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# Technology and the Energy Crisis: An Assessment of the Interrelationship and the Impact

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# TECHNOLOGY AND THE ENERGY CRISIS

# AN ASSESSMENT OF THE INTERRELATIONSHIP AND THE IMPACT

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### ABSTRACT

This paper presents an assessment of past and present technological innovations and research related to the present energy crisis- the impact and the interrelationship. In particular, it surveys the development of tidal power plants with particular emphasis on the past and present status of the Passamaquoddy-Cobscook Bay Dam Project. It examines the benefits and environmental effects associated with tidal power development, and explores the causes and effects of the tides. It concludes with a brief detail of the feasibility of other renewable sources of energy- and of the impact of technological developments on marine and international affairs.


### INTRODUCTION

In the United States today, the most prevalent and pervasive problem confronting the American public- second only to inflation -is the energy crisis, and even in their separate concerns, they are inexorably related through the hiatus of technology. The inflationary spiral is related to the snow-balling energy crunch, and the energy crunch is related to our overwhelming reliance on the effectiveness of innovations of technology to resolve problems of limiting energy resources. It is technology that uses hugh quantities of energy to sustain its existence; yet, little has been written on the intricate interrelationship of old and new technology to the existing energy crisis.

Technology requires energy to sustain its existence, and as technological innovations continue to increase the demands for energy- and as energy consumption and depletion continue to increase the demands for new technological developments of energy resources- nobody seems to be asking the question where will it all end. Perhaps there is the need to pause and reflect on how to stabilize that which we already have, how to live at the level to

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which our present technological innovations have brought us, rather than to continue new technological developments thereby utilizing valuable energy reserves for which there is no foreseeable replacement. We are in fact fueling the energy shortage by our technological spin-offs. Developments in technology impact on every area of human affairs, of marine affairs, and of international affairs. It seems time to halt this technological spinning wheel, and find a balancing wheel in the technological order, and especially in our use of energy resources; in this realm, we have violated a basic principle of nature. A rule of nature as pertains to Energy System Users, is stated as follows:

> "Any system which uses energy always seek an equilibrium at a condition of lowest possible energy." (Electrons fill the energy band from the bottom first, then move to the top).

However, the United States is rapidly exhausting its conventional energy sources which it produces, while its use of imported energy resources are subject to the varying political and economic whims of the nation states from which these resources are imported. If we agree that our conventional energy resources of our Universe are finite- that is:

| | | | |
|---|---|---|---|
| Natural Gas | Petroleum | Shale | Synthetics |
| Coal | Oil | Uranium | |

Then, we can agree that we have not balanced our use of these resources with our use of the unconventional and renewable energy sources that make possible the conventional forms of energy.

What we have done instead, is to create an annual and monumental renewable technological waste:

8 million automobiles
100 million rubber tires
40 million tons of paper
48 million cans
26 million bottles

The result is a 400-billion pound municipal waste heap.

The renewable (unconventional) energy sources on which we have not capitalized are:

Solar Power
Tidal Power
Thermal Power
Wind Power

It is estimated that the mean solar power input to the earth is $5.2 \times 10^{21}$ BTU/year = $1.73 \times 10^{11}$ Megawatts. The tidal energy dissipated by the earth is estimated as 1.4 million megawatts; 1.1 million megawatts is accounted for by oceanic tidal friction in bays and estuaries which could be captured and converted to electric power. Additionally, there is a tremendous amount of power available in the difference in temperature between surface and deeper waters of the oceans- so-called Thermal Energy- which can be used to generate electric power. Wind Power is as old as the earth, its use has pre-dated the other forms of renewable energy, and its availability has not lessened with time.

The following table shows the technological goals for the future as defined by the energy budgt of 2.5 billion dollars established by the Energy Research and Development Administration (ERDA) Budget:

| Fossil Energy Program | Budget |
|---|---|
| Direct coal utilization in utilities | $ 33 million |
| Magnetohydrodynamics | 30 million |
| Enhanced oil and gas discovery | 28 million |
| Coal gasification | 95 million |
| Coal liquefication | 97 million |
| **Solar Energy** | |
| Biomass conversion | 83 million |
| Electric application | |
| Heating/cooling- houses/buildings | |

| | |
|---|---|
| Geothermal | 26 million |
| Nuclear Energy/Fusion | 1.665 billion |
| Fusion | 197 million |
| Fission | Balance |
| Conservation | |
| Building & consumer products | |
| Electric conversion efficiency | |
| Electric power transmission & distribution | 26 million |
| Industrial energy efficiency | |
| Transportation efficiency | |

It has been stated by R. W. Schmitt and C. W. Stewart in Energy Policy, that:

> "It is time for the United States to move from development discussion of many energy options to the more difficult task of selecting a few for commercialization. Future energy growth will be slow, incentives are suggested to accelerate introduction of new energy technology under teese conditions."

It has been stated also that the development of renewable energy sources is not profitable, that it is not economical for private industry to engage in commercializing solar power, tidal power, and water power. However, it must be kept in mind that the profitability of a given energy form is not governed solely by the average unit cost of competitive sources, rather it is a function also of the structure of the prices of the energy form with respect to the time of generation and consumption.

Thirty-five (35) years ago, fuel consumption accounted for such a large proportion of the output costs of thermal power stations that the potential cost saving was an important factor in the profitability of a tidal power project, and general attention was focussed on this saving. Today, and for the future, we look at the price structure of nuclear energy and determine that the price saving becomes a more significant element in the economic return of a tidal power scheme.

If the present rate of inflation continues, the United States will not be able to afford even nature's free (renewable) sources of energy, though other forms may already be depleted. The United States is presently funding a study of the feasibility of establishing a tidal power plant in the vicinity of the Bay of Fundy- the Passamaquoddy and Cobscook Bay -in the Maine Region. The idea is not new, however the time could not be more critical to the promise for such a development. The French are operating a tidal power plant on the La Rance River, St. Malo, France; and in the Kislaya Bay, on the Kola Peninsula- a plant is operated by the U.S.S.R.

Basically, this is a review of the historical and update decisions on the harnessing of tidal energy.

## HARNESSING THE TIDES - A RENEWABLE ENERGY SOURCE

Renewable energy sources account for only about 5% of the energy consumed in the United States, and the bulk of this is in the form of hydroelectric power; other renewable energy sources have received little commercialization.

For the millenia of man's existence, he has recognized the sun as the primary source of energy to his natural surroundings, and has studied ways to concentrate that energy in a form suitable for warming his dwellings and for cooking his food. It was years before he realized that the waters surrounding his land was a natural repository of greater quantities of this stored energy, and could be utilized to generate power for his needs. This knowledge was intensified with an understanding of the nature of the rise and fall of the waters close to the shores and known as the "Tides". Of course, attempts were made to harness this energy long before Newton's "Principia" advanced the theory of the Earth-Moon and Sun's Gravitational System as being the combined force to "pull" the waters from the earth and generate the Tides.

The power evidenced in the rise and fall of the waters has been put to use since the dawn of early history. The Greeks attempted use of the tides in the Euripes, a rather narrow channel between Boeotia and the Isle of Euboea, near Thebae, Marathon and Plateea. Water mills were used to take advantage of the tidal currents, and other tidal mills were used to provide energy in Cephalonia near Agostoli (Ionian Sea). In Europe, tide mills have existed for centuries- Domesday Book mentions one in Dover Harbor (1066). Those of Bromley-by-Bow in the London region (built around 1135) are among the oldest in the British Isles; and one on the Deben estuary- built around 1170- was in use during World War II. Even London Bridge (in 1580) had a tidal mill used for pumping water. These mills pre-dated by far the 17th Century Newtonian Physics which supporttd the concept of a Theoretical Tide and an Equilibrium Tide; and which provided a predictive basis for determining times and heights of the water above the level of the Sea in Ports around the world.

According to R. H. Charlier, the Dutch built tidal mills in Zuid-Holland and Zeeland as early as 1200, and built such mills in New York in the 17th century where they settled as colonists; one of these on Spring Creek was working in 1899. The earliest tide mill in the United States is purporttd to have been built in Salem, Massachusetts, though it is claimed that one was in existence in 1617. Prior to 1800, at least two mills operated in Passamaquoddy Bay.

From the above, it is to be noted that the stored energy of the sea has long been recognized as a possible "driving wheel" for man's energy needs; however, as non-renewable energy sources became available and required no sophisticated mechanisms for transformation into heat, harnessing the energy of the tides was looked upon as being non-feasible- economically- requiring too great an initial cost outlay in systems designed to take advantage of its use in relation to the immediate benefits to be derived. Little thought seemed to have been given to the fact that once the cost of the investment had been realized, the energy source was perpetual and free, only the equipment needed renewal.

Many areas exist in the world where advantage may be taken of the tides (Figure 1); however, of these places, there are few where the rise and fall of the waters reach such spectacular heights as they do in the Bay of Fundy, off the coast of Maine, United States of America, and Nova Scotia. This is the area of the Passamaquoddy near the mouth of the Bay of Fundy- Cobscook Bay and the St. John's River are ideal areas of sufficient heights for building tidal power plants to generate energy; the sight of high tides in this area gave impetus to these interested in harnessing the tides.

PROPOSED TIDAL POWER PLANT- PASSAMAQUODDY-COBSCOOK BAYS, BAY OF FUNDY

Tidal power is one of the alternative sources of energy which Congress has ordered to be investigated. It is reasoned that the choice of where and how to develop new energy sources for the 1980's and beyond must reflect national and regional priorities. Presently, a study is on-going by the United States to determine the feasibility of utilizing tidal action in the Cobscook Bay Region of Maine as a source of electrical energy. In the same general area, a draft Environmental Impact Statement has been completed (1978) on the feasibility of building a hydroelectric plant on the St. John's River known as the Dickey-Lincoln School Lakes Hydroelectric Project. Both of these projects were proposed as a part of a tidal project known as the"International

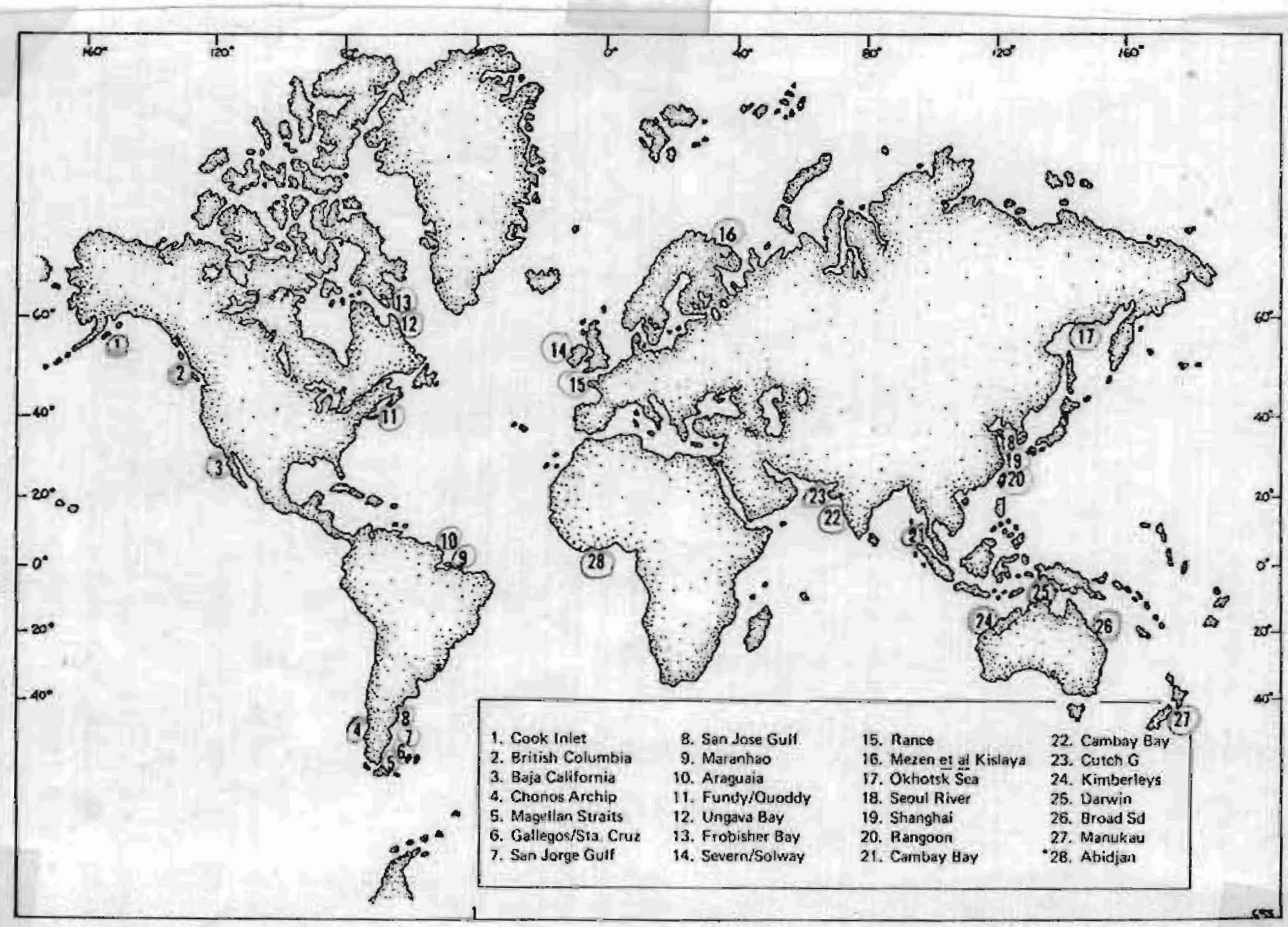



FIGURE 1. MAJOR TIDAL POWER PLANT SITES

Passamaquoddy Tidal Power Dam Project and Upper St. John's River Hydroelectric Power Development Project." This latter project was deemed as not feasible for United States development alone; thus, it was pursued with the support of the Canadian Government. However, on May 10, 1978, the Canadian Government-through correspondence received from its Embassy here in Washington, D. C., formally withdrew support from the project.

ORIGINAL PROJECT - PASSAMAQUODDY BAY

Passamaquoddy Bay, a part of the Bay of Fundy, lies at the northern-most limit of the Atlantic Coast of the United States. The International U.S./Canadian Boundary transects Passamaquoddy Bay. Cobscook Bay is located in the easternmost portion of the Atlantic seabord of the Unites States on the coast of Maine's Washington County; it abuts the U. S. Canadian boundary in the Passamaquoddy Bay region of New Brunswick Province (Figure 2).

The world's highest tides occur in this area as a result of a combination of the astronomical forces generating the tides; the narrowing gulf; and the progressively shallower bottom- these form natural funnels into which the tides swell to amazing levels. The flood tides of spring and fall may rise at the head of the Bay of Fundy to 70 feet; 40-foot tides are not uncommon at Eastport, Maine, where year-round the tide is 28 feet. Seventy billion cubic meters of water enters and leaves the basin during each tidal cycle. There are two high and two low tides each day, typical of a semidiurnal or mixed-type tide.

Plans were set forth as early as 1919 for harnessing this energy, and work on this project was started in 1935, and subsequently halted. In 1941, the Federal Power Commission in a report prepared pursuant to Senate Resolution 62, 76th Congress, 1st Session, concluded that the Passamaquoddy Tidal

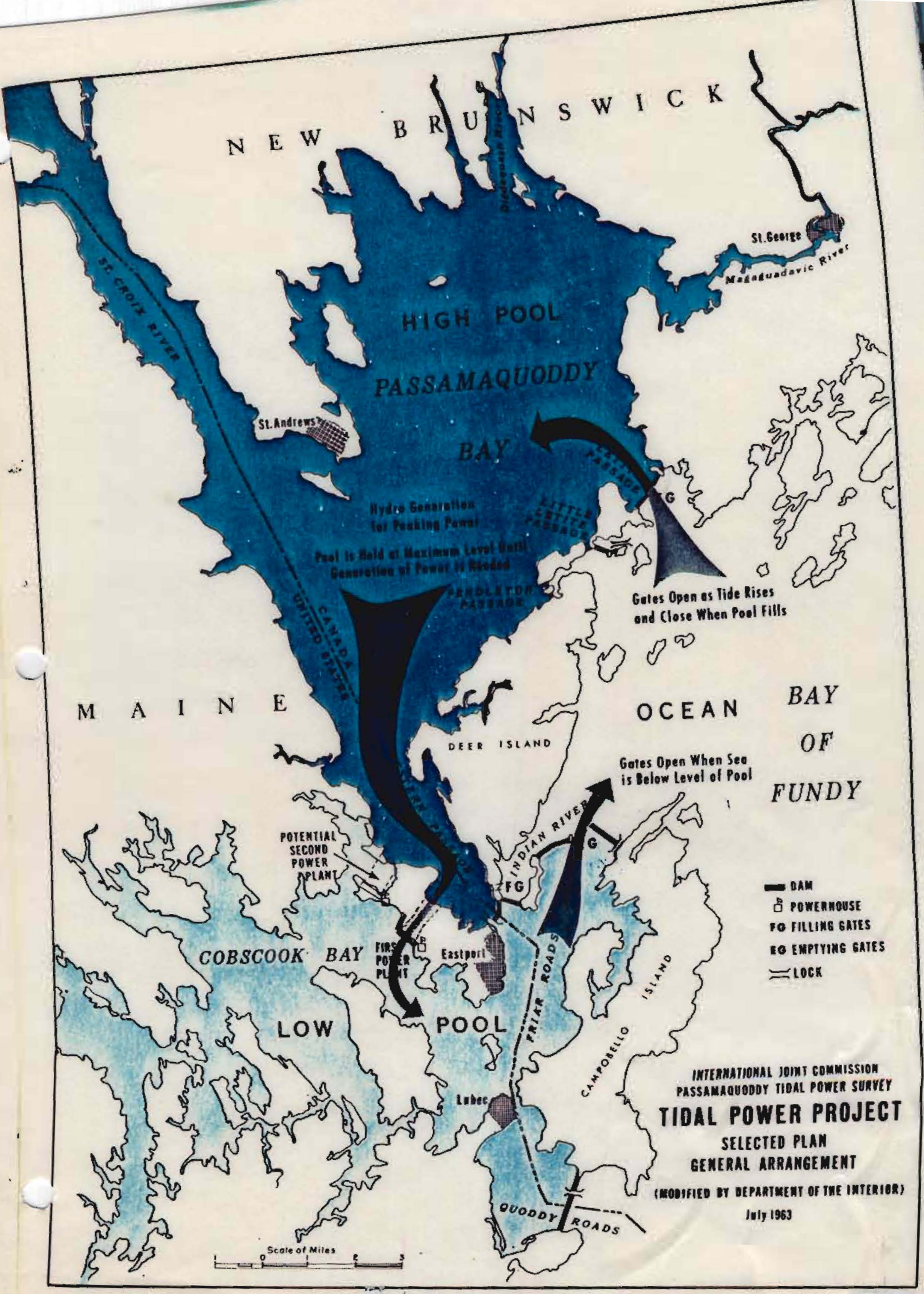



FIGURE 2. COBSCOOK BAY AREA

Power Project (development of the U. S. waters alone), could not compete successfully at that time with river hydroelectric potential available in the Sate of Maine, or with the power from modern efficient steam-electric plants. However, the Commission concluded that there was feasibility to establishing a large international tidal power project at Passamaquoddy by the Governments of the United States and Canada. By formal reference dated November 9, 1948, it requested an International Joint Commission to review plans and to determine its priority. In October 1950, the International Passamaquoddy Engineering Board (appointed by the Commission) concluded that the survey cost would be $3 million (including 300,000 for fisheries investigation). Studies of this project continued through 1961- finally resulting in a proposed tidal power plant for the area. The final project arrangements selected for design included 101 square miles of Passamaquoddy Bay as a high pool, and 41 square miles of Cobscook Bay as a low pool (Figure 3), with a powerhouse on Carrying-place Cove. The selected plant would provide an installed generating capacity of 300,000 kwh, with an average annual generation of about 1,843 million kwh. The characteristics are shown below:

CHARACTERISTICS

| | |
|---|---|
| High Pool - Passamaquoddy Bay | 100 sq. mi. |
| Low Pool - Cobscook Bay & Friar Roads, New Brunswick | 37.2 sq. mi. |
| Max. observed tidal range | 25.7 feet |
| Min. observed tidal range | 11.3 feet |
| Avg. tidal range | 18.1 feet |
| Max. tidal velocities | 10 feet per second |
| Max. Depth at construction | 300 feet |

Seventy billion cubic meters of water enters and leaves the basin during each tidal cycle.

