CANDIDATE ELECTRIC ENERGY TECHNOLOGIES FOR FUTURE APPLICATION IN THE RAILBELT REGION

APPENDIX K

SELECTION OF CANDIDATE ELECTRIC ENERGY TECHNOLOGIES

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Identification of potential candidate electric energy technologies for development of Railbelt Electric Energy Plans began with consideration of the classes of technologies which would either help offset future electric demand or which would help meet future electrical demand in the Region. Seven classes of technologies were identified, as follows:

- Base load generating technologies
- Cycling load generating technologies
- Energy storage technologies
- Fuel Saver (Intermittent) generation technologies
- Load Shaping Technologies
- Electric Energy Conservation Technologies
- Electric Energy Substitutes

Technologies considered were limited to those directly relating to electric energy production and conservation in conformance with the scope of the study. Thus, technologies related to other energy forms were considered only to the extent that they might serve to fuel electric generating facilities, serve as energy storage media in energy storage systems which might be used in conjunction with operation of an electric utility, or that might serve as a direct substitute for electric energy (i.e. wood for space heating).

Transmission technologies were not considered, as transmission intertie alternatives will be explicitly considered in the development of alternative electric energy plans in a later task of this study. Technologies related to the production of fuel for electric energy generating devices were not directly considered, as fuel availability and price is considered in a parallel task of this study.

Finally, technologies considered were limited to those normally operated in conjunction with an electric utility grid; off-grid application being outside the scope of the Railbelt Electric Power Alternatives Study.

TABLE K.1. Candidate Electric Energy Technologies

Technology	Candidate Electric Energy Technology	Rejected Technologies: Commercial Availability	Rejected Technologies: Technical Feasibility
Base Load Generation			
Coal-Fired Steam Electric	X	Commercial	
Natural Gas/Distillate-Fired Steam Electric	X	Commercial	
Biomass-Fired Steam Electric	X	Commercial	
Combined Cycle	X	Commercial	
Magnetohydrodynamic Generators	0	2000-2005	
Fission Reactors	X	Commercial	
Fast Breeder Fission Reactors	0	2005-2025	
Geothermal Electric	X	Commercial	
Fusion Reactors	0	2025	
Ocean Current Energy Systems	0	Beyond 2000	No (Resource Limited)
Salinity Gradient Energy Systems	0	Beyond 2000	No (Resource Limited)
Ocean Thermal Energy Conversion Systems	0	2000	No (Resource Limited)
Space Power Satellites	0	Beyond 2000	No (Latitude)
Cycling Generation			
Combustion Turbines	X	Commercial	
Diesel Generation	X	Commercial	
Hydroelectric	X	Commercial	
Fuel Cells	X	1985-1995	
Fuel Saver (Intermittent) Generation			
Wave Energy Systems	0	1990's	No (Resource Limited)
Tidal Electric	X	Commercial	
Large Wind Energy Systems	X	1985-1990	
Small Wind Energy Systems	X	Commercial	
Solar Photovoltaic Systems	X	Commercial	
Solar Central Receiver Systems	X	1990-2000	
Cogeneration	X	Commercial	
Energy Storage Options			
Pumped Hydro	X	Commercial	
Compressed Air Storage		(Not resolved as of this writing)	
Storage Batteries	X	1985-1995	
Hydrogen Storage		(Not resolved as of this writing)	
Electric Energy Substitutes			
Passive Solar Space Heating	X	Commercial	
Active Solar Space and Hot Water Heating	X	Commercial	
Wood-Fired Space Heating	X	Commercial	
Total Energy Systems		(Not resolved as of this writing)	
Electric Energy Conservation			
Building Conservation	X	Commercial	
Load Shaping			
Direct Load Control	X	Commercial	
Passive Load Control	X	Commercial	
Incentive Pricing	X	Commercial	
Education and Public Involvement	X	Commercial	
Dispersed Thermal Energy Storage	X	Commercial	

In conformance to the spirit of the study a broad spectrum of currently commercial, emerging and advanced technologies (meeting the criteria set forth above) were identified as potential candidate technologies. These are listed in the left-hand column of Table K.1. Nominations were based on suggestions of the contractors involved in the alternatives study, the State of Alaska, and the Project Monitor.

