OF POWER

The estimated cost of power from a SWECS installed in the Railbelt operating a 40% capacity factor are shown below. These costs are somewhat sensitive to the size of the installation.

	SWECS 0.01 MW (mills/kWh)	SWECS 0.002 MW (mills/kWh)
Capital	40	50
Fuel	0	0
Operation and Maintenance	6	7
Total Production Cost	46	57

If the SWECS were manufactured in the Railbelt, essentially all of the capital costs would be expended in the Railbelt. Almost all the O&M expenditures would be spent in the Railbelt.

ENVIRONMENTAL CONSEQUENCES

A potential hazard to low flying migratory birds could result from a SWECS, although this possibility is not considered serious. A compensating wildlife enhancement can be expected due to downwind sheltering from the turbines. Noise is not a problem with SWECS. Radio and microwave interference can be mitigated by proper blade design and the use of nonmetallic materials.

SOCIOECONOMIC CONSIDERATIONS

Land use in the cities would present significant problems for SWECS because of safety and building code considerations. In the rural areas, which make up most of the Railbelt, these factors would not be expected to weigh very heavily.

Typically, a two- to four-man crew can complete a SWECS installation in a few weeks. No construction socioeconomic impacts should occur in even the smallest community. Operation and maintenance also present no problems.

SOLAR ELECTRIC POWER

Two basic methods for generating electric power from solar radiation are under development: solar thermal conversion and photovoltaic systems. Solar thermal systems convert solar energy to heat via a working fluid such as water, steam, air, various solutions and molten metals. Energy is extracted from this working fluid to drive a turbine. In photovoltaic systems, solar energy is converted into electric energy in a photo sensitive substance.

POSSIBLE RAILBELT APPLICATIONS

The lack of winter sunshine in the Railbelt clearly limits solar energy as an alternative for electric power generation. Solar radiation data collected at Fairbanks and near Anchorage revealed that mid-winter values were a maximum of only 48 Btu/ft^2 in December and 1,969 Btu/ft^2 in June. This compares with Minnesota (a relatively poor site) where the year-around range is 550 Btu/ft^2 to 2,000 Btu/ft^2.

COMMERCIAL AVAILABILITY

Photovoltaic cells are commercially available from several firms. The cells are assembled in modular units of varying voltages and current outputs. Solar thermal feasibility is currently being evaluated in test and demonstration facilities in Albuquerque, New Mexico, and Barstow, California.

CONVERSION EFFICIENCIES

Photovoltaic system conversion efficiencies currently range from approximately 2 to 13%. Advanced concepts point to efficiencies approaching 40%. Conversion efficiencies for a power tower solar thermal system range from 10 to 70%, depending on climatic conditions.

ESTIMATED COST OF POWER

The estimated power cost for a 10-MW photovoltaic power plant operating at a 15% conversion efficiency is 620 mills/kWh. A comparably sized solar thermal system also operating at a 15% conversion efficiency could expect to generate electricity at 92 mills/kWh. The cost components are presented below:

	Photovoltaic (10 MW) (mills/kWh)	Solar Thermal (10 MW) (mills/kWh)
Capital	593	65
Fuel	0	0
Operating and Maintenance	27	27
Total Production Costs	620	92

RESOURCE AVAILABILITY

Low sun angles, characteristic of Alaskan latitudes, provide less solar radiation per unit area of the earth's surface than in other areas of the country. This creates the requirement for greater collector areas to achieve a given rated capacity. Increasing the "tilt" of collectors increases solar power densities but shades adjacent collection devices at low sun angles. These factors, plus low solar radiation availability during the months of greatest demand, severely constrains solar energy development in the Railbelt region.

ENVIRONMENTAL CONSEQUENCES

Air-quality impacts for photovoltaic and solar thermal systems are expected to be minimal. Water resource effects are also not expected to be significant for photovoltaic systems. Solar thermal conversion systems would produce water resource effects similar to those of other steam-cycle facilities. Many of the working fluids being proposed for solar thermal systems will require special handling to avoid undesirable ecological effects. Because of the land-intensive characteristic of solar systems, a significant environmental effect could be the loss of habitat.