POWERHOUSE

Two separate 50-unit plants (one recommended at present)- No. 1

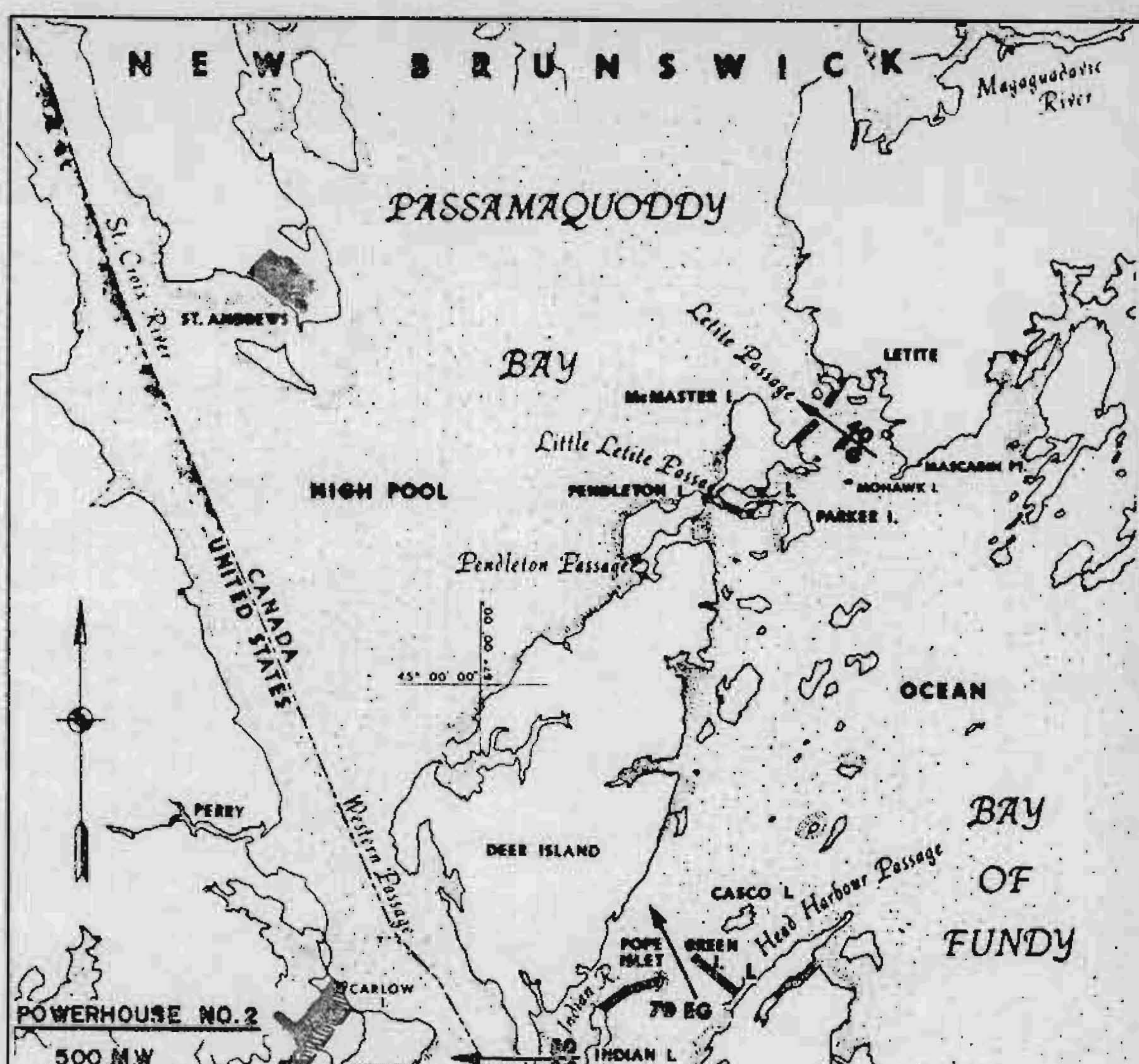



FIGURE 3. **TIDAL POWER PROJECT PLAN** 6/15/76

at Carringplace Cove, Maine, and No. 2 at Bar Harbor, Maine. Each with fifty 300-inch diamettr adjustable blades, adjustable gate propeller-type, inclined-axis turbines; speed 45 rpm, connected through a speed increaser to 10,000 KW, 13,800-volt, 3-phase, 60-cycle generators turning at 450 rpm.

DAMS

Earth and rockfill

| | |
|---|---|
| Total length ...................... | 35,700 feet |
| Max. height ...................... | 315 feet |
| Crest elevation .................... | 25 feet mean sea level |

FILLING AND EMPTYING GATES

Ninety 30' x 30' verticle lift, submerged venturi filling gates.
Seventy 30' x 30' verticle lift, submerged ventury emptying gates.

NAVIGATION LOCKS

| | |
|---|---|
| Head Harbor Passage .............. | 415 x 60 x 21 |
| Western Passage ................ | 415 x 60 x 21 |
| Little Letite ...................... | 95 x 25 x 12 |
| Quoddy Roads ...................... | 95 x 25 x 12 |

The United States is now looking at an all-American plan for Cobscook Bay, Maine, because of the fact that the Canadian Government's indication that they would pursue separate tidal power studies, and would provide an observer to the U.S. efforts in this regard. The Canadians deemed that higher tidal ranges could be achieved in the Upper Bay of Fundy, that the project would not be economically feasible for them unless the interest rate was 1/2 of the proposed 7% rate.

Funding to the Cobscook Bay, Maine study has been continuous since 1976-77. The President's budget request to Congress for FY 1980 had $860,000 for a tidal power project alone- about $1,100,000 has been allocated out of a total of $916,000,000 pre-authorized general investigation allocation. Additionally, the President's FY 1980 budget request had $710,000 for the Dickey-Lincoln School Hydroelectric Project which was authorized by the 1965 Flood Control Act, Public Law 89-298, dated October 1965. It was considered feasible because the benefit-to-cost (BCR) ratio was 1.9 to 1 at 3 1/4% interest. (Figure 4).

Funding was provided to this project since 1967; out of a $745,000,000 pre-authorization general investigation appropriation - $8,944,000 was allocated in 1978, and $1,756,000 in 1979 for pre-construction planning (data received from the Corps of Engineers, May 1979, Washington, D. C.).

The Department of Energy (DOE), Energy Research and Development Administration (ERDA), indicated that tidal power development was not economically feasible in the Passamaquoddy Bay region where evaluation was on conventional methods of analysis for water resource projects; the Cobscook Bay, Maine project is continuing under study because evaluation on a life-cycle basis indicated that the project may be feasible. Proposed also was an oil refinery and marine terminal for Eastport, Maine.

ORIGIN OF PASSAMAQUODDY BAY TIDAL PROJECT

A scheme to harness the energy of the tides was proposed by Dexter P. Cooper in 1919, the principal question was one of cost. In 1921, Franklin D. Roosevelt is said to have discussed the possibility of harnessing tidal power in the Passamaquoddy Bay region with the General Electric Company which made a rough survey of the area and concluded that the project was "of interest and well worth studying, but that demand for power at that time did justify anything further".

In April 1925, the State Legislature of Maine passed, and approved in September 1925, an Act incorporating Dexter P. Cooper, Inc. "for the purpose of developing and utilizing the power of the tides in the Bay of Fundy". In 1926, this company received a charter from the Canadian Parliament; however, no construction was done in the 3-year period provided by the Canadian Govern-

WASHINGTON POST 7/23/79

# A Dam's Future In Conflict With A Town's Past

By Margot Hornblower
Washington Post Staff Writer

ALLAGASH, Maine—Deep in the north country woods where the state highway finally turns to dirt, the town of Allagash, lacking perhaps a future, is searching for its past.

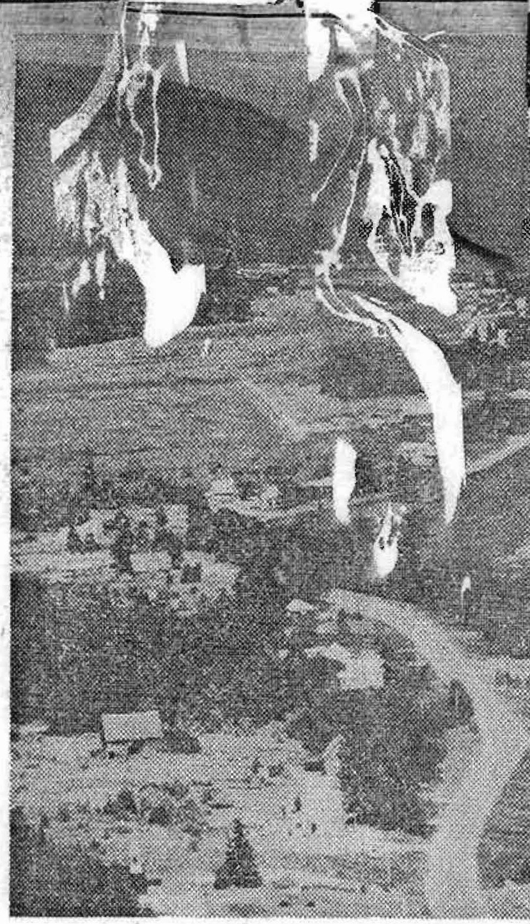
The past, for this isolated timbering village, is enshrined in a newly built log cabin, headquarters of the Allagash Historical Society. It is half full of rusty handsaws, rosary beads, copper hinges, old pipes, sheep shears, a family Bible—remnants of a century's simple life.

More than ever lately, people here are tracing genealogies, writing histories and collecting family photographs before they are scattered or lost.

They are pursuing the past because the future of Allagash, as envisioned by the U.S. Army Corps of Engineers lies under water. The proposed Dickey-Lincoln dam, 27 stories tall and nearly two miles wide, would flood the village to generate electricity for New England.

This week, a House-Senate confer-

See DICKEY, A12, Col. 1



Allagash, on the St. John River: Flooding from th ... or The Wa ... te the M

# A Dam's Future Is i... With a Maine Villag...

DICKEY, From A1

ence committee will decide whether to approve $710,000 to plan the project. The House is opposed. The Senate, in one of the closest water project votes ever, voted 51 to 46 last week to fund it.

Environmentalists, who defeated Tennessee's Tellico dam last week with administration support, are focusing on Dickey-Lincoln as the water project battle of the year. But the Carter administration, which had Dickey on its 1977 "hit list," now is recommending funding.

The stakes in the Dickey fight in and around Allagash, a modest little town of trailers and white clapboard homes strung randomly along a two-lane highway and logging rigs parked on untended lawns.

But Allagash is a place of clannish ethnic pride. Since its settlement in the 1830s, cousins have married cousins, retaining their Scotch-Irish brogue and their independence from the French-speaking, potato-farming towns down the road.

"It's a matter of roots," says Edith Kelley, 55, who lives on her grandfather's homestead by the rver. "The descendants of people who settled here still live here. It's a unique way





FIGURE 4. FUTURE OF DICKEY-LINCOLN DAM

memt, and the company's Canadian rights expired automatically. The Canadian Government believed that construction of dams would have an adverse effect on the fisheries of the region, consequently- they would not renew the Charter.

Dexter Cooper's plan called for a two-pool concept, and a series of dams and gates to impound tee incoming tide in Passamaquoddy Bay and form what he called a "high pool". When convenient, millions of tons of water would rush through raceways into a "lower pool" in adjacent Cobscook Bay. The cascading streams of water would turn turbines and gtnerate electricity. The flow would cause the lower pool to fill up, but at Ebb Tide, the gates would be opened to allow the excess to flow back to the ocean (Figure 5).

The possibilities of this scheme were viewed by General Electric in 1927, and it was foreseen that 1,594 million kwh could be generated at a cost of approximately $125 million. However, it was considered too big for private industry as it involved more than 7 miles of ocean dams (150 square miles of basin area). In 1933, at the direction of the President, the U. S. Corps of Engineers studied the project and found it feasible. The project was suggested as a joint United States-Canadian venture; thus, when the depression hit in the 1930's, President Roosevelt considered teat this project would provide a source of cheap power; would revitalize a badly depressed area; and would give jobs to thousands of unemployed. In 1935, Congress allocated $10 million to this project, it was placed under the jurisdiction of NRA and the Army Corps of Engineers. The project was hastily conceived, and poorly managed; Congres refused to allot more money to its completion.

It is stated that if Cobscook Bay Tidal Project had been built in 1936, the estimated annual cost over its 100-year life would have been $4million. The cost of energy from a plant estimated to produce 308,000,000 kwh annually would have been 7.8 mills/kwh- a cost of 1¢/kwh.

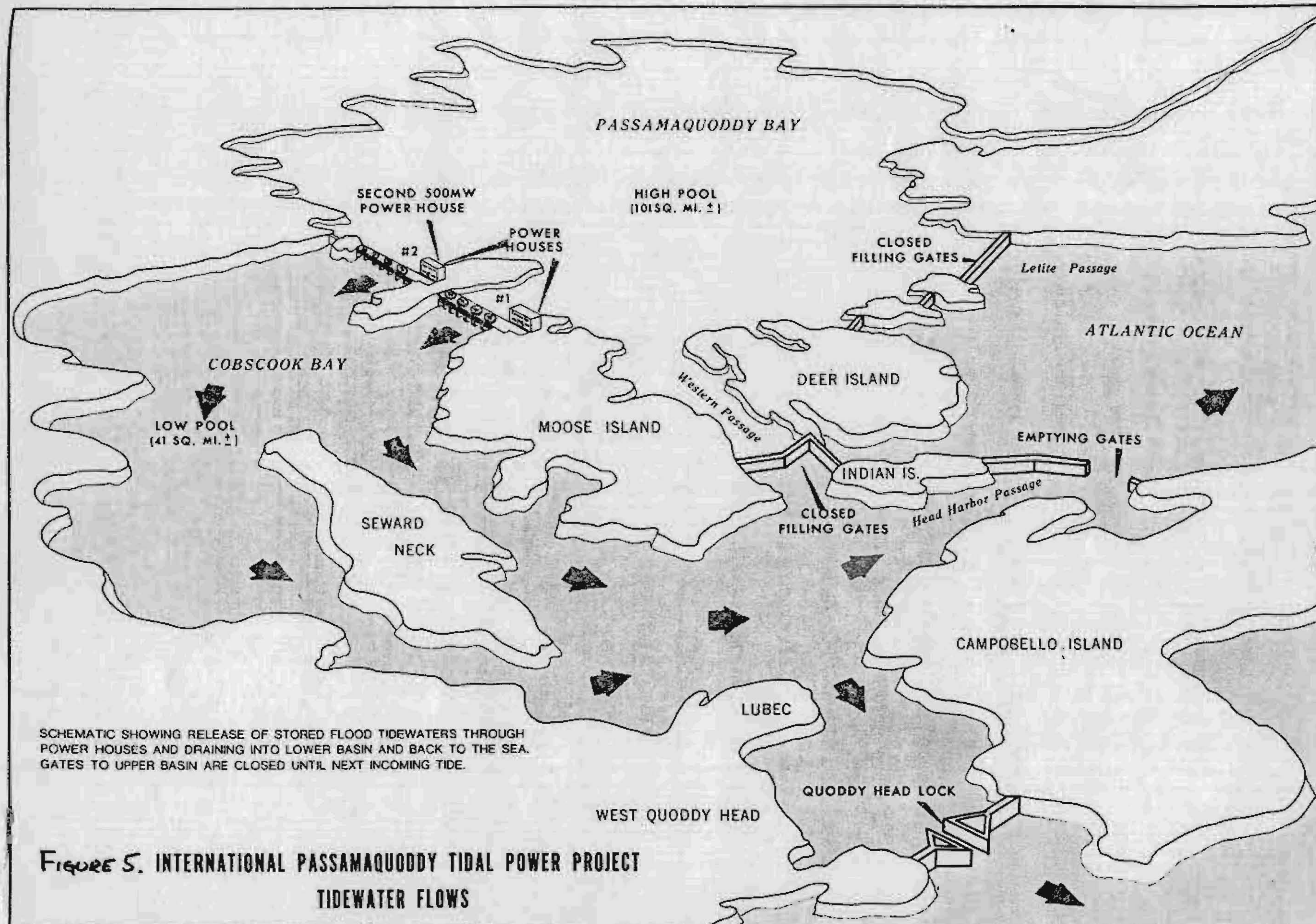



Figure 5. INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT
TIDEWATER FLOWS

Two dams were actually built before the project was stopped in 1937 due to lack of funds. Cobscook Bay was the high pool where water discharged through the Powerhouse into Western Passage. The plan provided for 5 to 10- 300-horsepower vertical turbine generators for a total of 62,000 kw of tidal power, and 30,000 kw by a diesel auxiliary plant. The total estimated annual energy output was 262 million kwh; the plans called for future additions of 5 to 12- 500 kw units. The final estimated cost was $38 million, and included a powerhouse (5 to 12- 500 kw units, one-way flow); filling gates (12-each on Treat Island), Navigation Locks (56' x 360" on Treat Island and 5 dams.

The project surfaced again during the Truman Administration; from 1948 to 1961, the engineering and economic feasibility of the tidal project in Passamaquoddy Bay had been studied and reviewed by the International Engineering Board. In October 1950, the Commission concluded that it was feasible to build a large international tidal power project at Passamaquoddy Bay by the governments of the United States and Canada. The 1959 and 1961 plans included 30- 10,000 Kw vertical-type units for a total of 300 mw. The average energy was 1,843 million kwh at a cost of $532,000,000 with interest. The plans contained provisions for auxiliary hydropower at Rankin Rapids, Maine, and a pumped Plant at Digdequash, New Brunswick (Figure 6).

Four project combinations were selected by the Engineering Board for evaluation as shown in Table 1. Based on that information, the final significant conclusions were the following:

1. The most favorable project combination is the tidal power project operated in conjunction with a river hydroelectric auxiliary built at the Rankin Rapids site on the upper Saint John River in Maine. The combined cost of the tidal project and the Rankin Rapids auxiliary is $630 million. With interest during construction, the investment would

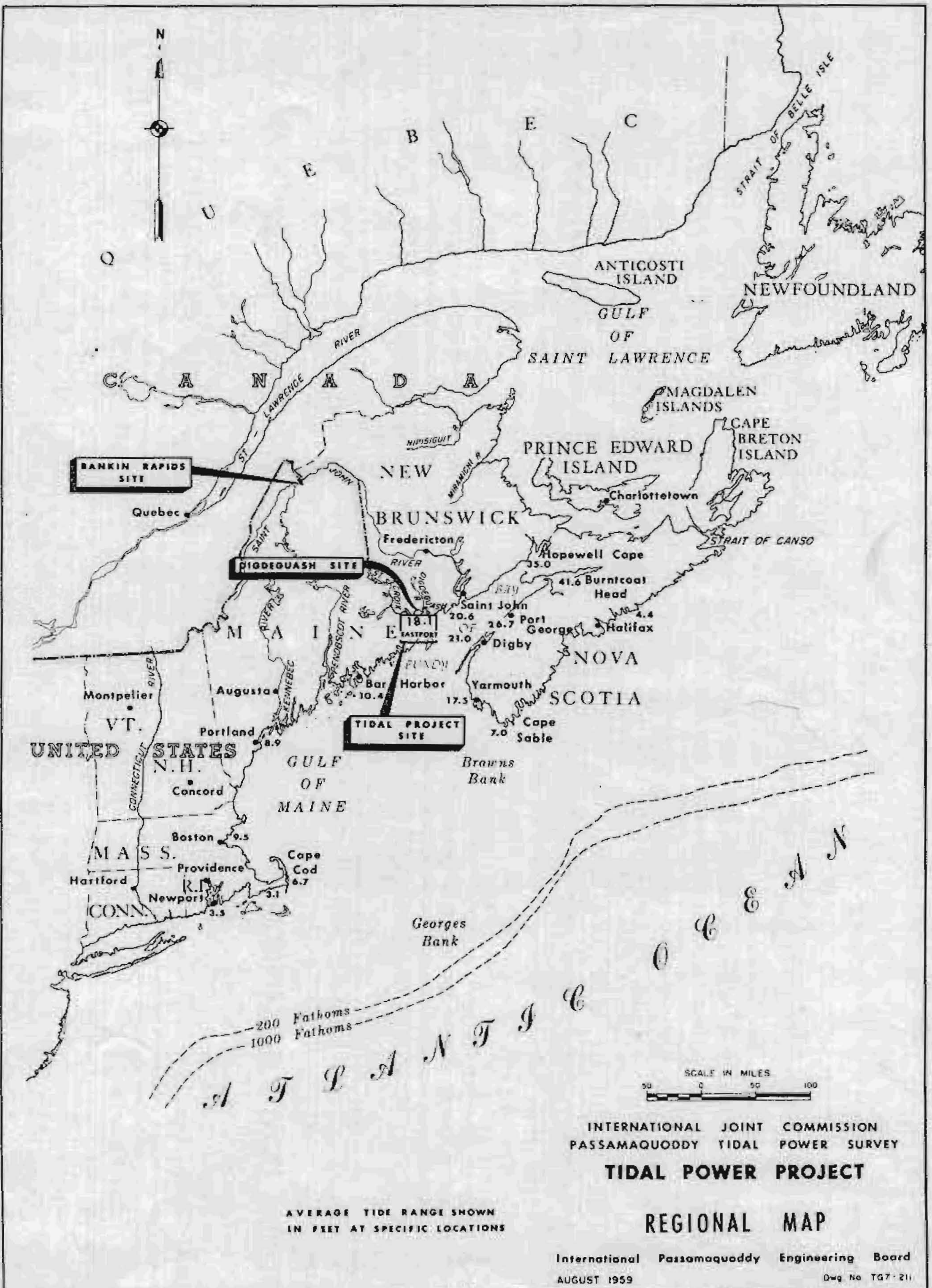



FIGURE 6. TIDAL POWER HOUSE PLANS

TABLE 1.
FOUR PROJECT COMBINATIONS FOR PASSAMAQUODDY TIDAL PROJECT

| Project Combination | Installed Capacity (1000 KW) | Dependable Capacity (1000 KW) | Average Annual Generation (Billion KWH) | Capital Investment (At Site) (Millions of Dollars) | Capital Investment (Including Transmission To Market) (Millions of Dollars) |
|---|---|---|---|---|---|
| (1) Tidal Project Alone | 300 | 95 | 1.843 | 532.1 | 546.8 |
| (2) Tidal Project and All of Rankin Rapids | 700 | 555 | 3.063 | 687.7 | 732.1 |
| (3) Tidal Project and Incremental Capacity only at Rankin Rapids | 526 | 355 | 1.843 | 565.7 | 600.0 |
| (4) Tidal Project and Digdequash Pumped-Storage Storage Project | 560 | 323 | 1.759 | 568.9 | 586.4 |

| | 50-Year Amortization | | 75-Year Amortization | |
|---|---|---|---|---|
| | Benefit Cost Ratio | Cost per KW-Hr. (Mills) | Benefit Cost Ratio | Cost per KW-Hr. (Mills) |
| Tidal Project Alone | | | | |
| United States | 0.60 | 10.8 | 0.70 | 9.3 |
| Canada | 0.34 | 14.9 | 0.37 | 13.7 |
| Tidal Project and All of Rankin Rapids | | | | |
| United States | 1.31 | 8.4 | 1.53 | 7.2 |
| Canada | 0.58 | 11.5 | 0.63 | 10.6 |
| Tidal Project and Incremental Capacity only at Rankin Rapids | | | | |
| United States | 0.93 | 11.5 | 1.08 | 9.9 |
| Canada | 0.42 | 15.8 | 0.45 | 14.5 |
| Tidal Project and Digdeguash Pumped-Storage Auxiliary | | | | |
| United States | 0.91 | 12.2 | 1.06 | 10.5 |
| Canada | 0.42 | 16.8 | 0.46 | 15.4 |

be $687.7 million. The dependable capacity of this combination would be 555,000 kilowatts, and average annual generation would be 3,063 million kilowatt-hours.