A "technology profile" discussing the significant characteristics of the technology was to be prepared for each candidate electric energy technology. To ensure the most productive application of study funds, candidate energy technologies were limited to those technologies having a reasonable probability of significantly contributing to the generation or conservation of electric energy in the Railbelt region during the planning period encompassed by this study (1980-2010). Thus, selection of candidate electric energy technologies was based on two screening criteria: Commercial availability and Technical feasibility.

Commercial Availability. A candidate technology should be currently commercial or be projected to be commercially available by the year 2000. A technology which would be commercially available by year 2000 would have the potential to significantly contribute to the electric energy needs of the Railbelt prior to the end of the planning period of this study. Projections of future commercial availability of emerging and advanced technologies are based on current developmental progress (i.e. do not assume unanticipated acceleration in the rate of development.

Several potential candidate technologies do not appear to have the potential to achieve commercial maturity by the year 2000. These are indicated in Table 1, and include Magnetohydrodynamic Generation, Fast Breeder Reactors, Fusion Reactors, and Ocean Current Energy Systems, Salinity Gradient Energy Systems, Ocean Thermal Energy Conversion Systems, Space Power Satellites.

Technical Feasibility. Candidate technologies should demonstrate reasonable potential to operate successfully in the Railbelt environment. As noted in Table K.1, five technologies do not at this time appear to have this potential. Four are resource-limited, in the sense that the energy source required for their operation is not available in adequate concentrations in or near the Railbelt region. These technologies include Ocean Current Energy Systems, Ocean Thermal Energy Sytems, Salinity Gradient Energy Systems and Wave Energy Conversion Systems. One technology, Space Power Satellites, does not appear to be technically feasible at the latitude of the Railbelt because of the large area of antenna required to received micro-wave power transmitted from space power satellites in geosynchronus equatorial orbit.

Technologies qualtying as candidate electrtic energy technologies are indicated by an "X" in the second column of Table K.1. A profile has been prepared for each of these technologies and is included in the main body of this report. Technologies not qualifying as candidate electric energy technologies, for the reasons discussed above, are indicated by a "O" in the second column of Table K.1. Brief overviews of the rejected technologies are provided below.

MAGNETOHYDRODYNAMIC GENERATORS

Technology and Siting Requirements

Magnetohydrodynamics (MHD) is an energy conversion technology that has the potential to increase the efficiency of electrical generation plants from about 34% to 48% (Corman & Fox 1976).

In an open cycle MHD generation system, fossil fuel is burned at a sufficiently high temperature so the product gases are ionized (4000-5000^{o}F). Electrical conductivity of the hot gases is increased by "seeding" with readily ionized material (salts of cesium or potassium).

When passed through a magnetic field, this produces an electric current in the gas. The current (DC) can be removed directly with metal rods or "electrodes."

The DC output of the MHD channel is converted to ac in solid state inverters (Corman & Fox 1976). The gases exit through a series of heat exchangers and a steam generator, which drives an AC generator.

Seed material K_2CO_3 is used to both increase conductivity and tie up sulfur as K_2SO_4. The seed recovery system and integral clause plant converts K_2SO_4 to seed material plus elemental sulfur. Problems which may delay implementation of MHD technology include predicted poor forced outage rate, short life expentancy, inflexible operation (difficult at minimum load), difficult operation and control, corrosion problems, poor potential for retrofit (Corman and Fox 1976).

Current Status of Development

A 250 hr test of a 200 kW system was run successfully in 1978 (Energy Daily 1978) at Avco Everett Research Laboratory in Everett, Massachusetts. A coal fired power plant with a demonstration open-cycle MHD generator is under construction in Butte, Montana.