SOCIOECONOMIC CONSIDERATIONS

Both solar photovoltaic and solar thermal systems require a relatively large construction force but a small operating staff. A 10-MW photovoltaic plant would require a construction force of about 100 and an operating staff of 10. Little socioeconomic impact could be expected if a solar plant were located near a major load center.

SMALL HYDROELECTRIC AND MICROHYDROELECTRIC POWER

Small-scale hydroelectric plants are facilities having installed capacities of 100 kW to 15,000 kW. Units with 100 kW or less of capacity are classed as microhydroelectric units. Small-scale hydroelectric and microhydroelectric power plants are similar in principle to conventional hydroelectric facilities but differ from these installations in several important ways. First, the small-scale hydroelectric and microhydroelectric units usually operate with a hydraulic head of 100 ft or less. They are also typically single-purpose (power only) facilities. Finally, they operate as run-of-the-river units, having no working storage. While small hydro power facilities may be the most economically feasible alternative to meet a particular power need, the above characteristics can lead to relatively high per-kilowatt capital costs.

POSSIBLE RAILBELT APPLICATIONS

Although 16 small-scale hydro power plants are currently operating in Alaska, only one, the 15-MW Cooper Lake project on the Kenai Peninsula, is operating within the Railbelt region. Feasibility studies have been completed on potential small-scale hydro projects at Grant Lake, near Seward, and Allison Creek, near Valdez. Thirteen additional technically feasible small hydro sites have been identified. The potential for microhydro development in the Railbelt region is estimted to be 9 MW in generating capacity. Most of these sites could be expected to be developed in the Anchorage load center area.

COMMERCIAL AVAILABILITY

Packaged turbo-generator units for small-scale and microhydroelectric power plants are available from many domestic and foreign manufacturers.

CONVERSION EFFICIENCY

Efficiencies for hydroelectric facilities range from 50 to 85%, depending on the type of equipment used and scale of operation. As flow rate and/or head vary, the efficiency of the turbine can drop off from a maximum of 90% at 100% capacity to about 75% at 20% rated capacity. Microhydro system efficiencies generally range between 50 and 70%. Grid-connected microhydro and small-scale hydro units are operated as fuel savers at a 60 to 100% plant capacity factor.

ESTIMATED COST OF POWER

The estimated cost of power for grid-connected small hydro and microhydro plants ranges widely from 14 to 254 mills/kWh for local, and from 111 to 343 mills/kWh for remote facilities. The broad cost difference is the result of major costs of access roads and transmission systems. The broad range within each category is largely the result of varying system operating conditions and equipment types used in these installations. An estimated 60% of the capital expenditures can be expected to be spent outside of the Railbelt area.

ENVIRONMENTAL CONSEQUENCES

Special consideration will have to be given to mitigating potential problems with the passage of anadromous fish. The presence of power transmission and access road corridors through the forest could potentially disrupt wildlife migration patterns. The aesthetic aspects may become significant if numerous microhydro and small hydro plants were developed within a limited area. Because of the relatively small plant capacities involved and limited number of feasible sites, impacts should be minimized through careful site selection.

SOCIOECONOMIC CONSIDERATIONS

Socioeconomic impacts should be minor to modest, as a relatively small labor force for construction and operation will be required. The construction force for a small-scale plant could range up to 20 individuals for a 12- to 24-month period. Small towns with undeveloped infrastructure could experience some detrimental impact.

LOAD MANAGEMENT

Load management is any action taken by a utility to directly affect customer loads or to influence customers to alter their electrical use characteristics. The objective of load management is to shift, shed, or shave peak loads to derive a more economical load profile.

