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

Executive Summary

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Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

RAILBELT ELECTRIC POWER ALTERNATIVES STUDY

Volume I - Railbelt Electric Power Alternatives Study: Evaluation of Railbelt Electric Energy Plans

Volume II - Selection of Electric Energy Generation Alternatives for Consideration in Railbelt Electric Energy Plans

Volume III - Executive Summary - Candidate Electric Energy Technologies for Future Application in the Railbelt Region of Alaska

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

Volume V - Preliminary Railbelt Electric Energy Plans

Volume VI - Existing Generating Facilities and Planned Additions for the Railbelt Region of Alaska

Volume VII - Fossil Fuel Availability and Price Forecasts for the Railbelt Region of Alaska

Volume VIII - Railbelt Electricity Demand (RED) Model Specifications

Volume VIII - Appendix - Red Model User's Guide

Volume IX - Alaska Economic Projections for Estimating Electricity Requirements for the Railbelt

Volume X - Community Meeting Public Input for the Railbelt Electric Power Alternatives Study

Volume XI - Over/Under (AREEP Version) Model User's Manual

Volume XII - Coal-Fired Steam-Electric Power Plant Alternatives for the Railbelt Region of Alaska

Volume XIII - Natural Gas-Fired Combined-Cycle Power Plant Alternative for the Railbelt Region of Alaska

Volume XIV - Chakachamna Hydroelectric Alternative for the Railbelt Region of Alaska

Volume XV - Browne Hydroelectric Alternative for the Railbelt Region of Alaska

Volume XVI - Wind Energy Alternative for the Railbelt Region of Alaska

Volume XVII - Coal-Gasification Combined Cycle Power Plant Alternative for the Railbelt Region of Alaska

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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.

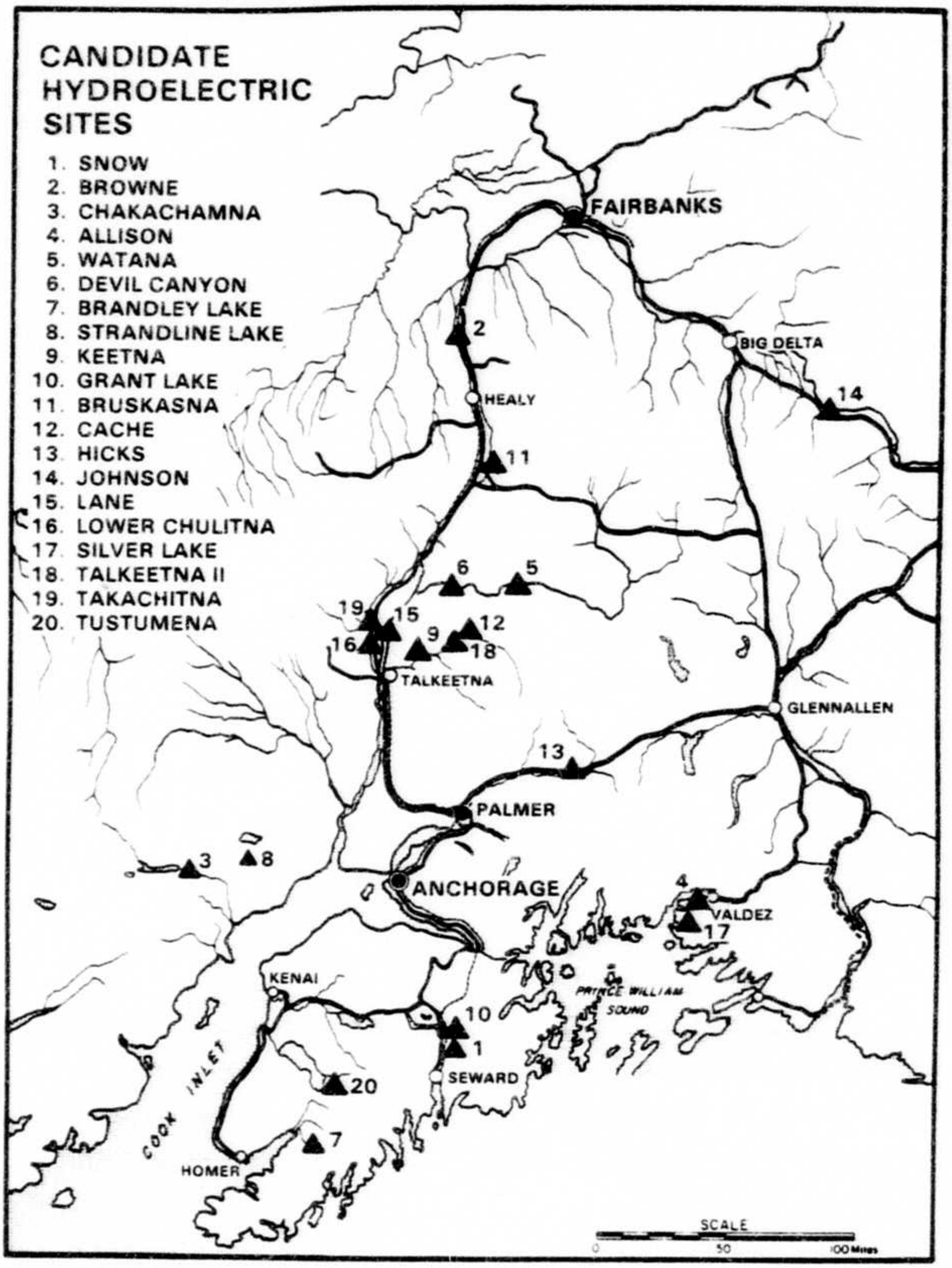

FIGURE 1. Candidate Hydroelectric Sites

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 Water-fowl Nesting and Molting Area	Spawning in Vicinity	More than 50% Suitable Soils	Selected for Wilder-ness 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 Water-fowl Nesting and Molting Area	Spawning in Vicinity	50% of Upland Soils Suitable	Nearby Primitive Area	Boating Potential	Not Available	Not Available	64[(e)]
Iustumena	Black Bear Dall Sheep	None Identified	None Identified	None Identified	Selected for Wilder-ness 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).