It was estimated in 1976 that a commercial MHD facility could be operational by 2003 (Corman and Fox 1976). In an International Energy Agency study, the reference start year for a coal-fired MHD electric power plant was 2005 (IEA). However, funding of MHD has been cut from $60.5 million in FY 1981 to zero in 1982. Confirmation of the engineering feasibility of MHD and commercial demonstration will become the responsibility of the industry (DOE 1981).

Applicability to the Railbelt Region

The time scale for development of commercial MHD conversion systems is not consistent with the time frame of the Alaska Railbelt Electric Alternatives study.

An open cycle MHD facility would be located at a large central fossil-fired power plant. Gaseous emissions of NO_x and SO_x are estimated to be substantially less than those from a conventional coal-fired power plant (Corman and Fox 1976). A MHD facility is estimated to consume only 60% as much make-up water as a conventional steam plant, and use less than 40% of the total water requirement of a conventional plant (Corman and Fox 1976).

FAST BREEDER FISSION REACTORS

Technology and Siting Requirements

A fast breeder reactor (FBR) is a facility designed to generate electricity by using the heat produced by controlled nuclear fission of plutonium. A breeder produces more plutonium from uranium than it consumes.

When isotope ^{238}U (which constitutes 99.3% of natural uranium) in the fuel absorbs a neutron, it decays to ^{239}Pu, which is the main energy source for the breeder. The heat generated by fission is removed by the liquid sodium coolant in the primary loop. Heat is exchanged to an intermediate sodium loop. From the intermediate coolant loop, heat is exchanged to water coolant in the steam generator. At that stage, the steam cycle is similar to that of any other conventional thermal power plant (fossil or nuclear).

The overall thermal efficiency of an FBR is slightly higher than that of a light water reactor (LWR) because it operates at higher temperature. The product of a comercial breeder facility would be about 1000 MWe, baseload power.

Siting considerations are the same as those for conventional nuclear plants. These include adequate water available for cooling, geologic and seismic stability, and 100-400 acres of land remote from a large population center. In addition, access to reprocessing facility is required by an FBR. Impacts from a breeder plant, like any large thermal power plant include local impacts during construction, heat release to the environment and fog created by cooling towers.

A principal problem for breeder development is in the fuel cycle. Reprocessing and fabrication facilities for breeder fuel must be built for continuing breeder operation. Fuel reprocessing provides for recovery and purificaton of plutonium contained in the spent fuel, so it can be recycled. Fuel fabrication prepares the recovered fuel for recycle in a power plant.

Current Status of Development

Current U.S. experience with breeders is being acquired at the Fast Flux Test Facility (FFTF) which achieved full power in December 1980. The reactor capacity is 400 MW thermal, approaximately equivalent to 133 MWe, but is not being used for generation of power. The Clinch River Breeder Reactor (CRBR) will generate 350 MWe. The CRBR has been restored to the FY-1982 DOE budget (DOE 1981).

The conceptual Design Study reactor (CDS) is a 1000 MWe gross facility. The proposed schedule calls for completion in 10 years. A 1200 MWe commercial prototype reactor is expected to be operational about 2001, with the first commercial plant to be in the 2006-2023 time frame (DOE 1979).

Applicability to the Railbelt Region

Breeder reactors will not be established on the commercial market by the year 2000, and are thus out of the time consideration of this project.

FISION REACTORS

Technology and Siting Requirements

Fusion power results from the conversion of mass into energy when two light nuclei-collide and combine "fuse" to become a single, heavier atom. The heavy isotopes of hydrogen, deuterium (D) and tritium (T) are employed in DT fusion, the first likely commercial candidate. The reaction is as follows:

$$^{2}_{1}D + ^{3}_{1}T + \text{plasma energy} \quad ^{4}_{2}He + ^{1}_{0}n + \text{fusion energy}$$

Deuterium is present in water in sufficient quantities to be available for millions of years. The other fuel atom, tritium, is created by neutron capture in a lithium blanket region surrounding the fusion reaction chamber (Dingee 1979).