POSSIBLE RAILBELT APPLICATION

The Railbelt utilities are currently employing load management alternatives. However, opportunities for additional load management in the Railbelt region appear to be limited, mainly because few loads are controllable. If low-cost power becomes widely available in the future, with resulting increased space and water heating electrical loads, aggressive load management programs may become desirable.

COMMERCIAL AVAILABILITY

Load management techniques were first used in Europe. Recently, in the United States, many load management programs have been implemented or are under development. Although many of these programs have proved to be cost effective, they are generally still in the experimental or demonstration phases.

Examples of load management methods include direct load control, passive controls, incentive pricing, education and public involvement, and dispersed thermal energy storage.

1. Direct load control is the control of specific customer loads by the utility. Residential loads for water heating can be controlled directly but can cause customer inconvenience or discomfort. The use of clothes dryers can often be shifted to off-peak hours. Direct control devices include clock timer switches, temperature sensing controllers, and photo controllers. Control can also be obtained remotely using the existing transmission and distribution system to transmit a signal.

2. Passive controls are load-control devices that are owned and controlled by the customers themselves. They can be used to control water heaters, and most significant electrical loads within a home.

3. Incentive pricing of electricity allows the customer to take advantage of reduced electricity rates by voluntarily shifting his use of electricity to off-peak periods where rates are less. This is a means of achieving load management objectives through the market mechanism.

4. Education and public involvement programs are designed to appeal to the public to voluntarily reduce and change electricity consumption patterns for their own benefit and for the overall public economic well being

5. Dispersed thermal energy storage stores heat produced during off-peak periods for use in space or water heating during peak periods. Thermal storage systems may range in size from large central storage units to residential-scale devices. Water is the most commonly used fluid for storage because of its abundance, low cost, nontoxic nature, and relative ease of handling.

COST-EFFECTIVENESS OF LOAD MANAGEMENT ALTERNATIVES

Load management programs are effective if the energy cost savings exceed the added cost of alternative electricity generation and transmission plus the costs of implementing load management techniques. Effective load management will reduce operating requirements for peak and possibly intermediate load capacity. The need for new peaking capacity may also be deferred.

SOCIAL AND ENVIRONMENTAL CONSIDERATIONS

Successful load management rests on the premise that certain individual choices can be opted in favor of a "fair" program developed for all customers. In most areas where load management has been tried, programs have been well accepted. With an effective public communications program by local utilities, similar results can be expected in the Railbelt region as the need for such programs grow in the future. Delays or elimination of new electric generation facilities can be expected to defer associated environmental problems.

ELECTRIC ENERGY CONSERVATION IN BUILDINGS

Four factors determine the energy efficiency of any building and, if implemented, offer the greatest potential for energy savings in both new construction and retrofit of existing structures:

1. an insulation envelope to reduce conduction of heat through the building structure
2. adequate sealing to minimize in filtration of air
3. a vapor barrier to retard moisture transfer
4. efficient space heating and hot water systems.

POSSIBLE RAILBELT APPLICATION

Most buildings constructed in the Railbelt use materials and techniques better suited for temperate climates. Only recently have builders and designers begun to recognize the need for an "Alaska-specific" approach for designing a building's thermal envelope. Some individuals in the Railbelt have reduced their fuel bills as much as 70% by adding extra insulation and by thorough sealing. Energy-conserving retrofit methods in existing structures and energy-conserving measures in new construction will receive increased emphasis as the cost of energy increases. Electricity demand through conservation will not be significantly reduced while low-cost electricity is widely available.

COMMERCIAL AVAILABILITY

Energy conservation measures are widely used, although most people are still not aware of the technology's economic benefits. Well-developed technology is available on optimizing the use of insulation to reduce conduction on sealing to reduce air infiltration, on constructing properly to retard moisture transfer, and on optimizing space heating and hot water systems.