2. Construction of the tidal project at Rankin Rapids combination would increase low flows in the lower Saint John River by a considerable amount, thus increasing substantially the usefulness of the river for downstream generation of power. Downstream benefits accruing to existing power plants were included in the economic evaluation.

3. The total output from the tidal power project and Rankin Rapids hydroelectric plant can be absorbed readily by the growing utility markets of Maine and New Brunswick.

4. The Passamaquoddy tidal project and Rankin Rapids combination, if built entirely by the United States at an interest rate of 2-1/2 percent, is economically justified.

However, because of the adverse environmental impact of the Allagash River (now a designated "Wilderness Waterway"), the proposed Rankin Rapids feature was discarded in favor of an alternative location on the Upper St. John River at Dickey, Maine- just upstream of the point where the two rivers converge. In 1964, new power values provided by the Federal Power Commission indicated that development of Passamaquoddy by itself could not be justified economically; Dickey-Lincoln School Lakes still retained its favorable Benefit-to-Cost Ratio (BCR); thus, it was reindorsed for immediate authorization.

In 1963, the International Joint Commission recommended- on review- that there be 1000 MW in two 500 MW powerhouses, the plants would be used basically for producing peaking power (1,213 mill kwh) and would have been integrated with storage and hydroelectric power development in the upper St. John River (Dickey-Lincoln School Lakes). The combined projects were considered feasible based on an interest rate of 2 7/8% at a BCR of 1.27 to 1. The subsequent increase in cost and decrease in BCR is shown below:

| Year | Cost ($x 10^6$) | BCR | Interest Rate | Annual Charges | Annual Benefits |
|---|---|---|---|---|---|
| 1965 | $ 586 | .86 to 1* | | | |
| 1973 | 974 | .70 to 1 | 5 1/2% | $56,522,000 | $41,229,025 |
| 1974 | 1,072 | .75 to 1 | 5 7/8% | 70,300,000 | 57,760,000 |

*This new BCR led to the recommendation that the construction of the Dickey-Lincoln School Lakes Project be given immediate authorization (it was authorized by Congress in the Flood Control Act of 1965); and that the Passamaquoddy Project continue to be studied, re-examined, and re-designed to take advantage of the latest technological advances with a possible reduction in capital costs. The total ultimate installed capacity of the combined Passamaquoddy and Dickey-Lincoln School Lakes Projects was projected at 1750 megawatts, and a total construction cost of $1 billion.

In view of the rising costs, on 15 December 1975, Congres passed and sent to President Ford an appropriations bill which included $150,000 to begin a current feasibility study of the Passamaquoddy Tidal Project. A Canadian report subsequently concluded that tidal power would not be economically feasible for them unless the interest rates dropped to 1/2 of the 7% prevailing at the time of study; they decided to pursue a tidal study separate and apart from that of the United States.

The United States decided to continue study of a modified project of the 41 square miles of Cobscook Bay, Maine; consequently, a series of public meetings were held on this plan, and subsequent recommendations were made.

## COBSCOOK BAY, MAINE

Cobscook Bay, Maine, with tides of 18 feet is considered to have the greatest tidal range in the Continental United States; thus, it is considered as a prime site to test the feasibility of tidal power generation (5.65 meters- 18 feet is considered minimum for tidal plant operation).

New England's heavy dependence on imported petroleum makes it mandatory that alternative sources of energy be found and developed. Choices of what energy sources to develop, and where to develop them must reflect both national and regional priorities; thus, it is significant that tidal power is one of the alternative sources of energy which Congress has ordered to be investigated.

Cobscook Bay covers approximately 39 square miles of water surface (it reduces to approximately 26 square miles at low neap tide), and 407 square miles of adjacent land drains into the Bay. The depth of the Bay ranges up to 140 feet- the maximum spring tide is about 25.7 feet, and the minimum neap tide is 11.3 feet for an average range of 18.1 feet. The terrain features four small rivers which drain into the Bay, as well as many inlets and peninsulas which offer possibilities for numerous tidal power configurations. The Bay has active fisheries in lobster, clams, groundfish such as shrimp and flounder; the most important fishery is soft-shell clams.

The Bay was carved from glaciers after volcanic action left deposits of rocks and clays. It is a special natural habitat for Atlantic salmon. Fish processing is a local inductry though commercial fishing is not a major occupation. Much of the population resides in small towns and villages located primarily on the St. Croix River. Adjacent to Cobscook Bay resides the Passamaquoddy Indian Tribe.

PLAN OF STUDY FOR COBSCOOK BAY, MAINE

The study of Cobscook Bay, Maine will be funded entirely by the Federal Government, and will be managed by the New England Division Engineer, U. S.

Corps of Engineers.

The design of the project (one or two pools) will affect the availability of power at given times; additionally, the type of power produced will influence its marketing.

To accomplish an economic update of tidal power potential in Cobscook Bay, numerous alternative layouts with installed capacity between 5- 450 MW were investigated. It was deemed that the annual power output would be 16-790 million kwh/year. Area redevelopment, recreation, fisheries, and mariculture were not investigated, nor were environmental concerns assessed and evaluated. Ninety (90) tidal power alternatives were considered for Cobscook Bay, Maine, including the single pool, multi-pool-linked basin configuration with various impoundment areas and different sizes of generating plants. Various construction features were given attention also- such as dams, navigational locks, powerhouses, emptying and filling gates, switchyards, fishways, roads, service facilities and electrical transmission lines to the nearest feasible point of connection to the New England power grid.

The project costs were outlined as betieen $274 and $635 million, depending on the ultimate size, and at a Federal Interest Rate of 6 5/8%. The estimated annual electric generation concepts range from 292 x $10^6$ kwh to 615 x $10^6$ kwh, The BCR for the all-American plan for power benefit was .31 to .45, with anticipated ancillary benefits of .55 to .77. The cost of installed power on per kilowatt varies between 2,540, and 7,121 for five (5) alternative sources.

Plans were prepared for three single pool- all-U.S. System by the New Division of the Corps of Engineers, based on June 1976 price levels (int. rate of 6 3/8%)- the project comprises 5- 12.5 MW units plus a 30 MW auxiliary generating unit. The total investment cost is $281.7 million; the total annual cost of operation, maintenance, equipment, replacement, interest and amortization is $24.3 million.

For a larger project of 10- 12.5 MW units without auxiliary capacity, the estimated investment was $371.8 million, with annual costs of $24.9 million; the 20- 12 MW units cost $635 million to build, and $42 million to operate annually.

DELIVERING THE POWER

It is stated teat in 1976, there were 150 entities having 250 power plants and providing 4.7 million customers in New England (1/2 million in Maine), with an annual revenue of $3 billion- three times what it was a decade ago due to escalating fuel costs. Services are provided by investor-owned utilities, mainly- the remainder is supplied by municipal systems, cooperatives and other entities. The annual generation is 71.2 billion Kwh with a combined total generating capacity of 21,000 MW.

Since it is deemed not economically feasible for any single utility to provide demand by consumers, arrangements have been made to pool the region's powre supply into an interconnected grid in which electricity can be dispatched by a central control point in the system. This arrangement adds reliability and provides the most economic mix of power to meet any and all demands.

It is reasoned that the building of a tidal generating facility will bring a new, pollution-free, and self-renewing source of energy to the New England Power Pool.

RECOMMENDATIONS

It is recommended that: (1) bulb-types of turbines and generator units be utilized in lieu of slant-type units utilized in the 1963 and 1977 reports. Use of the bulb units required a smaller civil-type structure to house teem; (2) the depth of dams in Cobscook Bay are not as great as those recommended in the previous international studies; (3) large size vessels do not traverse Cobscook Bay as in the Western Passage, Head Harbor Passage, and Passamaquoddy Bay. This alternative configuration included the smaller navigational locks, and provides adequate care for local fishing and recreational boats. Alternatives utilizing dams at Dudley Island includes larger locks, those up to 1250-foot lengths might be required if plans include the proposed oil refinery.

GENERAL OBSERVATIONS

Since the alternative for linked or multi-pool tidal power configurations is nuclear power, and since an installed capacity that is approximately 3-4 times the dependable capacity is required due to the nature of the tides it appears that schemes designed for dependable capacity are too expensive, and Tidal Power Projects should be designed to maximize energy (plant factor) rather than dependable capacity.

Single pool alternatives with large impounded bay and relatively small installed-capacity generating plants yield the greatest economic (energy) advantage.

DICKEY-LINCOLN SCHOOL LAKES PROJECT

The Dickey-Lincoln School Lakes Hydroelectric Project was recommended for construction along with the International Passamaquoddy Bay Project;

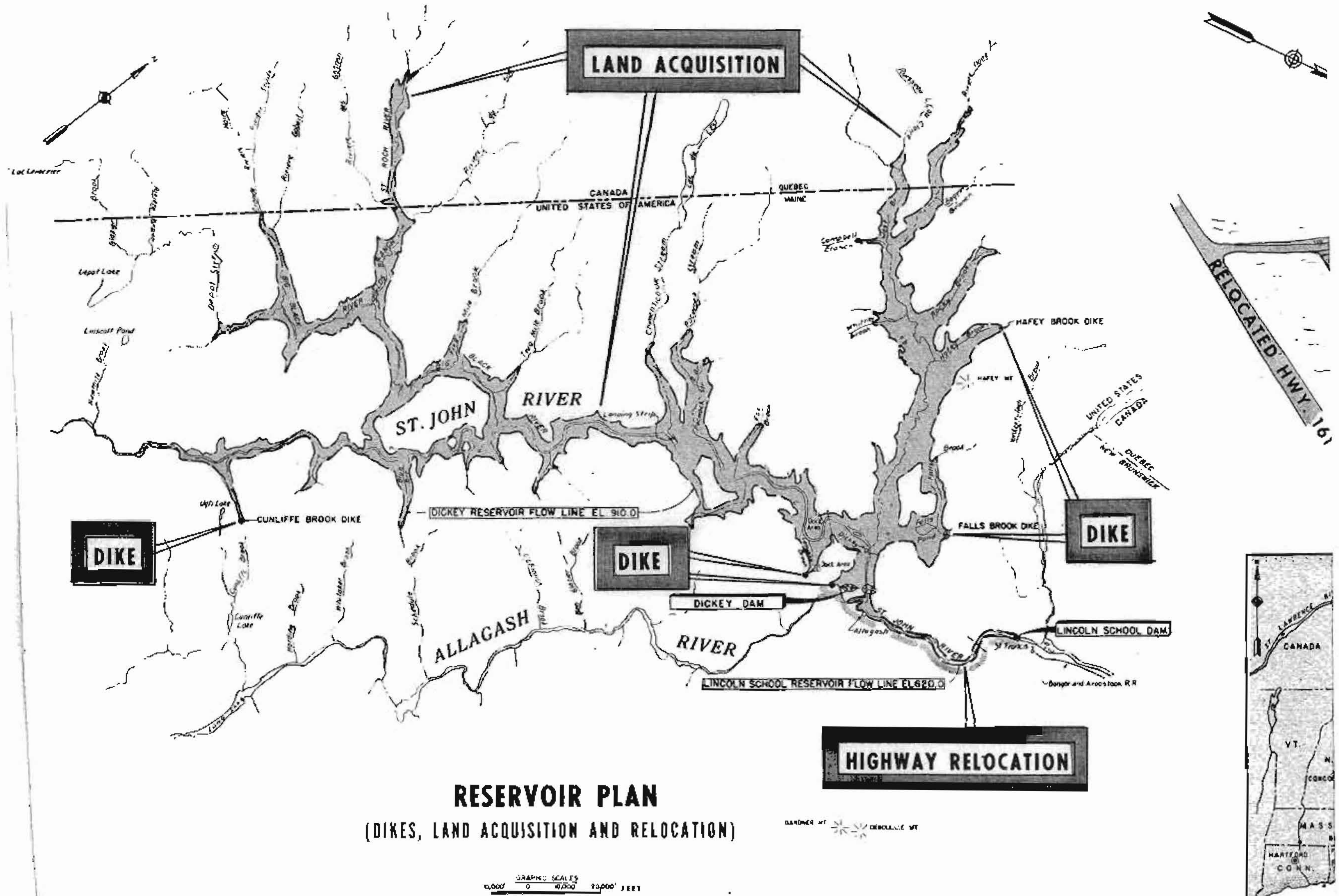
however, it was subsequently recommended for construction separately as a multi-purpose installation on St. John River, because of the high Benefit-to-Cost Ratio (BCR). It is a combination hydroelectric power and flood control project, and is located in Aroostook County, Maine, near the Canadian Border (Figure 7).

Two earth-fill dams located at Dickey are proposed- one of 10,200 feet in length and with a maximum height of 335 feet; the other located 11 miles downstream at Lincoln School would be 2100 feet in length, and 90 feet above the existing streambed. Together, they would impound 7.7 million acre-feet of water at a maximum pool elevation of 910 feet (Figure 8). The dam will backwater in the St. John's River onto Canadian soil, downstream- the Lincoln School dam will be providing regulatory flows from the hydroelectric plant on the St. John's River in New Brunswick; thus, Canada will get additional power.

The project represents a source of electrical generating capacity which would be integrated into the coordinated New England Power Pool (NEPOOL) system.

The initial power installation at Dickey Dam would be 760 megawatts (mw) with the potential for an additional 380 mw of capacity in the future. Lincoln School Dam would have a total installed capacity of 70 mw. Construction time for the dam structures and facilities would be about eight years. Initial filling would begin in year 2005, and would be completed in year 2008.

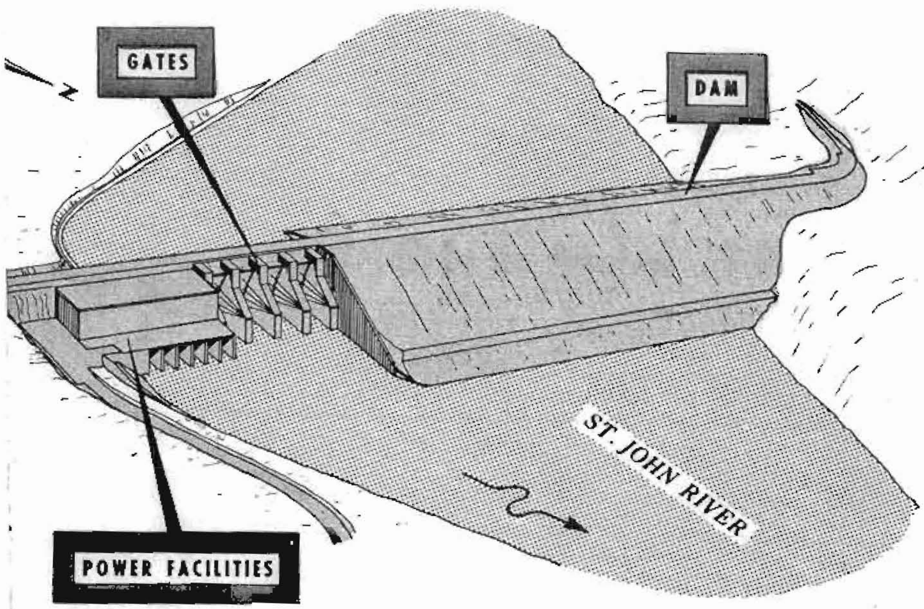
Electrical transmission facilities associated with the proposed action include: a 138 kilovolt (kv) transmission line from the proposed Dickey Dam substation to Fish River substation in Fort Kent, Maine; a steel double




**RESERVOIR PLAN**

(DIKES, LAND ACQUISITION AND RELOCATION)

Figure 7.




ENLARGEMENT OF

LINCOLN SCHOOL DAM


UPPER SAINT JOHN RIVER
WATER RESOURCES DEVELOPMENT

# DICKEY AND LINCOLN SCHOOL LAKES

## MULTIPLE-PURPOSE POWER PROJECT

1 JANUARY 1979

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS

DICKEY AND LINCOL
MAIN

ON: NEW ENGLAND

REFERENCE ER 11-2-240,
BUDGETARY INFORMATION I
OUTSIDE THE DEPARTM
UNTIL 1 FEBRU

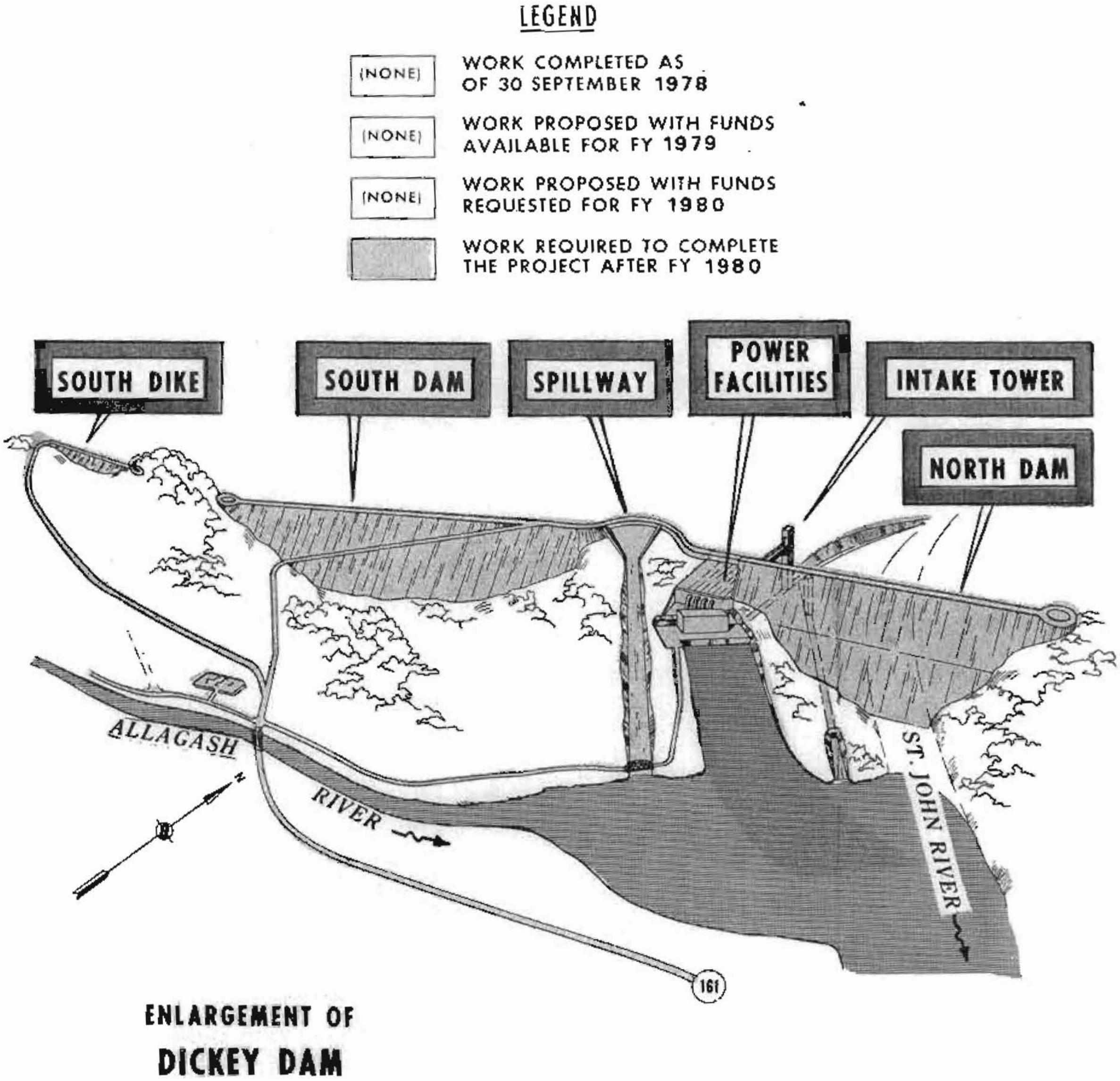

LEGEND
(NONE) WORK COMPLETED AS OF 30 SEPTEMBER 1978
(NONE) WORK PROPOSED WITH FUNDS AVAILABLE FOR FY 1979
(NONE) WORK PROPOSED WITH FUNDS REQUESTED FOR FY 1980
WORK REQUIRED TO COMPLETE THE PROJECT AFTER FY 1980
SOUTH DIKE
SOUTH DAM
SPILLWAY
POWER FACILITIES
INTAKE TOWER
NORTH DAM
ALLAGASH
RIVER
ST. JOHN RIVER
N
161
ENLARGEMENT OF
DICKEY DAM

Figure 8.

TABLE 2.