The heat produced would be used with conventional steam generation (Dingee 1979) via an intermediate heat exchanger or possibly closed-cycle MHD. Fusion power plants are projected to be large, 1000 MWe for example, and would be operated as base loaded facilities. Siting considerations are similar to those for a conventional LWR fission plant. A site should be near a load center, with cooling water available, satisfactory geology and seismology, transportation facilities to burial site for solid radioactive wastes. In addition, large land area is required to preclude effects on the public of magnetic fields, and interference on electrical and communication systems.

The inventories of tritium would be greater than for present fission designs (Strand and Thompson 1976). Consequently, some tritium is anticipated to escape the plant in both liquid and gaseous effluents.

Because of the high temperature involved, fusion plants may be more efficient than present LWRs. But large heat releases and fog created by cooling towers may have significant impact on the siting of the plant.

Current Status of Development

Energy breakeven requires the product of confinement time (sec) and density (ions/cc) to be greater than 200 trillion at a temperature over 100 million^{o}F. No fusion device has yet to reach "breakeven" -- where fusion energy release is just equal to the energy supplied to run it. It is expected that breakeven will first be reach by Tokamak Fusion Test Reactor sometimes in 1983 (Blake, 1980).

Applicability to the Railbelt Region

This time scale is not consistent with the Railbelt Electric Energy Alternative Study.

OCEAN CURRENT ENERGY CONVERSION

Technology and Siting Requirements

There have been a number of proposals for the extraction of power from ocean currents. These are, in principal, relatively simple installations--such as turbines and paddle wheels (Isaacs and Schmitt 1980).

DOE has supported preliminary studies of a large ducted turbine for ocean current energy conversion. The device is an undersea, moored, ducted turbine, driven by current flow kinetic energy, which drives electrical generators and transmits power to shore with a sea-floor cable. The structure envisioned is on the order of 200 to 300 feet in diameter, and has a rotational speed of 1 RPM. The proposed structure would be of hollow aluminum construction. An individual unit would provide 75 MWe (Lissaman et al. 1980). The designers of this device have proposed mooring 132 such turbines in the Florida current to deliver 10,000 MWe to the Florida power grid.

The Florida current of the gulf stream is the only candidate for U.S. Production of Energy from ocean currents (Booda 1978). Even a major current has very low energy density, equivalent to about 5 cm of water head, or about 1000 times lower than for thermal gradients. The Florida current runs at about 2.5 to 2.9 knots off Miami, whereas the Alaska current runs at 1 knot (U.S. Department of the Interior 1970). Since kinetic energy is proportional to the square of velocity, the Florida current energy density is approximately 6 to 8 times that of the Alaska current.

Status of Development

The preliminary design study of ocean current energy conversion was funded by DOE. The study calculated turbine and power extraction performance, and tested a 1-meter rotor model (Lissaman et al. 1980).

In 1980 it was projected that ocean turbines could be commercialized by 1999. However, that assumed that DOE funded work would continue and a full-scale prototype would be complete in 1985. Since Ocean Energy systems has no funding for FY1982 and beyond (U.S. DOE 1981) the development of ocean current energy conversion is in doubt.

Applicability to the Railbelt Region

The future of ocean current power in the U.S. is uncertain at this time. Apparently, it will not be commercial in the U.S. by the year 2000, which puts it out of the time scale of this study. If ocean current energy conversion were commercial, Alaska would not be a good location for a facility, considering the very low energy density of the Alaska current.

SALINITY GRADIENT ENERGY CONVERSION TECHNOLOGY AND SITING REQUIREMENTS

Salinity gradient energy conversion is a large potential source of power. The concept involves converting the energy of mixing of high and low saline waters into usable energy.

The energy density of this process is equivalent to about 240 m of water head, (equivalent to an OTEC Plant with a temperature difference of 23^{o}F) (Isaacs and Schmitt 1980). The energy available represents a theoretical power of 2 MW for a flow rate of 1 m^3/sec for a freshwater river flowing into the sea (Olsson, Wick and Isaacs 1979).