COST AND PERFORMANCE

Conservation benefits are difficult to measure on an area-wide basis due to its dispersed nature. Retrofit costs can vary substantially, depending on each dwelling's age and type of construction. When comparing a "typical" existing Alaskan house in the Railbelt region, adding retrofit conservation measures could return savings of 41.8% of the typical annual heating load. For new construction on a house costing $100,000, "superinsulation" can cost an additional $7,000. In an Alaska-specific designed residence, where conservation ("superinsulation") was built into the structure, savings amounted to 72.3% over the "typical" Alaskan home.

ENVIRONMENTAL IMPACTS

Building conservation technologies have few detrimental environmental impacts. Because building "styles" would not change significantly, the technology need not have any impact on community appearance.

The impact on occupants of buildings having a minimum of air exchange is being assessed. The major area of concern relates to the quality of indoor air as measures to reduce infiltration or the introduction of outside air are incorporated. The potential for adverse health impacts is increased as the rate of interior air exchange is reduced. The safe level is difficult to establish, however, as it depends on building-specific pollutant sources. Air-quality concerns can be rectified with air-to-air heat exchangers. The exchangers are available at modest cost to exchange "stale" inside air with "fresh" outside air while conserving 60 to 80% of the energy content.

SOCIOECONOMIC IMPACT

The socioeconomic impact of energy-conserving technologies are not expected to be great. An energy-conserving building is comfortable and relatively draft free. The reduced cost of heating allows occupants to keep the building warmer for less money. Additional jobs are expected to be created from the manufacture, sale, and installation of conservation materials and services.

ELECTRIC ENERGY SUBSTITUTES

Electric energy substitutes include passive solar space heating, active solar in hot water and space heating, and wood space heating. Dispersed active solar technologies differ from passive solar in that they require auxiliary pumping energy to function properly. Passive solar energy applications require very little or no auxiliary energy.

PASSIVE SOLAR SPACE HEATING

Passive solar systems rely on a combination of a thermally efficient building envelope to contain heat, south facing windows to capture solar energy, some form of thermal mass to store captured energy for release at night or during cloudy periods, and design techniques to distribute heat by convection. Passive solar uses no mechanical means such as pumps or fans to distribute heat from the sun into the living space.

Possible Applications to the Railbelt

Although passive solar for space heating is fairly new in the Railbelt, several buildings that rely on the sun for a large portion of their heating needs have been constructed in the last few years. Passive solar may appear to be an inappropriate technology for the Railbelt because the resource is providing a minimum amount of energy when the need is greatest (December and January). However, the high heating loads and length of the heating season make passive solar attractive. During late winter and early fall, a properly designed, passive solar structure in the Railbelt region can obtain a large part of its space heating needs from the sun.

Commercial Availability

Hundreds of passive solar structures are now working successfully in the United States. The technology for incorporating passive solar features in new construction is well developed and is continuing to expand.

Performance

A combination of energy conservation and passive solar in new construction can cut energy demands by 60 to 70% in an individual dwelling.

Although the potential of passive solar and conservation in existing buildings is difficult to quantify without knowing the structure's existing condition and solar access, incorporating this technology in existing structures could reduce the heating load by an estimated 30 to 50%. Several structures in the Railbelt are using 25 to 30% as much space heating as their neighbors by combining an efficient thermal envelope (conservation through insulation addition and minimizing air leakage) with passive solar heat.

Cost of Implementation

Virtually no work has been done for the Railbelt on capital costs for passive solar. Preliminary studies show an increase of between 6 and 10% above normal construction costs for a passive solar, super insulated home. The estimated unit energy costs for installation of passive solar and super insulation in a new residence ranges from $4.49/MMBtu for a 10%, 30-year term, $6,000 state loan to $5.86/MMBtu for a 5%, 20-year term, $10,000 alternate energy loan. This compares with fuel oil, which is in the $8.20 to 8.40/MMBtu range in the Railbelt area.

Insolation

Insolation is the total amount of all solar radiation that strikes a surface exposed to the sky. Insolation varies throughout the Railbelt region, but has an overall average of about 300,000 Btus per square foot per year. While this insolation value is less than half of what one might expect in New Mexico, for example, the long heating seasons and high heating loads justify use of available radiation.