SUMMARY OF PERTINENT DATA
DICKEY-LINCOLN SCHOOL LAKES PROJECT

Dickey Dam

Purpose -------------- Multipurpose
Location ------------- St. John River, Aroostook County, Maine
Streamflow Data
Ave. Annual Runoff -- 3,309,300 acre feet
Max. Discharge ------ 87,200 cfs
Min. Discharge ------ 129 cfs
Ave. Discharge ------ 4,569 cfs
Reservoir
Drainage area ------- 2,725 sq. mi.
Max. Operating level- 910 MSL
Min. Operating level- 868 MSL
Inactive Storage ---- 4,800,000 acre feet
Active Storage ------ 2,900,000 acre feet
Total Storage ------- 7,700,000 acre feet
Area ---------------- 86,024 acres
Embankments
North Dam ----------- Earth Fill
Length ------------- 3,860 feet
Top Elevation ------ 925 MSL
South Dam ----------- Earth Fill
Length ------------- 4,380 feet
Top Elevation ------ 925 MSL
Spillway ------------ Uncontrolled
Elevation ---------- 910 MSL
Crest Length ------- 600 feet
Power Plant
Penstocks ---------- 4 27-foot dams
Powerhouse --------- indoor
Power Units -------- 3 Francis-type turbines
- 190,000 KW, 3 phase, 60 cycle generator
1 Francis-type pump/turbine
- 190,000 KW, 3 phase, 60 cycle generator/motor
Nameplate Capacity
Initial ------------ 760 MW
Future ------------- 1,140 MW

Lincoln School Dam

Purpose -------------- Streamflow regulation, power and afterbay for pump-back
Location ------------- St. John River, Aroostook County, Maine
Streamflow Data
Ave. Annual Runoff -- 4,780,300 acre feet
Max. Discharge ------ 110,000± cfs
Min. Discharge ------ 220± cfs
Ave. Discharge ------ 6,600 cfs
Reservoir
Drainage Area ------- 4,086 sq. mi.
Max. Operating level* 620 feet MSL
Min. Operating level* 590 feet MSL
Inactive Storage* --- 27,265 acre feet
Usable Storage* ----- 59,090 acre feet
Total Storage* ------ 86,355 acre feet
Area ---------------- 2,619 acres
Embankment
Type ---------------- Earth Fill
Length -------------- 1,520 feet
Top Elevation ------- 630 feet MSL
Spillway ------------- Gated, 4-60 ft. x 50 ft. tainter
Elevation-top of gates--620 feet MSL
Power Plant
Powerhouse ---------- indoor
Power Units --------- 3 Kaplan-type turbine 3 phase, 60 cycle generators
Nameplate Capacity -- 70 MW

* Until the Dickey Plant is expanded to ultimate capacity, the normal Lincoln School pool range will be 595 to 612 feet MSL (32,450 acre-feet active pondage).

circuit single tower 345-kv transmission line from Dickey Dam substation to Moore substation near Littleton, New Hampshire; a 345-kv wood pole transmission line from Moore substation to Granite substation near Barre, Vermont; a 345-kv wood pole transmission line from Branite substation to Essex substation near Essex Junction, Vermont. The total length of the proposed line is 365 miles. Right-or-way widths are 100 feet for the 138 kv lines and 150 feet for the 345 kv lines. The action also includes the construction of three new substations; the expansion of three existing substations; and construction of 12 micro-wave communication stations.

In total, 80,455 acres of terrestrial habitat would be lost in the reservoir area and 6030 acres modified by the transmission lines; 36,893 acres of deer wintering yards would be innundated and 138 acres impacted by the transmission lines. Flooded reservoir areas and right-of-way clearing would cause 81,946 acres of timberland to be removed from production resulting in a loss of annual net growth of timber of 25,825 to 34,525 cords. The total project including transmission facilities has a BCR of 2.1 to 1, based on an authorized interest rate of 3 1/4% at October 1977 price levels, and a BCR of 1.2 to 1 at 6 5/8% interest rate.

The proposed project would provide 830 mw of installed capacity and 1.2 billion kilowatt hours annually of peaking energy, and 262 million kwh annually of intermediate range energy to the New England system. The downstream impact of flow regulation on Canadian power plants would be to increase their annual energy output by approximately 350 million kwh. This impact would result from flow augmentation during naturally occurring low flow periods. (Table 2).

Storage of spring snowmelt would provide flood protection for downstream communities and agricultural lands.

LEGAL REQUIREMENTS OF FEDERALLY FUNDED POWER PLANTS

By statutory requirements, power generated at Federally-financed facilities must first be offered for sale to so-called "[illegible]" cooperatives and municipal utilities. The responsibility for tmansmission and marketing of electric power from Federal projects is given to the Department of Energy, as authorized by Section 5 of the 1944 Flood Control Act. The statute requires that power be sold in such a manner as to encourage the most widespread use at the lowest possible prices consistent with sound business practice.

It is possible that Federal-state-private cooperation will assure for Maine, the best benefit of power produced.

Investment of public funds to build a Federal power facility are recoverable in the revenues obtained by the sale of power to utility customers in the life of the facility.

MARKETING

The Financial Feasibility study of DOE notes that after considering transmission losses and offsetting load diversities, approximately 900,000 kw of capacity, and 1.2 billion kwh of streamflow energy would be available for sale at the customer's premises (Dickey-Lincoln). The present concept envisions marketing of 700,000 kw as peaking power to New England outside of Maine, and marketing of 200,000 kw in Maine (50% intermediate load, 438 million kwh, and 50% peaking power- 95 million kwh). These allocations include the assumed United States portion of additional energy generated at downstream Canadian projects.

Repayment rates are established to recover costs of power production and transmission including annual operation and maintenance expenses. The total investment allocated to power must be repaid over a reasonable period (50 years specified by the Administration); the established interest rate for Fiscal Year 1978 was 7%. Tentative wholesale rates (derived in the feasibility study) were $56/kw for capacity, and 15 mills (1.5¢)/kwh for energy.

Because the rates were competitive with existing bulk power rates in New England at substantial savings to some customers, and modest rates to others- DOE concluded that sufficient revenue could be obtained to make the investment recoverable in a 50-year period, and thus the project was financially feasible.

TIDAL POWER PLANT AT ST. MALO, LA RANCE RIVER, FRANCE

The French devoted resources to the development of tidal power technology because of two considerations:

The first is that until 1955, nearly half the growth of energy needs was met by new hydroelectric schemes. When faced with the prospect of lack of sites offered by nature which were capable of satisfying requirements on an industrial scale, it seemed logical to consider the tides as an extension of the hydroelectrical potential of the rivers.

The second is that public opinion has always considered scarcity of energy as a reality- the war and the Suez Crisis contributing to this opinion; added to this was the fear that limited reserves might fail given the rate of consumption present.

In this atmosphere, attention was given to the savings of coal that a tidal power installation would promote; thus, by 1960, the tidal power project had been prepared, work began in 1961, and was completed in 1966.

The Tidal Power Plant is located in the northwestern part of France at St. Malo, on the La Rance River (Figure 9). It has been operating for 11 years, having been commissioned in several stages between August 1966, and December 1967. The tide ranges in this area are as high as 13.50 meters (44 feet) at equinoctial spring tides. The heights are due to the geographic configuration constraint presented by the Cotentin Peninsula to the tide entering the English Channel from the Atlantic Ocean; this configuration serves to concentrate the volume of water into a smaller area- a feature of the Tidal Bore. There are two high tides here in a 24 hour 50 minute cycle; maximum power is therefore available at certain times rather than at peak demand.

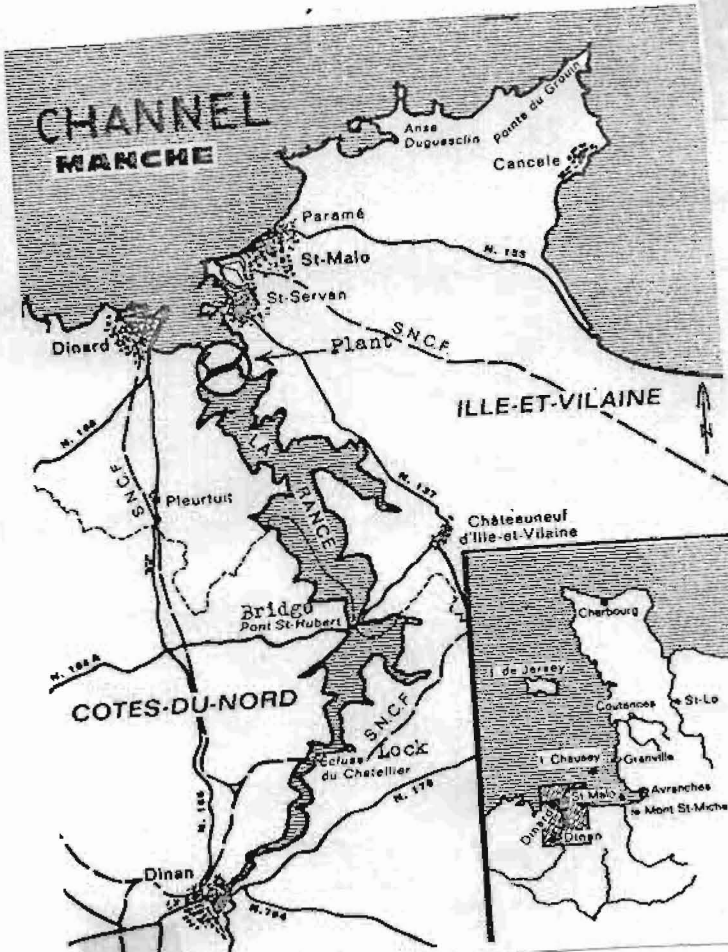
There are two ways to design and operate the tidal power station so as to provide a certain amount of dependable capacity:

(a) One way is to operate between two pools, according to the Belidor cycles, thus making a variable but continuous output available.

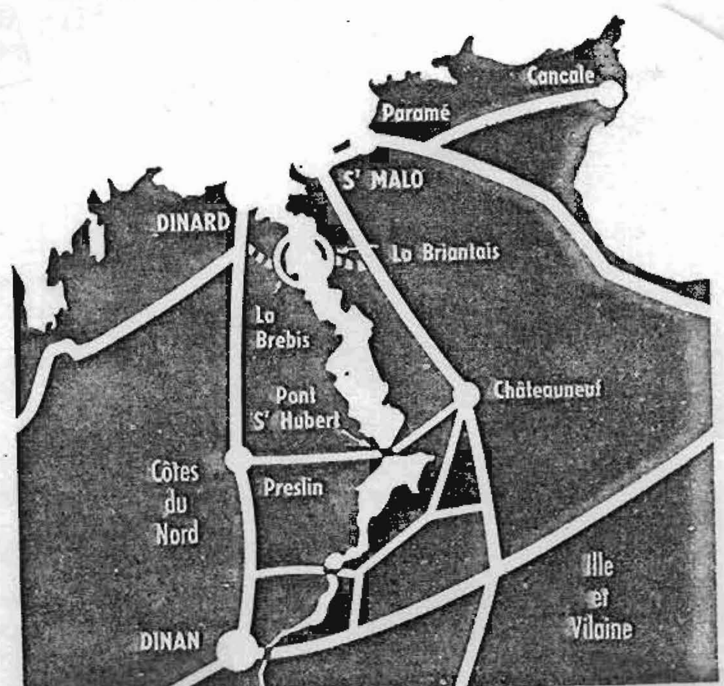
(b) The other way is to link a pumped storage plant to the tidal power station so that power can be generated independently of the tides.

The Rance Tidal Power Plant is operated with the t.de ranging between roughly 9 and 12 meters one week and between 5 and 9 m. the next week. The aim is to have the working head equal to or greater than 6 meters at all times, and to have at all times the maximum quantity of water stored (the minimum head is 5.65 m.). The plant has twenty-four 10 mw generators and produces a mean annual energy of 500 Gegawatt hours (GWh), with a mean capacity throughout the year of 65 mw. If a stable cost of living is assumed, this is an internal rate of return of 4%.

The plant has reversible operation, therefore power is tapped from the waters at high tide as they rush upstream, and again as the waters recede to




Rance River estuary and the tidal-power plant. (France)




Rance River estuary and surrounding area.

Circle shows location of tidal-power plant.

FIGURE 9.

the sea. Reverse generation involves reduced head and storage volume for the next direct generation; however, the gain associated with reverse generation largely outweighs the loss involved in direct generation. Turbines generate power as the reservoirs fill and as they empty; the flow amounts to 18,000 cubic meters per second. The power plant is 390 meters long by 33 meters wide, and all 24 generating units are put to work when it is in full operation.

An improvement in the transmission system has made more pumping power available so that the reservoir levels and raised by pumping; the volume of water displaced amounts to 718 x $10^6$ cubic meters. Where tidal ranges are higher than 9 to 10 meters, there is no requirement for direct pumping, as sufficient water volume is available with regard to installed plant capacity. For these tides, both the ebb and flow may be used for producing electricity; this generating mode called "double acting cycle" results in a continuous electricity production.

For low tidal ranges, the sets can be operated only in one direction because of the reduced head; only the ebb is used for generating electricity because the efficiency in direct generation is better than in reverse generation. Direct pumping is necessary that more water may be stored and consequently increase the head so that a working head of 5 to 6 meters can generally be attained.

## ENGINEERING THE RANCE PLANT

From the left bank of the river, which had to be constructed first to avoid navigational problems during main construction work, the structure includes a lock, a power station, and a sluice section (Figure 10). The river bed is comprised of granitic rock overlain in some places by sand and

FIGURE 10. RANCE RIVER POWER PLANT

pebbles. The plant is situated to take advantage of the deep part of the river.

The power station consists of a hollow concrete structure (which acts as a dyke), which is reinforced with buttresses 13.3 mettrs apart on both upstream and downstream faces. The station is 390 meters long by 33 meters wide, and houses 24-bulb units- each of 10 MW capacity, together with 3 transformers (a bulb unit can be defined as a hydroelectric power unit installed in a hydraulic duct with its centerline coinciding with the flow axis (axial flow propellor or Kaplan Turbine with a horizontal or inclined shaft). Access to the equipment is provided by a shaft from the left bank, and by a gallery under the lock (Figure 10).

The lock chamber is 65 meters long and 13 mettrs wide, and has 2 lift bridges on the seaward side for two road crossings. The 163 meter long dyke connects the east end of the power station to Chalibert Island; the 115 meter long sluice structure is located on the eastern, between Chalibert Island and the right bank. It consists of six fixed roller gates, each 10 m high and 15 m. wide, and which will pass a flow of 9600 $m^3$/sec. under a Head of 5 m.

The set may be operated in both directions for pumping as well as for power generation. As pumps, they accelerate the tidal effect at small water level difference between the 184 million cubic meter storage basin and the sea; as turbines, they operate when one level is considerably above the other. This operation from basin to sea and from sea to basin gives an optimal two-way operating cycle.

The right bank, including the gate-structure dam, was the second enclosure. It needed two separate cofferdams- upstream and downstream- between Chalibert Island and the right bank. Closure had to be completed against a tidal range between 13.5 m. at equinoctial spring tides, and 3.5 m. at neap tides, and flows ranging from 18,000 cubic m/sec. to 4000 $m^3$/sec. The section of the estuary to be cut off was 360 m. long, with the lowest point at 13 m. below the ordnance datum (Figure 11). The plant bridges the estuary at 4 kilometers from the river's mouth, between the resort and the fishing towns of St. Malo and Dinard. The river's width here is 750 m.; the dam crosses the points of La Briantais and La Brebis and passes through Chalibert Isles.

The cofferdams were of light construction and were erected in separate compartments; they were hydraulically filled with material taken from the river bed. The central section, 360 m. long consisted of 19 cylindrical reinforced concrete caissons, each 9 m. in diameter; a compressed air caisson was used to prepare the foundation for these concrete caissons. The project cost was close to $100 million, and required the removal of 1,500,000 cubic meters of water.

The works as a whole needed 400,000 $m^3$ of earth moving; 350,000 $m.^3$ of reinforced concrete; 16,000 tons of reinforcing steel; and 275,000 $m^2$. of shuttering.

The Rance output is sent in three directions to Paris, Brittany, and southwards tr the Rennes-Nantes area; pumping energp is available only from the latter gmid area. Inadequate transmission lines resulted in a shortage of pumping power- with an imporved transmission system, lack of pumping occurs only between 9 and 11 p.m. It can be as high as 150 MW, but may be restricted to 50 MW.

FIGURE 11. AERIAL PHOTO OF LA RANCE POWER PLANT

INDIRECT BENEFITS OF THE RANCE PROJECT

The Rance schemt, a full scale pilot study, has provided valuable exjerience in tidal power and in terms of knowledge of resistance of materials to corrosion- particularly problems related to concrete, metals, and paints.

It was found that ordinary steel almost always needed cathodic protection, and because of the anti-fouling properties of aluminum bronze, it stands up well to corrosion though it may have no cathodic protection. Where local corrosion may be caused by shellfish and seaweed, cathodic protection is necessary for 17% chrome and 4% nickel steel. The large dam gates and the lock gates were provided also with cathodic protection.

Additionally, bulb sets have been perfected such that large sets up to 40 MW have been developed; seawater corrosion mechanisms are better understood- this is useful information since large thermal and nuclear plants use sea water for cooling. Finally, the project has developed an incredible tourist interest. The dam's use as a road or for a railroad is enhancing, as is the improvement of navigation to estuary ports. An underdeveloped region, such as Brittany, has been improved substantially.

TIDAL POWER PLANT AT KISLAYA BAY, USSR

In the U.S.S.R., there are many gulfs that exttnd into the Barents Sea and other water bodies to give that northernmost Russian Territory one of the gmeatest tidal power resources in the world (Figure 12); tides range between 1.2 and 11 meters. It is estimated that the small gulfs could provide 8.2 million kw, and the White Sea alone has a potential of 16 million kw.

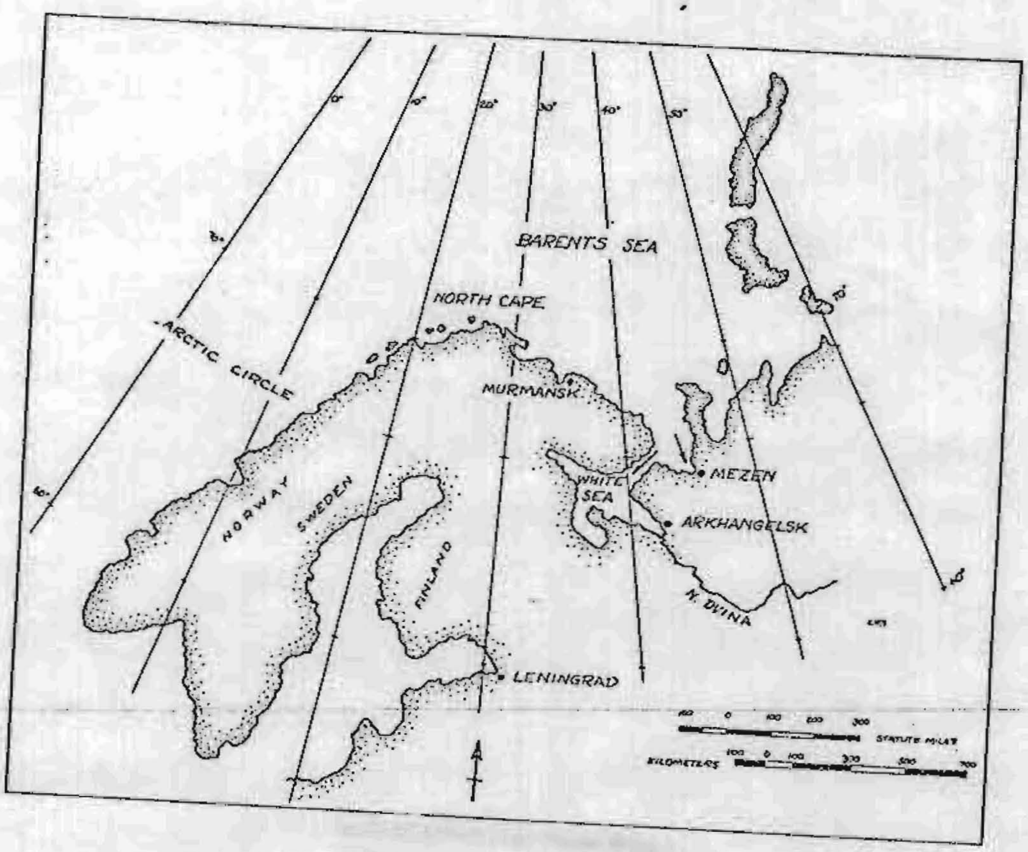



FIGURE 12. TIDAL POWER SITES OF USSR.

Power stations are planned on the Kislaya Bay near Murmansk (operational), and for two sites at the entrance to the White Sea. The pilot-tidal scheme which they built on the Kislogubskaia near Murmansk is using the French-type submersible bulb units. The station's maximum power is 400 kilowatts.

The Russians had to overcome the problem of severe Arctic temperatures which caused the freezing of concrete; use was made of jet black ashy sea-and-frost resistant materials, used in successive layers of 12 to 15 cm. thick to provide insulation and allow for "bulk-settling". Problems of design construction in deep water using electro-vibrators were also solved, pointing up the value of the experience gained by French engineer/scientists. For further information on the Russian Tidal Plant operations, refer to R.H. Charlier, "Harnessing the Energies of the Oceans", MTS Journal 3 No. 4, July 1969.

ASSESSMENT OF THE TIDES AS AN EFFECTIVE SOURCE OF ENERGY

Utilization of the tides to generate a substantial quantity of power requires provisions for the storage of large quantities of water so that discharges may be made from a higher to a lower elevation through hydraulic turbines. Using tidal pools is similar to a river hydroelectric system. The amount of power generated by both methods is proportional to the amount of water flowing, and the height (Head) through which it drops. The Head at the tidal power project is considerably less than at most conventional river hydroelectric projects; thus, larger volumes of water must be used to generate the same amount of power.

Further, there is inconstancy in what head there is, and it is available for only a fraction of a day. Hydroelectric plants have been favored because dams are usually easier to build, and though rivers have inconstant flow, the flow can be "averaged out" if there is a sufficiently large reservoir behind tee dam. Since tides are on a lunar cycle and man is on a solar cycle, tidal power may be better utilized for peaking power unless methods can be found to provide a constant flow of sufficient height. A river power project requires dams, channels, gates, powerhouses and fish-ways; these are the same requirements for a tidal plant.

One great feature of tidal power is that there is no danger to its depletion, and though there may be inconstancy in the amount of head available- the times of at least some Head are predictable.

OPERATION

A large single pool may be built to entrap or exclude water from the oceans, but generation of power is limited to those times in the tidal cycle where the differential in elevation between the ocean and the pool is sufficient for operation of turbines. A combination of two storage pools for simultaneous entrappment and exclusion of water from the ocean can provide for some generation at all times. Either may be arranged to accomodate reversible units capable of pumping and generating flow from either direction; thus, further increasing power potential and providing greater flexibility for coordinated operation with power sources.

Compared to most river hydroelectric projects, the potential average hydraulic head of tidal flow is quite small, but very large quantities of water are available for power production, and is accurately predictable for years in the future.

DESIGN PROBLEMS

The following are the requiremtnts for a Tidal Power Plant:

1. A large tidal range to provide a Head (the minimum is 5.65m. (18 feet).

2. A large capacity reservoir (the quantity of energy to be generated depends on an available storage capacity).

3. A short dam length for lower construction costs.

Knowledge of tidal power generation is dependent upon:

Astronomy
Geophysics
Systems integration of sources in interconnection
New type turbines
Hydraulic and civil engineering- damming high discharge streams

The mean power dissipated by the tide over the whole world is 1,100 million kilowatts. Four movements are possible during a semidiurnal or mixed tidal cycle; they are- 2 generating and 2 pumping- thus making 16 potential combinations possible for harnessing the tides (14 days- 27 tides- 256 cycles).