There have been three approaches for extracting power from salinity gradients: 1) osmotic exchange against a hydrostatic pressure (or pressure-retarded osmosis); 2) the dialytic batter (inverse electrodialysis) (Isaacs and Schmitt 1980); and 3) vapor exchange between two solutions (inverse vapor).

Pressure-retarded osmosis uses the osmotic pressure gradient (about 23 atm) across a semipermeable membrane which separates seawater (at 35 parts per thousand salinity) and freshwater. To convert the osmotic pressure, one releases the pressurized solution through a hydroturbine (McCormick 1979). This concept requires large amounts of fresh water, and must be sited at a river.

The dialytic battery is made of anionic-permeable and cationic-permeable membranes in a battery type container. Salt water is passed between alternate membrane pairs, while fresh water separates one pair from another. Positive and negative charges are transferred to electrodes at the ends of the membrane stack. A 100 watt model has been studied (McCormick 1979).

Inverse vapor compression involves vapor exchange between two solutions, prefereably at elevated temperatures. Due to lower vapor pressure of salt water, water vapor will transfer from fresh water to salt water in an evacuated chamber. Power can be extracted if a turbine is placed in the vapor flow between the two solutions (Olsson, Wick and Isaacs 1979).

The third scheme uses no membranes, but only heat exchangers and turbines. Vapor pressure differences increase dramatically with temperature, so a low-grade source of heat would be advantageous. Power is required to create and maintain a vacuum in the chamber (Olsson, Wick and Isaacs 1979).

The energy density of a salinity gradient is a function of the concentration differences. The energy density of a system of saturated brine (260 parts per thousand) and fresh water is about 20 times greater than a seawater (35 parts per thousand) and fresh water system (Isaacs and Schmitt 1980).

Energy densities for Alaskan salinity gradient resources would be slightly lower than values presented because lower salinity of the sea water.

The salinity of sea water off alaska is 31.5-32 parts per thousand most of the year (U.S. Department of the Interior 1970, p. 83) about 10% less than salt water in the referenced experiments.

Status of Development

Salinity gradient energy conversion is in the experimental stage. Salinity gradient research was conducted by DOE Under Ocean Energy System, which will no longer be funded as of FY1982 (U.S. DOE 1981). Therefore, the commercialization of this technology is uncertain at best.

Applicability to the Railbelt Region

Considering the current low state of development of salinity gradient energy conversion technology and the funding situation, this will not be an option in the time frame under consideration to meet Railbelt power requirements.

SPACE PWER SATELLITES

Technology and Siting Requirements

The space power satellite (SPS) concept is based on large (5 km x 10 km) solar collectors in geostationary orbit that transmit power to a receiving antenna (rectenna) on the earth. The rectenna would consists of an array of inclined planar solar panels 3 m wide in long continuous rows. Power is converted from DC to AC and stepped up to 500 kV for transmission (Brown et al. 1980, p. 328). The microwave power transmission link cannot be scaled down economically to powers less than a gigawatt (1000 megawatts) (Sperber and Drexler 1980). The conceptual design of a satellite power station developed in the DOE/NASA Concept Development and Evaluation Program (1977-1980) calls for capacity of 5 gigawatts.

The rectenna requires a large area of relatively flat land with an area of low population density. Variables which exclude rectenna siting include inland water, military reservations, population density, marshland, or perennially flooded areas, interstate highways and unacceptable topography. Potential exclusion areas include Indian reservations, and national interest lands. Other variables which impact design and cost of the rectenna site include snowfall, freezing rain, sheet rainfall, wind, lightning density, hail, seismic risk, timbered areas, and water availability (Ankerbrandt 1980, p. 127).

The Ground Receiving Station (GRS) should be near the load center, but located to avoid radio interference. An optimum location would be a desert area. A prototype assessment of environmental impact of siting and construction of a GRS Used the California desert about 250 km north of Los Angeles for baseline data (Bachrach 1980, p. 525).