Environmental Consequences

Environmental impacts from passive solar technologies are minimal. Aesthetic concerns for passive solar structures can be handled by proper design. Reflected glare off south facing windows is a potential problem in passive solar applications. Proper building design and introduction of new glazing materials are expected to control glare within acceptable limits.

Socioeconomic Impacts

The socioeconomic impacts of passive solar technologies for space heating centers in the areas of land use, consumer convenience and control, and regional economics. Land-use planning would need to be implemented to prevent the degradation in efficiency of an individual solar application by a building being placed in the sun's path at a later date. Increased consumer benefits can be expected through reduced fuel expenditures, low maintenance of passive solar systems and greater security from having an independent energy source. Introduction of passive solar on a broad scale is expected to create jobs and new capital ventures at a local and regional level.

Development of a thorough understanding of the economy of various levels of passive solar design followed by education of designers, developers, builders, and consumers is the key to successful implementation of solar technologies.

ACTIVE SOLAR SPACE AND HOT WATER HEATING

"Active" solar systems require auxiliary pumping energy to function properly. Systems employing flat-plate collectors are the most common type used to retrofit homes and businesses. In these systems either a liquid or air is heated directly (or indirectly) within a closed, usually flat, collector. Heated air or a liquid is then usually stored directly or its energy transferred to another media; e.g., a rockbed for use during periods of high load.

Possible Railbelt Applications

Like passive solar systems, active solar for space heating in the Railbelt region appears to be inappropriate because the building heating load is greatest when the resource (solar radiation) is at its minimum. However, in many parts of the Railbelt, space heat is needed at least 9 to 10 months of the year. While active solar will not make a significant contribution to heating during mid-winter months in the Railbelt, it can reduce heating bills on an annual basis. Assessing the future level of application for active solar systems in the Railbelt region is extremely difficult because of a fundamental lack of information at all levels of the supplier user and financial communities. Unless technical and economic feasibility of active solar systems has been clearly demonstrated to the satisfaction of those who remain skeptical, widespread introduction of this within the Railbelt region will be inhibited.

Commercial Availability

Active solar system technology is well developed, with many thousands of installations throughout the United States. Active solar collectors, largely of local assembly, are currently available in the Railbelt. Technical assistance from designers, installers and dealers in optimizing the collector with the specific installation may not be available because of limited operating experience with this equipment in the Railbelt region.

Performance

In the Railbelt under optimum conditions, active solar collectors can be expected to make use of 30 to 40% of the sun's energy that strikes its surface. The presence of obstructions in the sun's path, the tilt of the collector and whether the heat is used directly or indirectly all have a significant impact on collector efficiency. The interaction of these variables and the low temperatures for 1 to 3 months has never been studied in Alaska.

Costs of Implementation

Costs of energy for active solar energy will likely vary between 12.50 and 34.20 $/MMBtu, depending on the type of system installed, the amount of collector used and the efficiency of the end use of the system. These unit cost figures are projections only. As additional systems are installed, a much better understanding of initial capital costs will be possible.

Insolation

Insolation is discussed under this section in "Passive Solar for Space Heating."

Environmental Consequences

The environmental effects of active solar energy use are minimal. Earlier concern over the aesthetic devaluation of neighborhoods from many roof-mounted solar collectors has been replaced in the southern United States by the increased real estate appraisal values for homes with solar systems.

Socioeconomic Impacts

Socioeconomic impacts of active solar systems would be similar to other dispersed technologies. As a result, a higher percentage of the cash flow would tend to stay in the region for a dispersed technology than for a large centralized project. In addition, the impact on one's life style from the active solar systems differs from the effect of passive solar systems. The potential benefits from reduced fuel usage and subsequent dollar savings are obvious. Some user maintenance will be associated with active systems, amounting to perhaps 3 to 6 hours per month for a well-designed system.