The design of power equipmtnt depends on the fundamentals of:

Heat transfer
Thermodynamics
Materials- strength and structure
Machine design

Although the above are but meteods necessary for most plants designed to utilize the fluid medium for operation, and though sophisticated methods for hydroelectric plants have existed for years, technology for tidal power plants has appeared only recently in imaginative hydraulic engineering machines and structures. Part of the problem is related to low heads of water available in the tidal plant such that typical vertical shaft water motors utilize a few of the feet of the head of water already available. Additionally, the head of water reverses itself every six hours. Power in modern plants must be generated on both the rising and on the falling tide since the output per day must be doubled (ancient tide mills operated only on the outgoing tide).

Design of turbines must be such as to allow flow through horizontal channels in the dam so that it impinges on the blades. The turbines must have horizontal shafts with reversible blades so that the pitch (or angle) can be adjusted with respect to the flow of water. As the speed of flow decreases, the blades are set flatter, the power output is reduced, but the shaft maintains a constant speed.

Operation of a tidal plant such as that in La Rance River, France- had to await highly advanced ttchnological development in mechanical, electrical, civil, hydraulic, and materials engineering. Design of a new type of turboalternator set, known as the bulb unit, and able to use low heads to drive a turbine in both directions and function as well as a pump was necessary. Additionally, expertise was necessary on techniques of damming a river of maximum flow of 18,000 $m^3$/sec- both at ebb and flood.

ECONOMICS OF TIDAL PLANT OPERATION

Use of tidal power for electrical energy generation requires substantial initial capital investment- thus, questions of need, cost, and recovery of investment- how to design and operate the tidal power scheme so as to provide a certain amount of dependable capacity- and what that amount is; teese have kept the development of this energy form at a low priority. However, compared tr fossil fuel-fired plants which have lower total investment costs, tidal power plants should be economically feasible over a long term basis because escalation in fuel prices won't uause escalation in prices over the life cycle of the project.

Determining the economics of power generation for Federal Financing is done usually by a comparison of anticipated benefits with anticipated costs- the so-called "benefit-to-cost ratio" (BCR). Where the ratio is less than one, annual costs are deemed to exceed annual benefits. Thus, by present standards, tidal plants may not seem feasible unless one compares long-term operating costs of these renewable energp plants with those plants that are dependent on non-renewable energy sources. Given the escalating oil prices and the possible depletion of this energy resource, a tidal power plant that seems uneconomical now may be the only economic reality for the future. A special difficulty arises because of the inability to make any long-term forecast of the future price of oil or of a substitute power source.

Since the Federal Energy Regulatory Commission (FERC) cut-off between combined cycle (31 mills/kwh) and nuclear power (7 mills/kwh) as alternative tppe power plants occur at a 40% capacity factor, tidal power plants are considered not economical at a greater than 40% capacity.

Currently, FERC considers nuclear power with 7 mils/kwh for an energy value as an alternative to any tidal plant having a capacity factor greater than 40%.

The nominal life of a tidal plant facility is estimated at one-hundred years, though 25% of the turbines and other equipment need replacement every 30 years or so. Although the cost of a tidal project is substantial, the initial costs are balanced by the fact that after the facility is complete and operational, the annual costs for generating power and maintenance are less than those for fuel-dependent plants.

The installation cannot be justified on economic grounds alone, there must be a minimum reliable output to allow it to be regarded as an alternative to a standby thermal plant of similar output.

ENVIRONMENTAL EFFECTS OF LA RANCE, FRANCE TIDAL PLANT

In the Rance Tidal Plant, difficulties were caused by high water salinities and "Start Up" during the day, as well as problems associated with construction.

High Salinities - Materials for turbines at the plant were either cupro-aluminum or 17% chromium 4% nickel steel. The unprotected steel runners became overgrown with seaweed, and encrusted with barnacles; additionally, there was pitting by corrosion underneath. This encrustation was overcome by cathodic protection which forms a protective calcium and magnesium coating on the components. With the provision, both of steel runners and the cupro-aluminum runners were in excellent condition after 70,000 hours under water and 40,000 hours of operation. Some stainless steel and aluminum bronze ducts, which experience straight-through corrosion, were replaced by plastic compononents, or they were eliminated entirely. Initially, cathodic protection was to be used only for sets combining various metals, however, it was extended with great success to large dam gates in 1968- and to lock gates in 1970. The top lock gates, the bulkhead gates and the metallic parts of the superstructure count not be provided with cathodic protection as they are either continually or intermittently above water; they will be repainted. Tremendous expertise has been gained in problems of impermeability, deformation, scouring, and corrosion.

FREQUENT START UP

Problems developed because of frequent start-ups; the units are shut down and started up four times daily- asynchronous starting and coupling caused teermal instability and high electro-dynamic stresses. For this reason, the iron circuits and windings must have very firm wedging and securing arrangements, as well as being very carefully designed. Rapid shut down of the units has caused a hazard of unpredicted surges on either side of the powerhouse. Generally, this can be prevented by having the computer re-open immediately the gate apparatus to reduce the surge- with the blades at a correct angle, the turbine speed can be reduced.

CONSTRUCTION

Construction work has caused changes to occur in the levels of the pool; the maximum spring tide levels have been reduced from 13.50 m. to 12.80 m., and the minimum levels are higher, more frequent, and remain steady for 3 to 4 hours. This new level has improved the living conditions for people on the shores in terms of flooding, yachting, etc.; the estuary has in fact become a lake.

Current speeds at spring tides have been reduced, so that the number of boats passing through the lock has doubled from 5,287 in 1968, to 10,380 in 1973. Shipping to and from St. Malo Harbor is dependent on the lock. When the powerhouse and sluices are in operation, high current speeds are present, this has resulted in the establishment of two prohibited areas for shipping- one on the seaward siden, the other on the estuary side. The control room is below water level close to the machine hall; it is equipped with a scanning television camers- the screen on the control panel monitors the prohibited area, the road, and other buildings.

Changes have occurred in species and location of fish, probably due to displacement of sandbanks which were previously awash at low tide.

One of the expected environmental effects did not occur; it was the expectation that the Rance Tidal Power Plant would be buried by sand. The high current speeds near the entrance to the set' and the sluices have swept the sandbanks from this section of the river. The sand and marine corrosion problems did not occur. The Rance River has a very small discharge, and no silt movement resulting from the tide; thus, no silting problem arises and the live storage capacity of the pool is maintained. It was thought that the bulb sets would vibrate- they did not.

PREDICTED ENVIRONMENTAL EFFECTS OF TIDAL PLANT INSTALLATION IN PASSAMAQUODDY AND COBSCOOK BAY AREAS

It was the conclusion of the Fisheries Board of the International Joint Commission that the construction of dams would cause changes in the Oceanographic features of the Passamaquoddy region as follows:

1. That it would raise the mean water level of Passamaquoddy Bay 6 feet, and that the tidal range would be reduced 4 feet, and that it would lower the mean level of Cobscook Bay by 5 feet and the mean tidal range by 8 feet.

2. That the opening and closing of the gates will affect the current patterns- lowering the velocities slightly when the gates open, thus making the counterclockwise circulation more pronounced, and altering the tidal streams.

Additionally, these reduced velocities will decrease vertical mixing, increase the stratification, and lead to greater seasonal variations in surface temperatures. The summer maximum is expected to be reduced tr 68°F, while in winter- ice cover is expected.

3. Mean surface salinities are expected to be lower in both pools (they were higher in the Rance, France plant), with no change in bottom salinities expected. Flushing times are expected to increase. A decrease in oxygen concentrations in the deep water inside the dam is an expectation during periods of maximum fresh water discharge.

4. No changes are expected outside the dams; thus, there should be no reduction in abundance of herring inside the bay, although rates of accumulation may be slower. Some herring weir sites are expected to be eliminated by dam construction. No changes are expected to occur in groundfish landings though the species composition may change. Inside the dams, an increase is expected in winter flounder, scallops, smelt, shellfish, and sea-run trout stocks; a reduction is expected in haddock, pollock, marine worms and rockweed.

5. A projected cost increase of $919,100 was established as a result of the decision to incorporate a Fish Passage Facility for anadromous species into the plans.

HOW TIDES ARE FORMED

A brief discussion will be given here on the origin of the tides and some of the dynamics causing differences in range, time, and heights of the tides in many places in the world. This is in keeping with the previous statement that science uncovers the available energy sources to Planet Earth, while it is the work of the Technologist to design systems to utilize this energe- in this particular realm, the technologist has failed. This failure of the technologist to provide the "Grand Design" scheme to use renewable energy sources may be due either to the profit motive, or to a lack of technological know-how; in either case, we are not now using the tides for profit in the United States of America.

Prior to the 17th Century, and Newton's Principia, many theories were advanced concerning the nature of the rise and fall of the waters of the earth and called tee "Tides". Early Maritime Nations even developed myths concerning the phenomena, including the myth that the earth was alive like an animal- and that the periodic rise and fall of the tide was due to the breathing of the earth; the water was its blood, and the tide the beating of its pulse. The Ancient Greeks and Romans developed few theories of the tide since they lived on the nearly tideless Mediterranean Sea (range of 3 1/2 feet). The Roman Historian, Pliny the Younger, established that the tides were related to the interactions of the Moon, the Sun, and the Earth; Johann Kepler noticed that the ocean waters had a tendency to move toward the Sun and Moon; Galileo attributed this to the orbital and rotational motions of the earth. However, it was Sir Isaac Newton who is called the

"Father of the Tides". In his Philosophise Naturalis Principia in 1689, he advanced two theories as form.ng the basis upon which the tides are reckoned. He took Kepler's laws governing the motion of planet in their orbits, and his own laws- and fashioned a Universal Law of Gravitation which stated:

> "Every particle of patter attracts every other particle with a force that varies directly as the product of their masses, and inversely as the square of the distance between them."

He coupled this law with the Equilibrium Theory, in which he hypothesized that the earth was covered uniformdy by an equal volume of water, and that these waters responded instamtly to the gravitational attraction of other bodies to raise the level of water on the side of the earth closest to the attracting body.

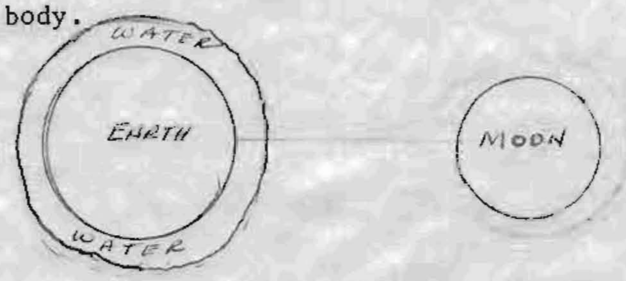



FIGURE 13. Equilibrium Surface

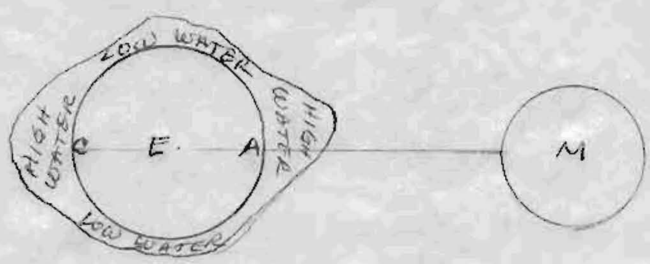



FIGURE 14. High and Low Water on Either Side of the Earth

His theory established the principle that the forces necessary to generate the tides were dependent upon, not only the size of the bodies involved, but the distance between them as well. The equation is as follows:

$$F = \frac{Mm}{d^2}$$

Where F is the attractive force on a line joining the centers of the particle masses (M and m), and d is the distance between these centers.

Without rotation of the earth on its axis, the fluid envelope would adjust itself to the resultant gravitational force set up by the Sun and Moon in combination; the lunar tide would occur twice monthly at any given place.

Because the size and distance of the bodies involved are important factors in raising the tide bulges on earth, only the Sun, and Moon's attractive forces need be considered, the other Planets are too far away. It is said that the tides mainly follow the moon- this is something of a paradox- the sun's mass is 26 x $10^6$ as great as the moon's, but it is 93 million miles away from the earth- the moon is only 240,00 miles away, thus the sun's effect is only 1/4 that of the Moon.

The Sun the Earth and the Moon are continuously changing their positions, and this of course changes the directions and magnitudes of the tide-producing forces. The three principal changes are: Alignment (phase); distance from the earth (Parallax); and angle with respect to the earth's equinoctial plane (declination). These features allow for predictions in the times of highest and lowest tides.

Phase - The effect of either the sun's or moon's gravitational attraction is to raise the tide bulges on either side of the earth along the line of attraction. Thus, when the sun the earth and the moon are aligned as below (a condition called syzygy), the independent bulges of the sun and moon are superimposed, and the heights of the tides are greatest ( called spring tides ; and occurring at New and Full Moon):


FIGURE 15. Sun, Earth and Moon in a Straight Line

In the figure below, the bodies form nearly a right angle, the tide heights are lowest (called neap tides, and occurring at first and last quarters of the moon):

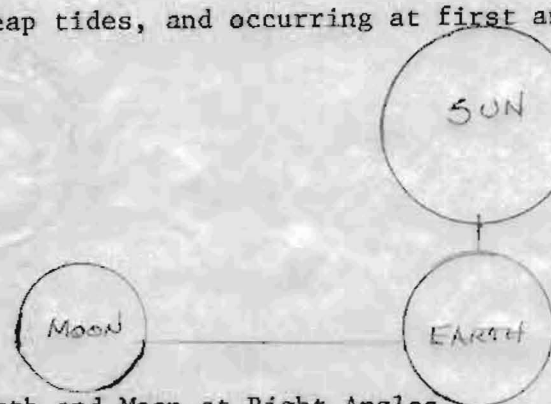



FIGURE 16. Sun, Earth and Moon at Right Angles

Distance - The forces acting on the water particles are proportional to their distance from the mass which causes the attraction. Because the orbits of the moon about the earth, and the earth about the sun are ellipses, the distance between their centers are always changing, and with it- the tide-producting forces. At the point where the moon is nearest the earth, it is said to be in Perigee (the Sun in Perhelion), and the tide forces are a maximum; when the moon is farthest away, it is in Apogee (the Sun in Aphelion).

Declination - The moon's distance above or below the plane of the earth's equator is known as declination; it varies between 18.5° vnd 28.5° N. or S. of the Equator during a period of 18.6 years. The angle that the sun and moon makes with the plane of the earth's equator (equinoctal plane) is called declination, and it describes the alignment of the the three bodies in a plane perpendicular to that considered before. At the time of the solstice, the sun reaches its maximum declination (23 1/2°), and the moon's orbit around the earth is inclined at an angle of 5° to the ecliptic. According to Newton, the type of tide is influenced by declination. When the moon is directly over the equator, the declination is zero- the tide bulge is symmetrical- and the resulting type of tide is semi-diurnal (two equal high waters and two equal low waters each day):

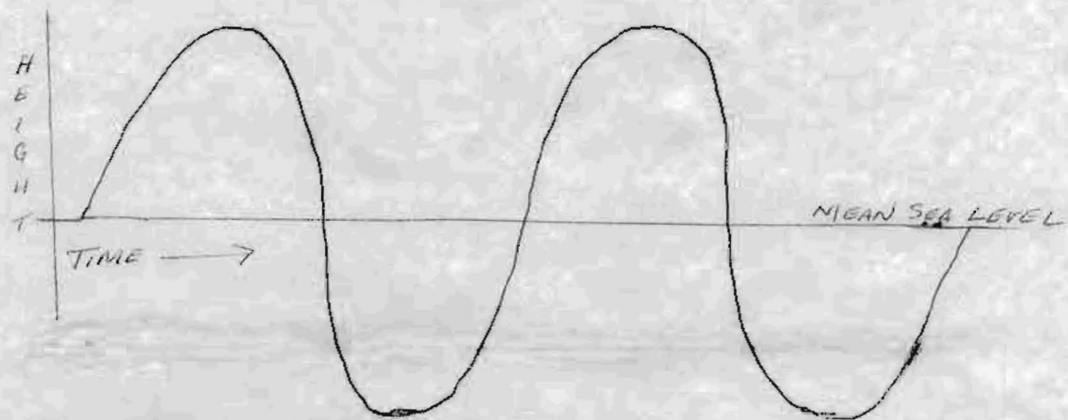



FIGURE 17. Semi-diurnal type tide

As the moon's declination increases, the resulting tide type is mixed (two high and two low waters, but unequal in heights):

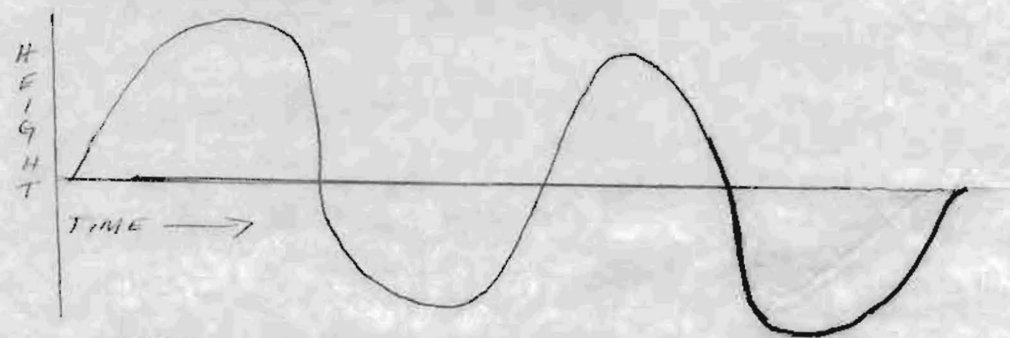



FIGURE 18. Mixed type tide

As the moon further continues its declination, the resulting type tide is diurnal (one high water and one low water each day):

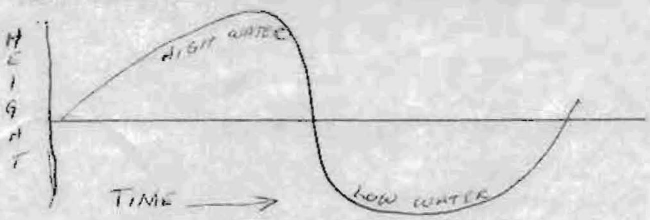



FIGURE 19. Diurnal Type Tide

The total tidal day is 24 hours and 50 minutes (24h 50m).

Actual conditions of the tides are not adequately explained by Newton's Equilibrium Theory, since his grand principle was that all forces in the Universe tend to a state of equilibrium or balance of forces, but did not take into account those modern concepts which consider tee dynamical behavior of the fluid once it is set in motion. Modern concepts are explained by the French Mathematician La Place (1774), who introduced hydrodynamics into tidal theory.

A great achievement of tidal studies is the possibility of predicting to a fair degree of accuracy, the value of sea level for a great number of Ports at any given time.

A typical tide curve showing all phases of the Moon is shown below:

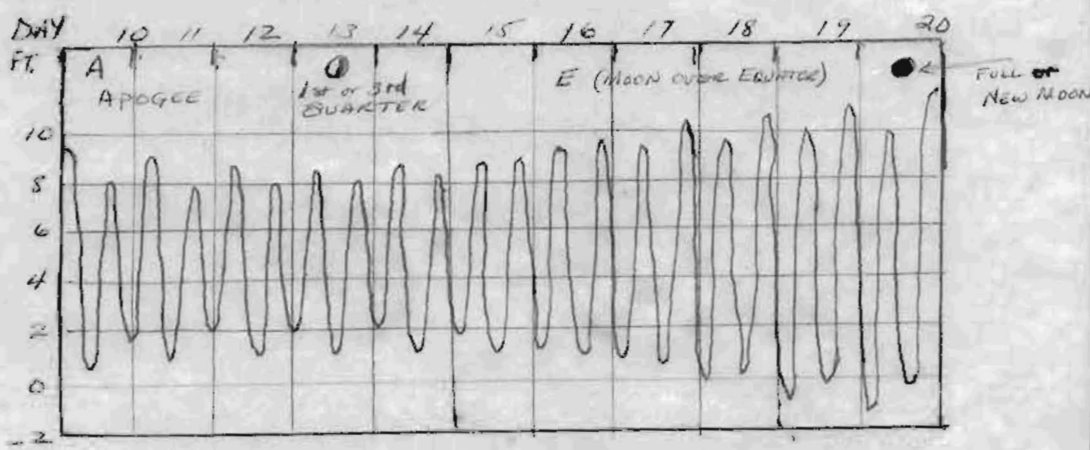



FIGURE 20. 17-Day Tide Curve

TIDAL BORE

One of the most striking features associated with the tides, and a phenomena causing very high tides in some areas of the world such as the Bay of Fundy, is a condition known as the Tidal Bore.

Three factors are critical for the occurrence of bores:

(1) The theory of standing oscillations- period is determined by the dimension of the basin (length and depth):

$$T = \frac{2\,L}{\sqrt{g\,h}}$$

T = period in seconds
L = length of basin (Bay of Fundy = 170 miles)
h = mean depte (Bay of Fundy = 240 feet)
g = acceleration of gravity (32.2 ft/sec$^2$.)

(2) Resonance - synchronism between the natural oscillation periods of Bays, Gulfs, Seas, etc., and the oceanic tide - the cyclic rythms of the astronomical forces.

(3) Geographic Configuration of the Basin - Decreasing width and shoaling depths- coupled with the earth's rotation, accentuates the range of the tides.