The land area required is about 400 km^2 at 35^o latitude. At the latitude of the Railbelt area, about 63^o, an area of about 1200 km^2 would be needed (Reinhartz 1980). Construction of a Ground Receiving Station in a desert area at 36^o is expected to require 25 months, with an average work force of 2500. Approximately 450 workers would be required for 24-hours, 365 days per year operation (Bachrack 1980, p. 525). A GRS facility in more difficult terrain that covers three times the area may then require a construction work force of 7500 or larger, and an operations crew of 1350.

Construction of a GRS facility would displace existing land uses, totally disrupt the ecology of the site, and have great socioeconomic impact from the immigration of construction workers. The most significant environmental issue from satellite power transmission is long term exposure to low level microwaves on telecommunication, particularly interference with defense requirements (Valentino 1980).

Current Status of Development

The objective of the DOE/NASA sponsored SPS program is "to develop by the end of 1980 an initial understanding of the technical feasibility, economical practicality, and the societal and environmental acceptability of the SPS concept" (Glaser 1980). The technology will not be developed for at least 10 years, and commercialized in no less than 20 years (Glaser 1980). The conceptual Development and Evaluation Study guidelines call for initial commercial operation of power satellites in the year 2000 (Schwenk 1980). The SPS assessment program has been completed, and the program is closed. There is no SPS funding for TY1981 or FY1982 (Riches 1981). Principal problems requiring resolution include solar cell conversion efficiency and cost, microwave power transmission, space transportation, and construction operation, maintenance and active control of the SPS structure (Schwenk 1980).

Prospects for Railbelt Application

An SPS system does not currently appear to be a candidate technology for supplying power to Alaska for several reasons:

- The time scale for development is uncertain; funding has been discontinued indefinitely.
- The projected size of generation system, 5 GWe (5000 MWe) is much larger than demand forecasts for the Railbelt region.
- The northern latitude location of the Railbelt region requires a much larger rectenna area and lower power density than a more southerly site, which makes the system even less cost-effective.

OCEAN THERMAL ENERGY CONVERSION

Technology and Siting Requirements

Ocean thermal energy conversion (OTEC) uses the temperature difference between surface water and ocean depths to generate electricity. A conventional thermodynamic cycle is used with ammonia or propane as the working fluid. The working fluid is boiled by the warm sea water, the vapor is run through a turbine where power is extracted, the fluid is cooled by cold deep-ocean water, and is pumped back to the warm water heat exchanger.

The efficiency of the system is based on the difference in temperature between shallow and deep water. Surface water in the tropics is heated by the sun to about 79 to 84°F. Cold water from about 3000 to 6000 feet deep originates in the Arctic or Antarctic, and has a temperature of 39 to 44°F (Booda 1978).

The efficiency of the OTEC closed-cycle is limited by Carnot efficiency of a heat engine. The ideal heat engine working at upper and lower temperatures of 80°F and 40°F (540°R and 500°R, respectively) would have an efficiency of 650-500/540, or 7%. Real equipment with friction and pumping losses would have efficiency of about 3%. A 100 MW plant would have to pump 30,000 cubic feet of sea water per second (Forbes et al. 1979).

OTEC powerplants are suitable for tropical or subtropical seacoasts or offshore regions. A minimum temperature difference of about 30°F and depth of about 2000 ft is required. DC power would be transmitted to the load center by undersea cables. The proposed size of a commercial OTEC plant is about 200 to 400 MW (Richards 1979). Potential impacts include interference with ocean transportation, fisheries and sea life, and influence on natural ocean circulation.

Status of Commercial Development

A demonstration of the feasibility of OTEC has been performed by DOE. The DOE budget for OTEC has been reduced from $34.6 million in FY81 to zero in FY82. DOE considers it the responsibility of the private sector to develop marketable systems once technical feasibility is established (U.S. DOE 1981).

A commercial prototype OTEC powerplant was envisioned about 1990 (Richards 1979). The reference start year for a commercial operation a 100 MWe ocean thermal gradient electric powerplant was taken to be 2000 in an International Energy Agency study (IEA 1980). The commercial sector will determine the actual development schedule for OTEC.