WOOD-FIRED SPACE HEATING

Wood has been a traditional fuel for space heating in Alaska. A significant amount of wood continues to be used in the Railbelt as a primary and secondary heating source. Fireplaces have largely been replaced by a variety of fireplace modification equipment (e.g., fireplace inserts) and stand-alone stoves, both of which have greatly improved wood burning efficiency over the standard open fireplace.

Possible Railbelt Applications

Recent studies point to a dramatic increase in wood burning in Railbelt residential areas. Many people, usually outside the larger urban areas, depend on wood for their sole heating source. In the larger population centers, wood heat tends to be more of a secondary source, although this may be changing to some degree. An expanded use of wood for space heating in the future will depend on the continued availability of wood fuel, the relatively low transportation fuel costs, the availability of low-cost electricity and hydrocarbon fuels, and the introduction of residential conservation methods.

Although determining the amount of space heating energy that wood-fired units could contribute to the region is difficult, eventually, 10 to 15% of total demand should be quite realistic.

Commercial Availability

Technology is well developed for wood burning systems. Suppliers of wood burning units in the Railbelt could meet considerably greater demand for both primary and secondary heating systems. Available equipment includes models that can accommodate hydrocarbon fuels as well as wood and that are adaptable to incremental increases in heating capacity without major system changes.

Conversion Efficiency

Conversion efficiencies for wood-burning equipment varies widely. The effectiveness of these systems is indicated not only by Btu output, but also by the ability to put the heat into the structure instead of losing it to the chimney. Conversion efficiencies of open fireplaces range up to 10%. The popular box stove (e.g., kitchen, Franklin, potbelly and parlor stoves) have conversion efficiencies of 20 to 30%; air tight and controlled draft stoves can have efficiencies between 40 to 65%.

Costs

Space heating costs using wood compare very favorably with other sources, especially when the wood is harvested by the dispersed, individual method. This situation is expected to continue unless transportation fuel costs rise dramatically. The unit cost for wood heating over the life of the structure is difficult to assess because of the uncertainties of future firewood costs to the user. The installed cost of a wood-burning unit will also impact unit cost and can range from $300 to $6000 depending on the application used. In costs per MMBtu, wood fuel ranges between $5.48 and $6.30 for Fairbanks and Anchorage, respectively. Fuel oil (January 1981 prices) for the same two locations ranged from $8.19 to $8.41/MMBtu.

Resource Availability

Although the dispersed individualized process of harvesting wood for fuel in the Railbelt area is not highly visible, demand for firewood has increased dramatically. Birch is the most common wood in the Anchorage area, while spruce is most common in Fairbanks. Wood is harvested on state and private lands but a greater amount is taken from private lands being cleared for development. Wood suppliers indicate that their sales are limited by accessibility to harvest areas and not by resource shortage. Forest management officers confirm that while the resource is sufficient to meet anticipated future demand, it must be made accessible for public use.

Environmental Consequences

Wood for heating poses three environmental issues: fire hazards, air quality effects, and environmental degradation from wood harvesting. Fire hazards increase with expanded use of wood for fuel. Most wood-burning-related fires are the result of improper installation and, to a lesser extent, operation. Following recommended installation and maintenance procedures for wood-burning systems can considerably reduce the hazard level. Air-quality monitoring in the Anchorage area has not detected particulates attributable to wood combustion. Monitoring for suspended particles in other Railbelt locations has not yet begun. Wood smoke creates a visual and odor impact for some people, although this does not appear to be a major problem. The degree of environmental degradation from harvesting wood fuel will depend upon harvesting methods and enforcement of land-use regulations.

Socioeconomic Considerations

An important aspect of wood for fuel for many is that it provides an independent source of heat in case of power failure. Unlike other heat sources, wood fires require regular attention, and for those harvesting their own wood, a considerable investment of time cutting, splitting, and stacking the wood. Some adjustments in life style might be necessary, particularly for those who would use wood as a primary space heating fuel. Land-use issues of wood harvesting must be addressed to assure a dependable long-term supply of wood.