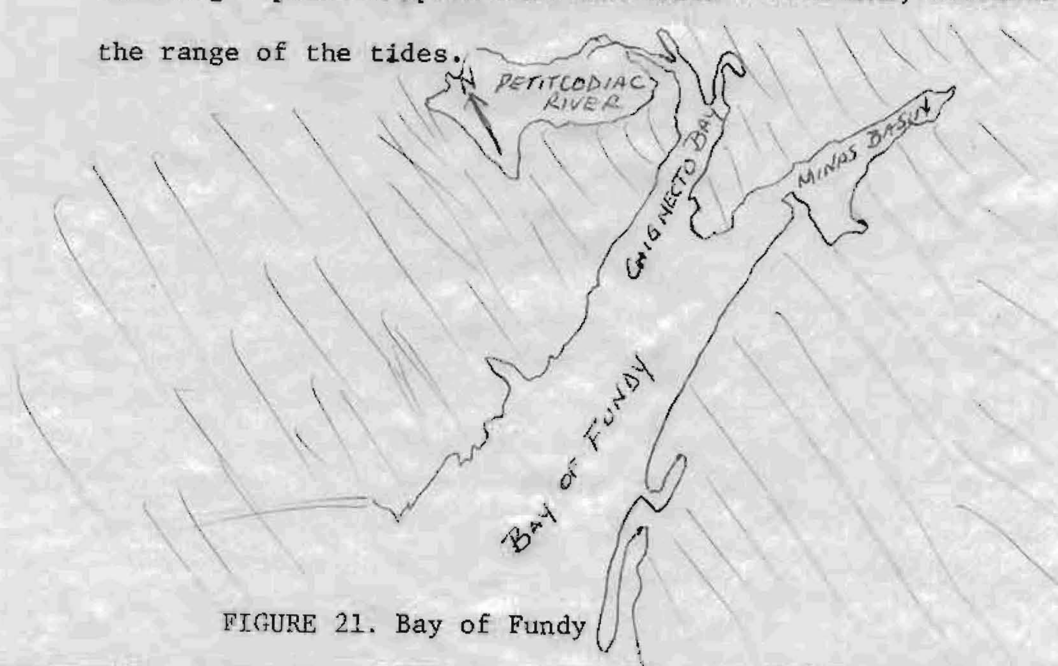



FIGURE 21. Bay of Fundy

TIDE INCREASE FROM MOUTH OF BAY TO HEAD (Minas Basin- Nova Scotia Side)

| Place | Mean Range | |
|---|---|---|
| C. Sable | 9.1 feet | |
| Yarmouth | 14.0 " | |
| Grand Passage | 18.2 " | |
| Digby Gut | 24.1 " ) | At Spring Tide, the |
| Port George | 27.8 " ) | rise is 14% greater |
| Black Rock Light | 31.5 " ) | |
| Horton Bluff | 42.0 " | |
| Noel Bay | 44.2 " | |

NORTH SHORE - Chignecto Bay

| | | |
|---|---|---|
| Tom Nevers Head | 1.2 feet | |
| Monomy Point | 3.7 " | |
| Nauset Harbor | 6.0 " | |
| Gloucester | 8.9 " ) | |
| Bass Harbor | 10.2 " ) | At Spring Tide, the |
| West Quoddy Head | 15.7 " ) | rise is 14% greater |
| St. John | 20.9 " | |
| Quaco | 26.3 " | |
| Folly Point | 39.4 " | |

The increase in the range of tide on the southern shore is brought by about by the Rotation of the Earth - all moving bodies are impressed with a force deflecting them to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere. On the flood tide, the water entering the Bay of Fundy is deflected to the right on the southern shore, hence, the high water is raised somewhat higher than on the northern shore. The effect of friction and river current on the advancing tide results in an increase in the period of fall, and a decrease in the period of rise.

The greatest travel up river of tides is in the Amazon River- the tide is little more than 10 feet, but the Amazon carries the tidal impulse 450 miles upstream. Three features characterize river tides:

(a) Tide advances upstream at a rate dependent on the depth of the channel:

$$r = \sqrt{g\ h}$$

(b) In going upstream, the duration of fall increases while the duration of rise decreases.

(c) The range of tide decreases from the Mouth to the Head. The energy derived by the tidal impulse becomes lessened by frictional resistance of the sides and bottoms of the channels. But if the energy is concentrated into a smaller volume, it amy overcome the range, decreasing the effects of the friction.

In the Bay of Fundy, the natural period of oscillation is computed to be 11.4 hours:

$$T = \frac{4 \times 170 \times 5280}{32.2 \times 240} = 11.4 \text{ hrs.}$$

The approximate period of the ocean tide is 12 hours. Thus, at high tide, the rise of water entering the Bay is superimposed upon the standing wave, and the trtal volume of water becomes more concentrated as the water must flow through a narrower area; these combined conditions cause some of the greatest range of tides in the world. The steeping heights (40-50 feet) are compensating for the lack of lateral area over which it could spread. The Bay of Fundy is long and straight-sided, and the end separates into two narrow areas- Chignecto Bay and Minas Basin; from a widte of 87 miles and 280 feet of depth at the Mouth of the Bay, it is reduced tr 30 miles wide and a depte of 130 feet at Chignecto Bay where the bay forks. Further up the bay, the contraction in width and the shallowing in depte increases rapidly; the advance is a spectacular wall of water called the <u>Tidal Bore</u>. In the Bay of Fundy, the bore is best seen at Moncton on the Petitcodiac River, where a sheet rf water is developed a half mile wide; at low tide, this is reduced to a stream of water 500 feet wide. Evidences of the advance of water is seen 131 miles up tee Hudson River where it is stopped by a dam at Troy, New York.

The best developed bore in the world is on the Tsiengtang (Chiang Tang Kiang) River in the China Sea, where the water stands 11 feet tall and travels at a speed of 16 knots; it is estimated teat 1 3/4 million tons of water moves past in 1 minute. If the bed of a river is destroyed by dredging or other means, the bore can disappear. The Seine in France had a well-developed bore called the Muscaret- it was destroyed by improvemtnts which took place in 1780.

It is deemed that the energy of the tides is continuously being dissipated at a rate- the order of magnitude of which is a billion horsepower.

Obviously, the power of the tides is tremendous, and harnessing this renewable energy source could provide longevity to the energy stockpile of the future. However, it is conceivable that we are moving toward the 21st Century using our technology- not to find the inexhaustible energy sources, but merely to fuel the inexhaustible technological developments.

## OTHER RENEWABLE ENERGY SOURCES

There are other renewable energy sources in addition to the tides, particularly:

Solar Energy
Thermal Energy
Wind Energy

Solar Energy - The use of solar energy is nothing new, the Greeks and Romans knew how to use it 2500 years ago, though they had not discovered cadmium salts, etu. as solar collectors; however, they had the architectural know-how to design, insulate, and site their homes to gather as much heat as possible.

The technical feasibility has long been established- early systems were assembled in days before oil and natural gas were the mainstays of the energy economy, and before assembly lines had an impact on industrial development. There were 50-hp solar irrigation pumps in 1913 at Meade, Egypt; today there is a 25-hp shallow well pump in Willard, New Mexico- central receiver technology is utilized in Odeillo, France in the form of a megawatt thermal solar furnace (MWT), as well as a 37-foot parabolic dish at Golden, Colorado. A 33 foot parabolic dish was built in Pasadena, Calif. in 1901.

On June 21, 1979, President Carter stated in the Washington Post that he was calling:

> "For the creation of a $100 million solar energy bank to help move the country toward a goal of getting 20 percent of its power from the sun and other renewable sources of energy by the year 200." He stated that "there is no question that solar energy is feasible and cost-effected, and that it is an increasingly important alternative source of energy to avert the danger of continued 'crippling dependence on foreign oil'."

According to administration officials, about one-third of the 20% goal would come from solar power, the rest will come from hydroelectric power, conversion of waste products into energy, and use of wind to generate power. The President proposed to Congress a series of steps, including new tax incentives; he linked funding to passage of the administration's proposed "windfall profits" tax on the oil industry, and creation of an "energy security fund" for development of alternative energy sources.

SOLAR TECHNOLOGY

Solar technologies are still in the early stages of demonstration; the general problem is related to the difficulty in concentrating the energy into an "energy bundle" with an intensity to be absorbed and converted into heat.

The radiant output intensity (solar constant) at the average sun-earth distance of 149.5 billion meters is found to be relatively constant at near 1.365 kilowatts/meter$^2$. The power input of solar energy to Planet Earth is 170 billion megawatts. The inputs to calculation of solar energy are:

Atmospheric moisture
Turbidity
Cloud cover or percent sunshine

The average values can be calculated of:

Direct normal insolation
Diffuse insolation
Total horizontal (global) insolation

The major parts of a solar energy conversion system are:

(1) Lenses or mirrors to collect and concentrate sunlight
(2) Heat receivers to absorb the concentrated sunlight
(3) Energy transport system (piping) to couple the receivers with the conversion and storage elements

(4) Energy storage elements, e.g. tanks containing high-temperature fluid
(5) Heat engines to drive generators
(6) Control systems to integrate and coordinate the operation of other elemtnts.

The advanced Thermal Technology Program concentrates on:

High temperature
High-efficiency heat transport and heat receiver systems where advanced technology can lead to lower system costs as a result of more efficient collector utilization.

At the Georgia Institute of Technology, the testing of high temperature air-cooled ceramic receivers has begun-temperatures are in the range of 1600°F to 2000°F for Brayton cycle heat engines as well as high-temperature processes. The Department of Energy's Solar Thermal Power Systems Program is structured around large (> 10 MW) and small (≤ 10 MW) power applications, both are expected to be available commercially by 1980.

## FUNDING

For FY 1978 (Oct. 1, 1978 - Sept 30, 1979) the overall Solar Thermal Power Systems Program funding level was $100 million/year.

| | FY 1978 | FY 1979 |
|---|---|---|
| Large Power | $21,800,000 | $ 27,000,000 |
| Small Power | 28,100,000 | 28,000,000 |
| Advanced Technology | 10,200,000 | 14,000,000 |
| BARSTOW Pilot Plant | 41,000,000 | 28,000,000 |
| Capital Equipment | 3,000,000 | 3,000,000 |
| | $104,000,000 | $100,000,000 |

Prior to 1972, solar energy research was privately funded.

The average availabilities of the sun's energy is compared with general energy production and requirements in figures 22 through 25.

## OCEAN THERMAL ENERGY CONVERSION (OTEC)

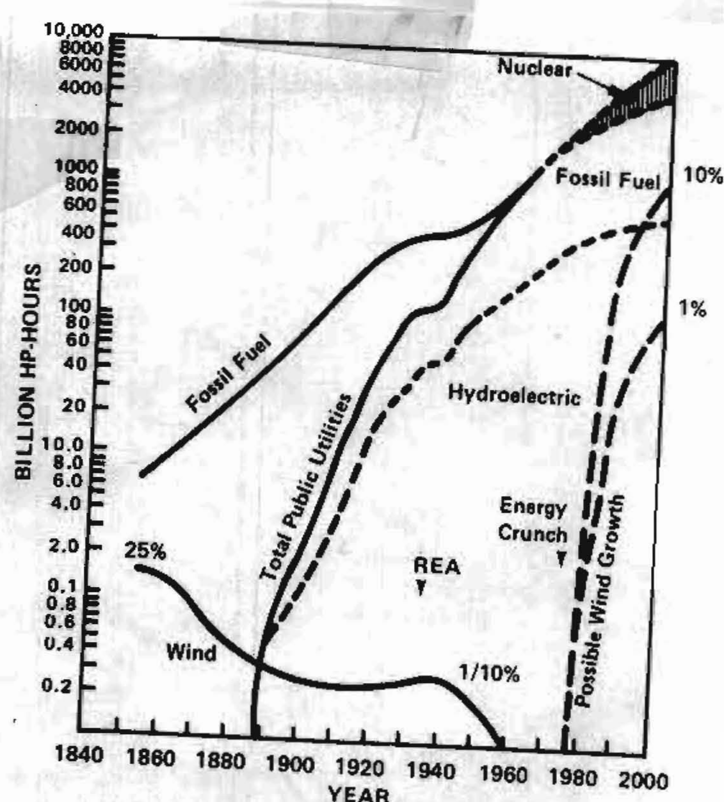
OTEC Plants require improved heat transfer technology; they require 4-10 million pounds of material to harness the difference between the warm surface water and the cold deep water. OTEC plants utilize the temperature differential present between the surface of the water and that at lower depths, converting this thermal energy into mechanical energy and eventually into electric energy. In this process, warm water intake occurs at the surface of the plant; it is pumped through a heag-exchanger-evaporator-vaporizing a working fluid, generally ammonia- which expands in a turbine. It turns the turbine to operate a generator, to provide electric power. The ammonia (or propane or whatever) leaves the turbine, a pump returns it to the heat exchanger-evaporator. The system is a closed-cycle system, thus the ammonia must be cooled before it continues its cycle to the heat

AVERAGE AVAILABILITIES OF SOLAR ENERGY

| Availability factor | Average on earth | In synchronous orbit | Average ratio, ground/orbit |
|---|---|---|---|
| S[illegible]nergy density, kW/m$^2$ | 1.1 | 1.4 | 4/5 |
| Hours of useful radiation/day | 8 | 24 | 1/3 |
| Percentage of clear skies | 50 | 100 | 1/2 |
| Cosine of angle of incidence | 0.5 | 1 | 1/2 |
| Product of all factors | | | 1/15 |

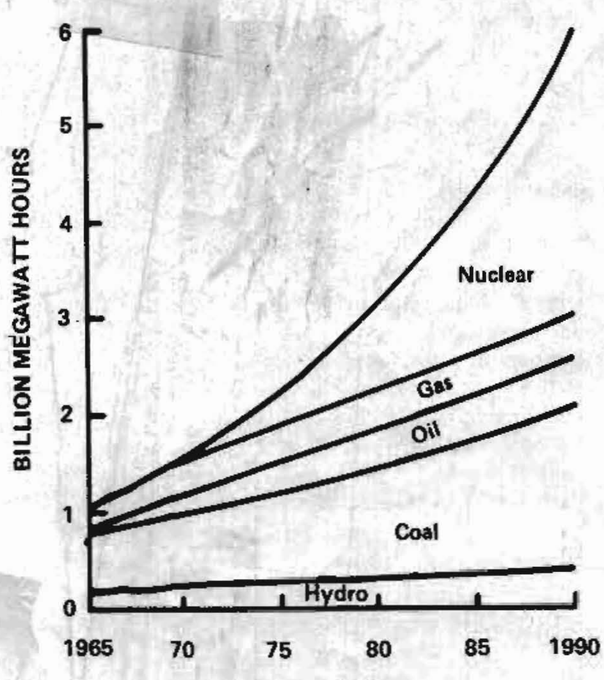
Source: J. T. Patha and G. R. Woodcock, "Feasibility of Large-Scale Orbital Solar/Thermal Power Generation," *Proceedings IECEC*, 1973, pp. 312-319.

FIGURE 22. AVERAGE AVAILABILITIES OF SOLAR ENERGY



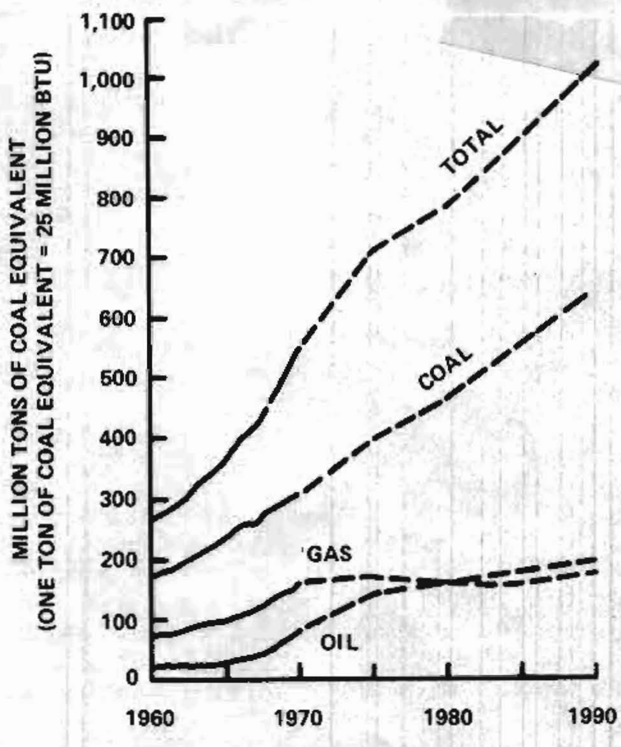

Source: NSF/NASA/Utility Wind Energy Conference Report, 17 Dec. 1974.

FIGURE 23. COMPARISON OF VARIOUS ENERGY SOURCES IN BILLION HP-HOURS




Source: Project Independence Report, Federal Energy Administration

FIGURE 24.
ESTIMATED ANNUAL ELECTRIC UTILITY GENERATION BY PRIMARY ENERGY SOURCES




Source: Project Independence Report, Federal Energy Administration

FIGURE 25.
ESTIMATED ANNUAL FOSSIL FUEL REQUIREMENTS FOR ELECTRIC UTILITY GENERATION

exchanger-condenser. For this, cold water is pumped in from the deeper depths of the ocean to cool the ammonia- thus it condenses; afterwards, the cold water is discharged at the lower depths (Figure 26).

The whole process involves great amounts of circulation in the water column located in the area of the OTEC Plants. Additionally, a suitable material must be used for the heat transfer process; basically, 3 kinds of materials are considered:

Titanium
Copper-nickel combination
Aluminum
Plastic material

OTEC plants are considered for operation in 3 different areas, possibly:

(1) less than 3 miles from a coastal state
(2) between 3 miles and the extent of the coastal state's jurisdiction
(3) beyond a coastal state's jurisdiction

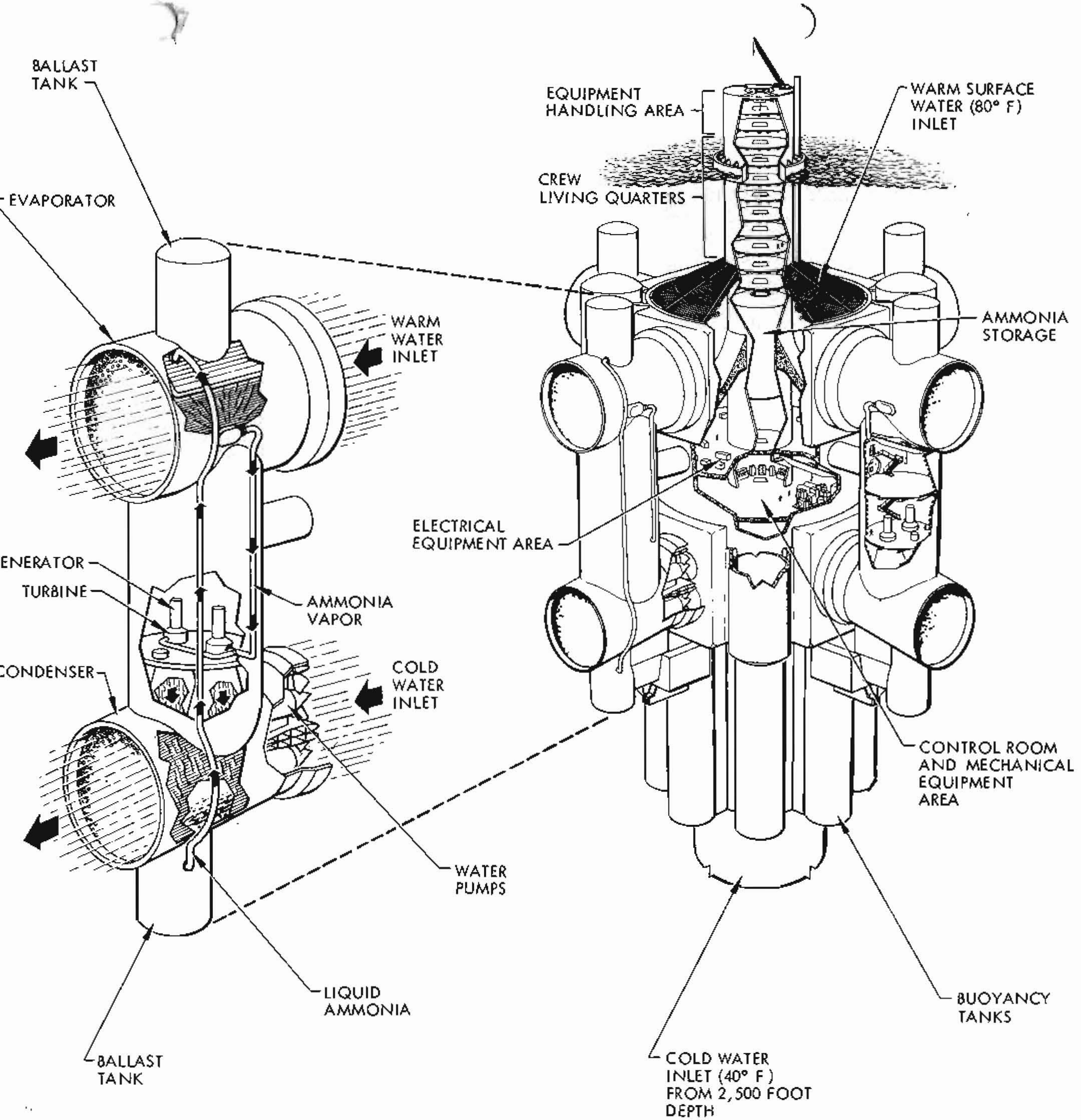
The moored structure will have substantial area exposed to the surface- within 50 feet; if the plant is moored in water 1 mile deep, the mooring must exttnd tr a minimum of 2000-4000 feet below the surface.