Railbelt Feasibility

Sites for OTEC plants are generally restricted to 20° north and south of the equator (Booda 1978). OTEC power cannot be considered in alaska because the concept depends on warm (80°F) tropical ocean surface temperatures. The mean surface temperature off the south coast of Alaska varies from 42°F in winter to 54°F in summer (U.S. Department of the Interior 1970, p. 83).

OCEAN WAVE ENERGY SYSTEMS

Technology and Siting Requirements

Many methods of ocean wave energy conversion have been suggested. Most of these methods fall into the following categories: 1) heaving bodies, 2) pitching or rolling bodies, 3) cavity resonators, 4) wave focusers,

5) pressure converters, 6) surging bodies, 7) flapping bodies, 8) rotating outriggers, and 9) combinations of the above (McCormick 1979). DOE sponsored efforts include a full-scale wave energy conversion program with the International Energy Agency (IEA). The apparatus, known as "Kaimei," is a cavity resonator system. There are three air turbines on the deck of Kaimei which have been designed and constructed in Japan, the United Kingdom, and the United States. The turbines are excited by the air motions above the rising and falling of the surface of the water. Each turbo-generating system is designed to deliver 125 kW in a 2 meter sea with a period of 6 seconds (McCormick 1979).

Another DOE-sponsored effort has been in wave-focusing systems. Wave focusing is accomplished by four techniques: 1) radient wave interaction, 2) Fresnel-type focusing, 3) refraction, and 4) channeling.

Radient wave interaction occurs when a body is in resonance with the incident wave. Fresnel-type focusing is done by a lens type structure which causes wave diffraction or refraction. A refraction wave energy device called DAM-ATOLL, was developed at Lockheed. The device is a submerged dome which causes incident waves to refract and focus on a vertical axis turbine located at the center of the dome. The device, a lenticular hump on the sea floor, could be produced by dredging or dumping (Isaacs and Schmitt 1980).

Wave focusing by converging channels appears to be feasible only in or near the surf zone where energy is relatively low. Thus, DOE Has not sponsored studies in this area (McCormick 1979). The U.S. wave energy program has concentrated on wave focusing systems and the cavity resonator because larger structures are not justified by the low energy density. Also, large structures undergoing significant motions while moored at sea is contrary to standard ocean engineering practice (McCormick 1979).

Wave energy density has been estimated to be equivalent to 1.5 meters of water head. This compares with 570 meters for OTEC, with a 36^{o}F temperature difference (Isaacs and Schmitt 1980). Siting requirements will include location in the ocean with consistent waves, near a load center. Such a facility would probably be used as a "fuel saver."

The DOE considers only the northern half of the Pacific coast a promising area. It is estimated that between 5 and 50 megawatts per kilometer of coastline could be generated (Booda 1978). The northern California and Oregon coasts have waves of height 5 feet and over 20 to 30% of the time in spring and winter, and 30 to 40% of the time in summer and autumn. Off the Alaskan coast, the frequency of waves of height 5 feet and over varies from less than 5% in the spring to 10 to 20% in the fall (U.S. Department of the Interior 1970).

Status of Commercial Development

Currently, wve energy systems are in the developmental stages. Problems requiring resolutin include the need to withstand large storm waves, corrosion and fouling, energy storage and/or transmission, capital costs of fabrication and installation (Forbes et al. 1979).

An International Energy Agency study assumed 1990 as the reference starting year for commercial operation of a 2 MWe wave powerplant (IEA 1980). Wave energy research programs have been supported by DOE and are dependent on government funding. Wave energy studies have been about 4% of DOE's Ocean Energy systems budget. Since Ocean energy systems will not be funded in FY1982 (U.S. DOE 1981), the fate of wave energy development is uncertain.

Applicability to the Railbelt Region

The coast of Alaska is not an optimum location for wave energy powerplants, as shown by wave height/frequency statistics. In addition, the development of wave energy technology is uncertain, and may not be available in the time frame under consideration.