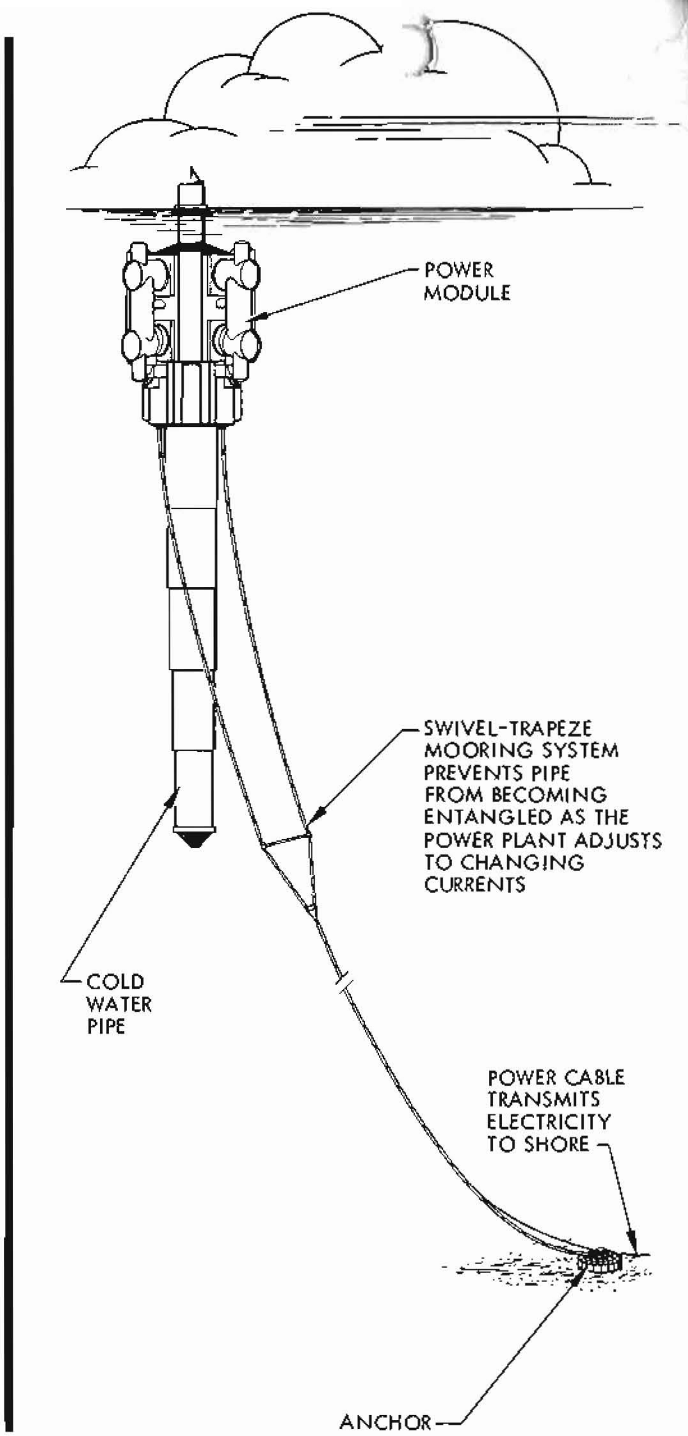
The electricity generated can be transmitted by cable to shore, or used for processing plants (aluminum, ammonia, hydrogen).

PHYSICAL PROCESS OF SUN'S ENERGY TO OCEANS

OTEC is a means for extracting the stored energy of the sun from the oceans using the heat differential present as a result of the depth to which the sun's energy penetmates, and tee circulation pattern by which this energy is distributed throughout the oceans. The conversion energy available is estimated to be of the order of $10^8$ to $10^{10}$ megawatts.

At the center of our solar system is the sun, it is 93 million miles away from the earth, but it is the primary source of energy to the earth;




**Lockheed Missiles & Space Company**

it drives the current system' of the oceans, it is responsible for the varying temperature changes in the atmospheric envelope, and is thus the deriving power of the winds. The surface temperature, which is transmitted to the earth, is 6000°C (11,000°F); the inner core of the sun has a temperature of $20 \times 10^{6}$°C, possibly as a result of thermonuclear reactions. The energy from the sun is received by the earth in the form of Electromagnetic Waves, in an amount equal to $17 \times 10^{20}$ calories per day (this represents only 45 to 55% of the energy leaving the sun's surface, the rest is scattered). These rays of energy penetrate to the oceans to a depth of approx.mately 100 meters, and is the available heat to be circulated through the ocean by mixing, etc. This available heat is responsible for the temperature difference that is present and from which OTEC plants derive their operational energy.

GULF STREAM OTEC

The more direct rays of the sun reach the earth at the Equator, thus it is possible that the best areas for OTEC plant operation may be in the tropical areas. A temperature difference of at least 17°C (30°F) is required for operation of the OTEC power cycle.

The University of Massachusetts in 1974, proposed acquisition of a large fleet of OTEC Plants for tee Gulf Stream. This body of water is 50 miles wide, and 1500 meters deep; it carries more than 4 billion tons of water per m.nute. The pecularities of the Gulf Stream are caused by the manner in which the trade winds drive the waters westward, providing a greater elevation on the west side of the Atlantic, and thus raising the sea level in the Gulf of Mexico. The Gulf Stream System thus has 3 parts:

(1) A southern portion made up of the Florida Current from the Strait of Florida to Cape Hatteras.

(2) The Gulf Stream proper- from Cape Hatteras northward to East of the Grand Banks (Longitude 45°W).

(3) The more diffuse current which branches out, widens, slows down and becomes the North Atlantic Drift.

The features of the Gulf Stream with the fastest current of 100 miles per day provide scientists with a basis for determining that the Gulf Stream is an ideal place for an OTEC Plant. There is no necessity for great pumping efforts to distribute the cold water through the plant.

It is estimated that this plant will supply 146 x $10^9$ kwh/year of electricity to New England- the 1990 projected demand. This will be done using the University of Massachusetts difference process and hydrogen link. It is estimated also that OTEC plants can produce energy intensive products such as hydrogen and ammonia- that the OTEC plant can be operated safely without harming the environment- and that a single 400 megawatt plant-ship producing ammonia can save 38 million cubic feet per day of natural gas.

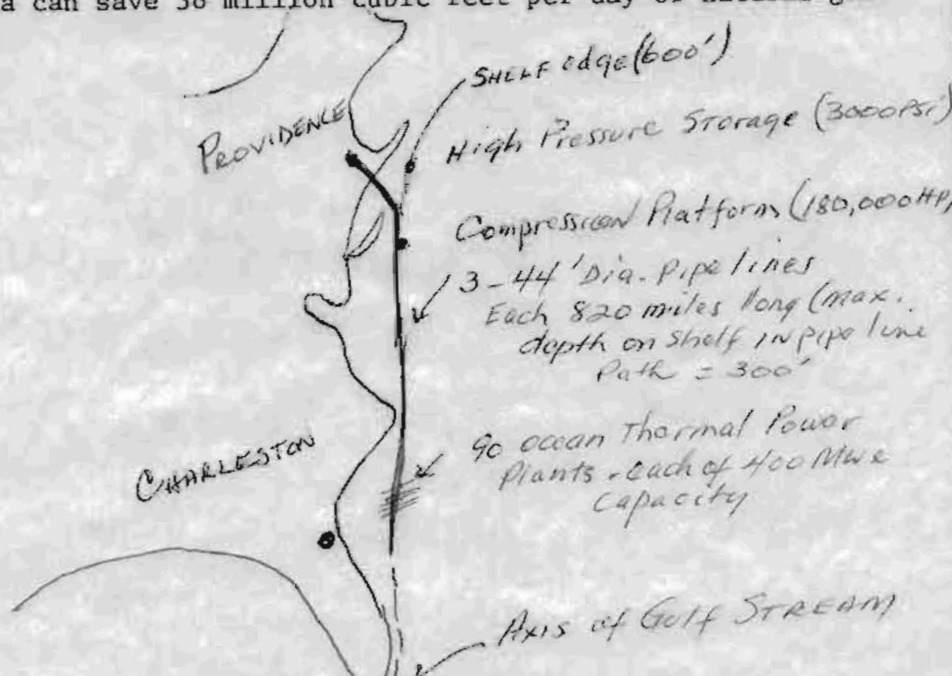



FIGURE 27. PROPOSED GULF STREAM OTEC PLANTS

WIND ENERGY

Though thermal energy and wind energy are given as separate renewable energy sources, they are in fact but different aspects of the sun's energy to the earte. Because the atmospheric envelope (air) is heated as the earth absorbs the sun's energy and reradiates it into the atmosphere, and because of the manner in which this heat is received in various places on earth- there is differential heating of the air. Differential heating of the air causes it to be heavier (higher pressure) in some places, and lighter (lower pressure) in others; this difference in pressure of the air from place to places gives rise to winds- winds are the force used by nature to attemjt to create a balance in the pressure of the air envelope.

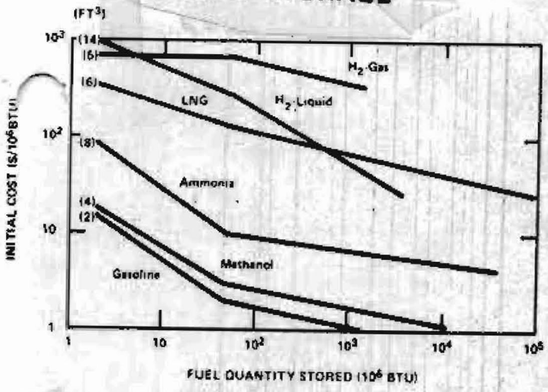
Wind energy has long been utilized by man; windmills were known in China and Japan as early as 2000 B.C. They have been common for at least 700 years in Europe and have been in wide use in the western United States until 1950. In remote regions on individual farms and houses, some are still used for pumping water into storage tanks, or generating electricity.

One characteristic requirement of supplementary energy sources as a full potential benefit, is an energy storage system such that the energy may be stored when available, and retrieved during periods of insufficient power (peak power requirements). Some storage factors are shown in Figures 28-30.

WIND ENGINEERING TECHNOLOGY

In the earliest application of wind energy, there was direct mechanical coupling of the wind turbine to the driven machinery or water pumps. However, this placed severe limitation on site selection and system configuration; today, all large scale experimental systems are designed to generate electricity.

## ENERGY STORAGE




Source: R. Thomas, et. al. Plans and Status of the NASA-Lewis Research Center Wind Energy Project. NASA TM X-71701, 1975.

FIGURE 28. **FUEL STORAGE INVESTMENT (1972 BASIS)**

### ENERGY DENSITY OF REPRESENTATIVE STORAGE SYSTEMS

| Means of Storage | Storage Conditions | | Energy Density Btu/ft³ |
|---|---|---|---|
| **Mechanical** | | | |
| Flywheel | Optimized Steel | | < 43,000 |
| Pumped Storage | 100 ft head | | 14 |
| **Thermal** | | | |
| Hot Rocks/Metal | 60-500° F | | 8,000-12,000 |
| Molten Salts | 60-500° F | | 10,000-20,000 |
| Steam | 15 psi | 212° F | 40 |
| | 120 psi | 347° F | 340 |
| | 500 psi | 467° F | 1,270 |
| Water | 15 psi | 212° F | 9,000 |
| | 130 psi | 347° F | 16,000 |
| | 500 psi | 467° F | 21,000 |
| **Chemical** | | | |
| Hydrogen | | | |
| • Gas | 15 psi | 60° F | 280 |
| | 1,000 psi | 60° F | 18,500 |
| • Liquid | 15 psi | -425° F | 200,000 |
| • Hydride ($Mg_2Ni$ or FeTi) | | | 250,000 |
| Ammonia | | | 340,000 |
| Methanol | | | 430,000 |
| Gasoline | | | 830,000 |
| Batteries | | | 10,000-80,000 |

FIGURE 29.

FIGURE 30. **CHARACTERISTICS OF ENERGY STORAGE TECHNOLOGY**

| Technology | Typical Economic Module (MWe) | Characteristics: Earliest Commercial Availability | Characteristics: Storage Efficiency (%) | Remarks |
|---|---|---|---|---|
| Batteries | 1 | 1975-82 | 70-80 | Proven Technology |
| Flywheels | 1 | 1985 | 70-90 | |
| Hydrogen/Fuel Cells | 1 | 1985 | 40-60 | Storage Options for Hydrogen |
| Compressed-Air (Adiabatic) | 10 (30 MwH) | 1982 | 70-80 | High-Grade Thermal |
| Compressed-Air (Isothermal) | 10 | 1975 | NA | Required Fuel |
| Pumped Hydro | 100 (?) | 1975 | 70-75 | Special Situations |
| Superconducting Magnets | 500 | 1995 | 90 | |

Source: Frank R. Eldridge (ed), *Wind Workshop 2*, Proceedings of the Second Workshop on Wind Energy Conversion Systems, The MITRE Corporation, Washington, D.C., June 9-11, 1975. NSF-RA-N-75-050, MTR-6970.

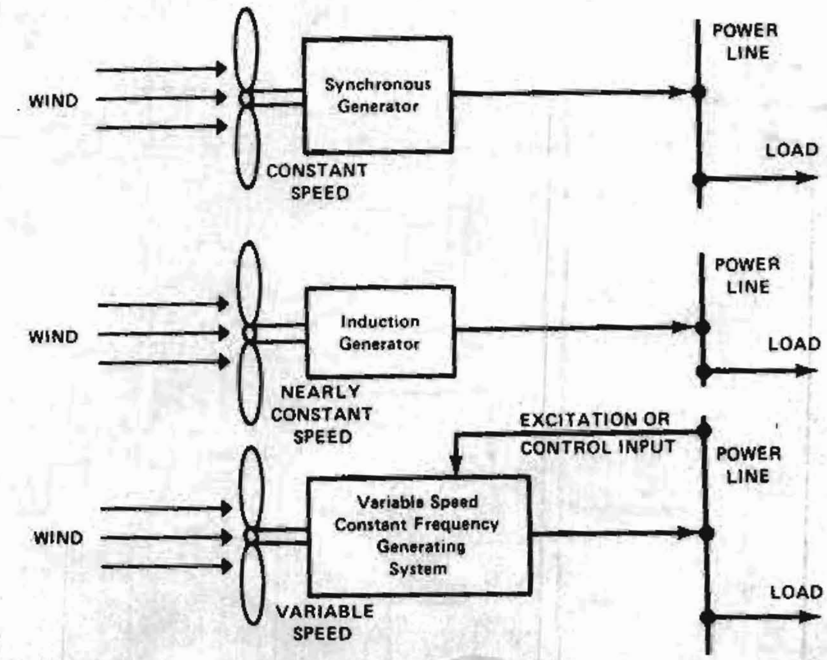
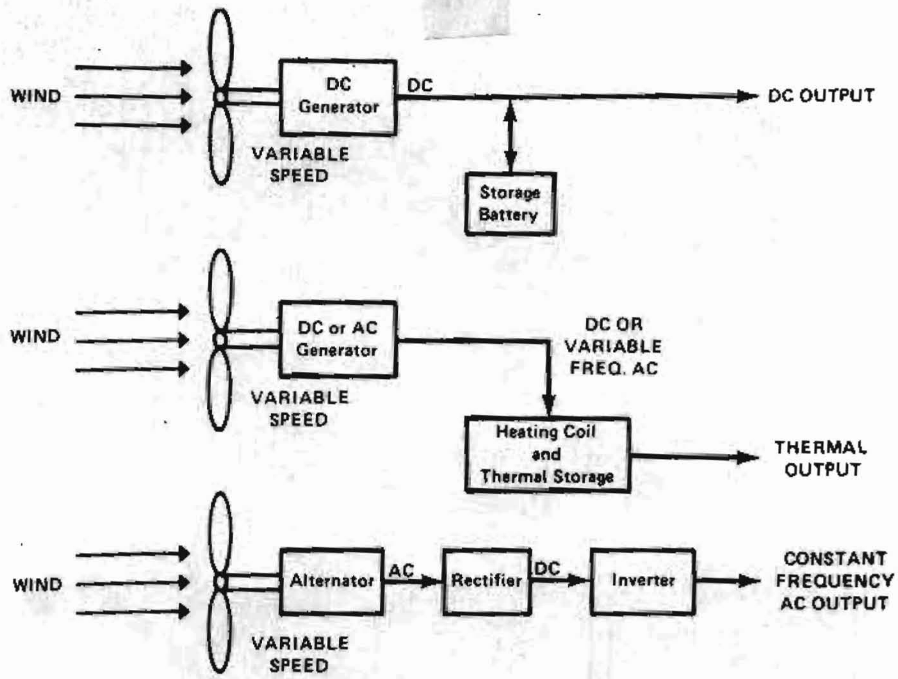



FIGURE 31. SCHEMES TO CONVERT WIND ENERGY TO ELECTRICITY




Source: R. Thomas, et. al. Plans and Status of the NASA-Lewis Research Center Wind Energy Project, NASA TM X-71701, 1975.

During the period from 1935 to 1955, a large number of experimental wind-powered generators were constructed, most were located in Europe. The United States had a Smith-Putman unit at Grandpa's knob, Vermont; in 1941, it fed wind generated power synchronously into a utility power grid. It was rated at 1250 kw in a 30-mile per hour wind, and was operated for 1100 hours over a 4 1/2-year period.

Generally, there are many types of wind turbines, but they all fall into two basic concepts: The horizontal axis design and the vertical axis design. The horizontal axis design requires some means of keeping the axis oriented into the wind (the vertical axis is omni-directional). One type of wind turbine is two-bladed, constant at 40 rpm with a 125-foot diameter rotor located downwind of the wind tower. The rotor drives a 100-kw synchronous alternator through a step-up gear box. The drive train and rotor are located in a Nacelle with the center-line 100 feet above the ground. The Nacell sits on top of a 4-legged steel truss tower. The wind direction is sensed by the wind vane on top of the Nacelle, and is used as a signal for yaw control for keeping the wind turbine aligned in the direction of the wind; schemes are shown in Figure 31.

Geothermal Energy possibilities are discussed in Figure 32.

## THE ORIGIN OF TECHNOLOGY'S IMBALANCE

The technologist proceeds to build on the strength of the mathematical and physical models of the Mathemvtician, the Physicist, and the Chemist; for these scientists, the natural order of the Universe is the model. However, the model for the technologist comprises the materials and processes to build and make the mrdel work- the technology of metallurgy; the heat of combustion; the sustainable pressures- profit is the

Washington Post
Sunday July 15, 1979

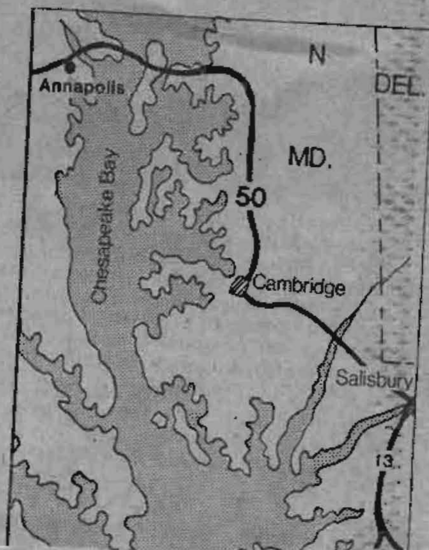
# Geothermal Energy Found On Eastern Shore of Md.

By John Tierney
Washington Star Staff Writer

CRISFIELD, Md. — A phenomenon called geothermal energy has finally made its formal debut on the East Coast. It had been around for centuries, but not until this summer did anyone bother extracting it from the ground.

It first surfaced on the outskirts of this Eastern Shore town, in a field lying between a tiny airport and an abandoned farm. Here, several hundred yards from the Chesapeake Bay, a team of oilmen hired by the U.S. Department of Energy began drilling a wildcat well two months ago.

The drillers were looking for hot water, and they found it 4,000 feet underground. It was neither as abundant nor as hot as scientists had hoped, but it w...




# Geothermal Drilling Strikes Hot Water on

Continued From A-1

heated with hot water from underground, and northern California generates electricity from its abundant reserves of steam trapped below the earth's surface.

But geothermal energy does not come easily or cheaply in most places, including Crisfield. When the $1-million drilling project began here, researchers hoped to find 160-degree water. They speculated that it might heat two schools and a hospital, or perhaps be used to process frozen onion rings and sweet potatoes at the Mrs. Paul's plant in town.

When they began extracting water from this well, the drillers discovered that the water was not flowing as rapidly as they had hoped. And the temperature was just 133 degrees — probably high enough to be useful in some buildings, but only in conjunction with conventional heating equipment.

Nevertheless, the researchers still call the experiment a success. It's the first proof that the East has substantial geothermal resources — a notion that didn't occur to anyone five years ago.

Scientists have long known about geothermal resources in the West, which is relatively young by geologic standards (the Rockies were formed a mere 70 million years ago). The West has obvious resources like geysers, where water is heated by molten rock underground, and the Energy Department has an extensive geothermal program out there.

The East's older rock formations have cooled down, so the region generally lacks the volcanic activity and land movement that generate heat. There are a few hot springs, but until recently no one seriously considered finding much available energy.

**New theory for the East**

But then John Costain came up with a theory. Together with colleagues at Virginia Polytechnic Institute, Costain noticed that granite formations in the Appalachian foothills contain abnormally large amounts of radioactive elements such as uranium and thorium, which give off heat as they slowly decay. This explained the heat source for the few hot springs in the Appalachians.

Costain reasoned that similar heat-producing granite formations extend underneath the Atlantic coastal plain. These formations were on the Earth's surface hundreds of millions of years ago, but erosion from the Appalachian Mountains gradually covered the granite with sediment.

Because the granite is insulated by these layers of sedimentary rock, Costain theorized that the granite's heat had been preserved underground. It had been trapped in the subterranean water and could be recovered by bringing up the water.

This still left a problem — how to find granite formations that lie a mile beneath the surface of the coastal plain. Costain tried to do so by analyzing distortions in the earth's magnetic and gravitational fields, relying on the fact that granite has more iron and is less dense than surrounding rocks.

After Costain pointed out some likely areas for underground granite, Energy Department researchers last year drilled 48 shallow wells, each 1,000 feet deep, along the coast between New Jersey and North Carolina. They were looking for hot spots underground, and Crisfield proved to be one of the hottest.

So in May the department's oilmen showed up in Crisfield with a 112-foot drilling rig borrowed from the Department of Labor, which keeps one on hand in case of underground mine disasters. The v
4,200 feet, to the dep
granite was supposed t

"The first hole cert
that the granite is do
just missed it," says J
deputy director of the
geothermal division
why the water was c
pected. "We thought t
the edge of it, but it t
we were just off it."

**Under the Chesapeake**

The center of the
tion appears to be di
neath the Chesapeak
does no one much go
tists think they've le
from this first well
one, perhaps early ne
are various spots un
tion, including the No
southern New Jersey.

Meanwhile, Crisfie
would like to get so
this well besides th
proving a geologica
field Mayor Charles
says that a new energ
help attract industr
which is one of the
state.

The Energy Depart

FIGURE 32. GEOTHERMAL ENERGY POSSIBILITIES

motive, there is little concern about the natural order of the universe- nor how the use of materials impact on this natural order. The consequence is that as technological skills are perfected, the models may become more high speed vehicles to use more sophisticated forms of energy. Technology's purpose seems questionable; it feeds upon its own expertise- designing and building those artifacts where and when the "know-how" becomes available.

As a point in fact, one might look at the constant energy requirements of vehicles, or to the building and improvemtnt of chemical plants:

(1) More accurate temperature regulators for chemical plants are required as they get more complicated;

(2) More sophisticated automatic machine tools are required to control the product quality by eliminating human factors and thereby increasing the product's quantity;

or (3) more accurate and faster response servo-systems are needed for high-speed air craft guns

or (4) more powerful electronic amplifiers are needed for expanding radio communications.

Like other technological requiremtnts, the above may seemingly have no connections, but they are all related to the feed back control and compensation theories developed in the technological design of radio amplifiers. Each technological step requires more technological development.

THE STOCKPILING OF WEAPONS OF TECHNOLOGY

In terms of stockpiling artifacts of technology, one may look at the 1950's as the age when the technological race began as an end unto itself. When Hahn and Strassman proved in 1939 that neutrons could split the nuclei of uranium, and Fermi, Meitner, and others demonstrated through Relativity and Quantum Mechanics the possibility of fission- technology began its orbit, and the energy of its spin continues today. In 1945, with the explosion of the atomic bomb, the production of technology's most sophisticated fuel began - Uranium-235 ($U^{235}$)- and the vehicles of this energy form continues full speed ahead in the 1970's.

Our technological development in weaponry, in high speed transportation systems; and in mass communications systems all began after World War II. Throughout World War II, cities were compact, mass transit service was so widespread that 85% of the travelling public used public transportation, walked, or bicycled. According to Stewart Udall, et al., in Energy Balloon :

> "In 1945, this country had a balanced transportation system; it had the best and most varied urban transit systemf and perhaps the finest overall railroad services in the world. Then they began to die, the automobile is now the major carrier of people- 85% of the traffic."

After World War II and the Atomic Bomb, those scientists who participated in this high speed energy form were keenly interested in fulfilling pre-war dreams of space flight- particularly the Germans. Rocket societies began in the 1920's in the U.S.S.R. and Germany; the American Interplanetary Society was the American Rocket Society. However, World War II closed rocket societies in all nations except Germany. The V-2 rocket produced by Werner Von Braun's group was a step forward for rocket technology. It was now necessary only to reach velocities necessary to achieve space flight. The International Astronautical Federation was formed by Societies in the 1950's, and the idea prevailed that the technology was at hand to build rocket-powered launch vehicles and space craft that could survive the atmosphere.

Opportunities for advancing the idea of space flight came in the establishment of the International Geophysical Year (IGY), the program of international cooperation among technologists, scientists, and geophyscists.

In July 1955, the United States established the earth satellite program- selecting the VANGUARD with 3-stage launch vehicle capable of placing a 21.5 pound instrumented satellite in orbit. The Soviet SPUTNIK program had developed much larger Intercontinental Ballistic Missiles (ICBM) capable of carrying nuclear fission warheads. The United States' Defense Department rejected the idea as having neither scientific nor military value.

The launching of the Soviet's SPUTNIK I in 1957 marked the beginning of technology's unrelenting quest for faster, more powerful vehicles that require larger and larger energy supplies with each pound of power, and each mile of speed. Thus, in post war America, technology became Holy Writ- no problem became so complex it wouldn't be solved by more ingenuous technology. The all-pervasive thought seemed to be "Today's Wonderful, Tomorrow Even Better". The United States finally launched the Army's JUPITER C Intermediate Range Ballistic Missile (IRBM), and it was capable of travelling 1500 miles; this grew out of the U. S.'s Satellite program of 1958.

If one takes a look at the increasing use and production of energy resources, and the increasing technological developments taking place at the same time- the correlation between technology's continuing innovation and the increase in fuel consumption is clearly evident.

The technology of the 1950's was an achievement in metallurgy- the handling of temperatures and pressures associated with thermal efficiencies;

the special high temperature alloys required to protect structures and boilers- alloys made of nickel, chromium, molybedum, manganese- added to steel- this caused resistance to corrosion and creep. In the same manner, expensive hydrogen at 10,000 lbs. of pressure must be added to coal to make gasoline; alloys are 25% to 50% more expensive than non-ferrous metals, and there is a problem of supply; Figures 33-36 shows Prices, Supply & Demand.

In 1950, twenty times more fuel was consumed than in the 40 previous years. The following are the technological brain-child of the different decades since World War II:

<u>1950</u>

V-2 Rocket
Solid-fuel ballistic missiles
JUPITER- 44-ft. high, 120 ft. in diameter, and weighing 80 tons- requiring a submarine of 8,000 to 9,000 tons to carry 4.
POLARIS
SPUTNIK
SEAWOLF ) Nuclear-powered submarines
NAUTILUS )
SATELLITES

<u>1960</u>

Moon Walk
Automobiles (Energy's greatest user- requiring $1.23 \times 10^8$ BTU just to manufacture one)
- 1900 - 8,000 cars
- 1927 - 20 million cars
- 1950 - 32.5 million cars
- 1970 - 110 million cars

Nuclear Energy - $U^{235}$ - Plutonium- Thorium
BREEDER REACTORS

<u>1970</u>

ENTERPRISE )
TRIDENT ) Nuclear-Powered Submarines

In direct relation to the above, Tables 3 through 7 shows energy production and consumption nationwide between 1925 and 1967, reserves

## TABLE 3

## ENERGY PRODUCTION AND CONSUMPTION, BY MAJOR REGIONS, 1925 AND 1967

*(All data based on coal equivalents)*

| Region | Production: Million met. tons | Production: Percent of world | Consumption: Million met. tons | Consumption: Percent of world | Ratio of production to consumption |
|---|---|---|---|---|---|
| | | | *1925* | | |
| North America | 779.0 | 49.7% | 748.9 | 50.4% | 1.04 |
| of which: United States | 765.0 | 48.8 | 717.7 | 48.3 | 1.07 |
| Western Europe | 532.4 | 34.0 | 517.0 | 34.8 | 1.03 |
| Oceania | 16.0 | 1.0 | 15.6 | 1.1 | 1.03 |
| U.S.S.R. & Comm. E. Europe | 92.1 | 5.9 | 80.5 | 5.4 | 1.15 |
| U.S.S.R. | 27.0 | 1.7 | 25.3 | 1.7 | 1.07 |
| Comm. E. Europe | 65.1 | 4.2 | 55.1 | 3.7 | 1.18 |
| Communist Asia | 22.6 | 1.4 | 23.7 | 1.6 | 0.95 |
| Latin America | 39.9 | 2.5 | 24.7 | 1.7 | 1.62 |
| Caribbean | 33.9 | 2.2 | 11.4 | 0.8 | 2.98 |
| Other Latin America | 6.0 | 0.4 | 13.3 | 0.9 | 0.45 |
| Asia | 71.1 | 4.5 | 60.3 | 4.1 | 1.18 |
| Middle East | 7.7 | 0.5 | 2.3 | 0.2 | 3.32 |
| Japan | 32.9 | 2.1 | 30.5 | 2.1 | 1.08 |
| Other Asia | 30.5 | 1.9 | 27.5 | 1.9 | 1.11 |
| Africa | 13.6 | 0.9 | 13.9 | 0.9 | 0.98 |
| North Africa | 0.3 | - | 3.0 | 0.2 | 0.10 |
| Other Africa | 13.3 | 0.8 | 10.9 | 0.7 | 1.22 |
| WORLD[a] | 1,566.6 | 100.0 | 1,484.5 | 100.0 | 1.06 |
| | | | *1967* | | |
| North America | 2,114 | 34.4% | 2,230 | 37.9% | 0.95 |
| of which: United States | 1,947 | 31.7 | 2,055 | 34.9 | 0.95 |
| Western Europe | 540 | 8.8 | 1,168 | 19.8 | 0.46 |
| Oceania | 46 | 0.7 | 67 | 1.1 | 0.69 |
| U.S.S.R. & Comm. E. Europe | 1,489 | 24.2 | 1,376 | 23.4 | 1.08 |
| U.S.S.R. | 1,124 | 18.3 | 989 | 16.8 | 1.14 |
| Comm. E. Europe | 365 | 5.9 | 387 | 6.6 | 0.94 |
| Communist Asia | 255 | 4.1 | 255 | 4.3 | 1.00 |
| Latin America | 451 | 7.3 | 224 | 3.8 | 2.01 |
| Caribbean | 383 | 6.2 | 126 | 2.1 | 3.04 |
| Other Latin America | 68 | 1.1 | 98 | 1.7 | 0.69 |
| Asia | 966 | 15.7 | 471 | 8.0 | 2.05 |
| Middle East | 764 | 12.4 | 68 | 1.2 | 11.24 |
| Japan | 61 | 1.0 | 249 | 4.2 | 0.24 |
| Other Asia | 141 | 2.3 | 154 | 2.6 | 0.92 |
| Africa | 284 | 4.6 | 97 | 1.6 | 2.93 |
| North Africa | 200 | 3.3 | 20 | 0.3 | 10.00 |
| Other Africa | 84 | 0.1 | 77 | 1.3 | 1.09 |
| WORLD[a] | 6.145 | 100.0 | 5,888 | 100.0 | 1.04 |

[a]World production totals differ somewhat from world consumption totals because (1) bunkers are included in production and excluded from consumption (which refers to inland consumption); and (2) because of unexplained statistical discrepancies, as discussed in Part Four of this volume.

*Source*: Data for 1925 from Part Three, tables X and XIV; data for 1967 are estimates, derived from United Nations, *Statistical Yearbook, 1968* (New York, 1969).

## TABLE 4.

### WORLD ENERGY CONSUMPTION, BY SOURCE, SELECTED YEARS, 1925-1968

| | 1925 | 1938 | 1950 | 1955 | 1960 | 1965 | 1967 | 1968 |
|---|---|---|---|---|---|---|---|---|
| | | | | *Million metric tons coal equivalent* | | | | |
| Solid fuels . . . . . . | 1,230.0 | 1,291.8 | 1,593.2 | 1,816.6 | 1,998.5 | 2,290.8 | 2,209 | 2,315 |
| Liquid fuels . . . . . | 196.7 | 375.8 | 722.2 | 1,092.7 | 1,499.0 | 2,159.1 | 2,489 | 2,702 |
| Natural gas . . . . . . | 47.9 | 99.7 | 252.1 | 389.6 | 612.6 | 912.1 | 1,064 | 1,157 |
| Hydroelectricity . . . | 9.8 | 22.8 | 43.4 | 59.2 | 86.0 | 112.6 | 126 | 132 |
| Total . . . . . . . | 1,484.5 | 1,790.1 | 2,610.9 | 3,358.2 | 4,196.1 | 5,474.6 | 5,888 | 6,306 |
| | | | | *Percentage distribution* | | | | |
| Solid fuels . . . . . . | 82.9% | 72.2% | 61.0% | 54.1% | 47.6% | 41.8% | 37.5% | 36.7% |
| Liquid fuels . . . . . | 13.3 | 21.0 | 27.7 | 32.5 | 35.7 | 39.4 | 42.3 | 42.8 |
| Natural gas . . . . . . | 3.2 | 5.6 | 9.7 | 11.6 | 14.6 | 16.7 | 18.1 | 18.3 |
| Hydroelectricity . . . | 0.7 | 1.3 | 1.7 | 1.8 | 2.0 | 2.1 | 2.1 | 2.1 |
| Total . . . . . . . | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Average annual percentage rates of change*

| | 1925-50 | 1950-65 | 1965-68 | 1925-65 | 1925-68 |
|---|---|---|---|---|---|
| Solid fuels . . . . . . | 1.0% | 2.5% | 0.4% | 1.3% | 1.5% |
| Liquid fuels . . . . . | 5.3 | 7.6 | 7.8 | 6.2 | 6.3 |
| Natural gas . . . . . . | 6.9 | 9.0 | 8.3 | 7.6 | 7.7 |
| Hydroelectricity . . . | 6.0 | 6.6 | 5.4 | 6.3 | 6.2 |
| Total . . . . . . . | 2.3 | 5.1 | 4.8 | 3.3 | 3.4 |

*Note*: As explained in the Introduction (see page 3), the nuclear contribution to total energy is excluded from the statistics except in the case of projections (tables 18-20). The nuclear portion amounted to 6 million coal equivalent tons in 1968, so that its inclusion above would increase world energy consumption to 6,312 million metric tons—that is, by less than 0.1 percent.

*Source*: For 1925-65 data, see Part Two, Profile No. 2; 1967 and 1968 figures as described in table 1.

## TABLE 5.

### PROJECTED SHARES OF THE DIFFERENT ENERGY SOURCES IN REGIONAL ENERGY CONSUMPTION, 1965-1980

| | Solid fuels | | Liquid fuels | | Natural gas | | Hydro-electricity | | Nuclear | |
|---|---|---|---|---|---|---|---|---|---|---|
| Region | 1965 | 1980 | 1965 | 1980 | 1965 | 1980 | 1965 | 1980 | 1965 | 1980 |
| | | | | *Percent of each region's total energy consumption* | | | | | | |
| United States . . . . . . . . . . . . | 23.7% | 20.9% | 40.4% | 38.9% | 34.5% | 34.7% | 1.4% | 1.4% | - | 4.1% |
| Canada . . . . . . . . . . . . . . . . | 15.5 | 10.2 | 47.5 | 43.9 | 27.2 | 35.7 | 9.8 | 8.2 | - | 2.0 |
| Western Europe . . . . . . . . . . . | 49.3 | 18.1 | 44.3 | 61.2 | 2.7 | 13.5 | 3.5 | 3.0 | 0.2% | 4.2 |
| Japan . . . . . . . . . . . . . . . . . | 36.9 | 12.7 | 56.5 | 80.5 | 1.5 | 2.0 | 5.1 | 2.5 | - | 2.4 |
| Middle East . . . . . . . . . . . . . | 12.8[a] | 8.0[a] | 74.8 | 75.9 | 11.6 | 14.4 | 0.8 | 1.7 | - | - |
| Other Asia . . . . . . . . . . . . . . | 58.1 | 55.5 | 34.8 | 34.7 | 4.8 | 6.3 | 2.3 | 3.0 | - | 0.5 |
| Oceania . . . . . . . . . . . . . . . . | 55.0 | 38.0 | 41.5 | 44.3 | - | 13.2 | 3.5 | 3.9 | - | 0.6 |
| Caribbean . . . . . . . . . . . . . . | 4.4 | 2.8 | 69.2 | 65.1 | 24.5 | 29.8 | 1.9 | 2.3 | - | - |
| Other Latin America . . . . . . . . | 7.5 | 6.3 | 74.3 | 68.2 | 12.7 | 17.7 | 5.5 | 7.5 | - | 0.3 |
| North Africa . . . . . . . . . . . . . | 5.7 | 2.0 | 83.2 | 68.6 | 8.5 | 25.0 | 2.6 | 4.4 | - | - |
| Other Africa . . . . . . . . . . . . . | 72.2 | 58.0 | 25.9 | 33.1 | 0.2 | 6.0 | 1.7 | 2.9 | - | - |
| U.S.S.R. . . . . . . . . . . . . . . . | 49.8 | 33.3 | 28.7 | 30.1 | 20.3 | 34.6 | 1.2 | 1.7 | n.a. | 0.2 |
| Communist Eastern Europe . . . . | 82.8 | 61.9 | 9.9 | 25.0 | 6.9 | 12.0 | 0.4 | 0.4 | - | 0.7 |
| Communist Asia . . . . . . . . . . . | 94.9 | 90.5 | 4.4 | 9.0 | - | - | 0.7 | 0.5 | - | 0.1 |
| WORLD . . . . . . . . . . . . . . . . | 43.2 | 32.3 | 36.7 | 41.3 | 17.8 | 22.2 | 2.2 | 2.1 | 0.1 | 2.1 |
| WORLD (million metric tons): | | | | | | | | | | |
| Coal equivalent . . . . . . . | 2,261 | 3,615 | 1,921 | 4,622 | 933 | 2,485 | 113 | 237 | 3 | 236 |
| Oil equivalent . . . . . . . . | 1,508 | 2,410 | 1,281 | 3,082 | 622 | 1,657 | 75 | 158 | 2 | 157 |

[a]The solid fuels entry for the Middle East arises largely from coal output and use in Turkey and Iran.

TABLE 6. Comparison of mid-1974 reserve estimates for oil and natural-gas liquids; reprinted with permission from the Mobil Oil Company and the U.S. Geological Survey.

| | Recoverable but as yet undiscovered oil and natural-gas liquids, $10^9$ bbl | | Recoverable but as yet undiscovered natural-gas reserves in the U.S., $10^{12}$ SCF | |
|---|---|---|---|---|
| Location | USGS estimates | Mobil Oil Co. estimates | USGS estimates | Mobil Oil Co. estimates |
| On-Shore | | | | |
| Alaska | 25 to 50 | 21 | 105 to 210 | 104 |
| Lower 48 States | 110 to 220 | 13 | 500 to 1,000 | 65 |
| Subtotal | 135 to 270 | 34 | 605 to 1,210 | 169 |
| Off-Shore | | | | |
| Atlantic | 10 to 20 | 6 | 55 to 110 | 31 |
| Alaska | 30 to 60 | 20 | 170 to 340 | 105 |
| Gulf of Mexico | 20 to 40 | 14 | 160 to 320 | 69 |
| Pacific Coast | 5 to 10 | 14 | 10 to 20 | 69 |
| Subtotal | 64 to 130 | 54 | 395 to 790 | 274 |
| Total U.S. recoverable but as yet undiscovered reserve estimates | 200 to 400 | 88 | 1,000 to 2,000 | 443 |

## TABLE 7

Economic activity, employment, and energy use by industry sector in the United States in 1972 in ascending order of VA/E

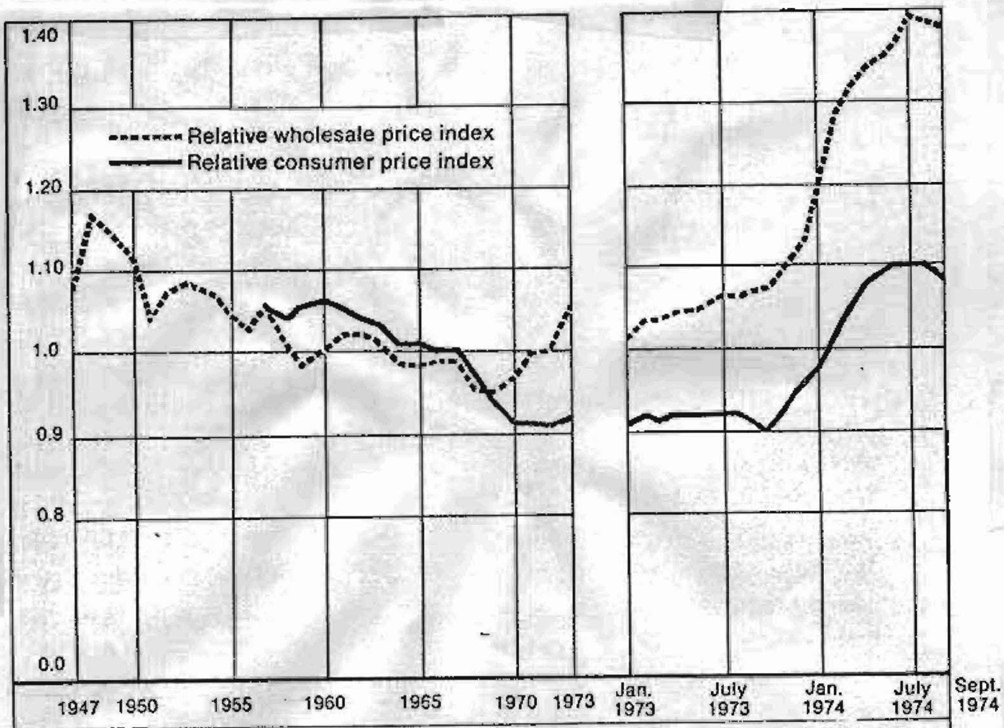
| Description of sector | Value added ($/yr)* | Primary energy use ($10^{12}$ Btu/yr) | Employment ($10^3$ persons) | VA/L ($/yr/employee) | VA/E ($/million Btu) | E/L (million Btu/yr/employee) |
|---|---|---|---|---|---|---|
| 1. Water transportation | 1,900 | 777 | 215 | 8,840 | 2.45 | 3,614 |
| 2. Chemical products | 7,442 | 2850 | 434 | 17,150 | 2.61 | 6,567 |
| 3. Chemical and fertilizer mining | 434 | 164 | 16 | 27,130 | 2.65 | 10,250 |
| 4. Primary iron and steel manufacturing | 9,795 | 3602 | 819 | 11,960 | 2.72 | 4,398 |
| 5. Nonferrous metal ores mining | 445 | 147 | 50 | 8900 | 3.03 | 2,940 |
| 6. Pipeline transportation | 601 | 194 | 17 | 35,350 | 3.10 | 11,412 |
| 7. Paper products | 5,645 | 1668 | 439 | 12,860 | 3.38 | 3,800 |
| 8. Petroleum refining | 6,059 | 1766 | 155 | 39,090 | 3.43 | 11,394 |
| 9. Air transportation | 5,572 | 1562 | 329 | 16,940 | 3.57 | 4,748 |
| 10. Crude oil and petroleum extraction | 8,299 | 2288 | 133 | 62,400 | 3.63 | 17,203 |
| 11. Primary nonferrous metal manufacturing | 4,554 | 1215 | 332 | 13,720 | 3.75 | 3,660 |
| 12. Stone and clay products | 4,785 | 1230 | 473 | 10,120 | 3.89 | 2,600 |
| 13. Iron, ferroalloy ores mining | 365 | 90 | 14 | 26,070 | 4.06 | 6,429 |
| 14. Paving mixtures and blocks | 219 | 53 | 10 | 21,900 | 4.13 | 5,300 |
| 15. Plastics and synthetic materials | 2,558 | 576 | 208 | 12,300 | 4.44 | 2,769 |
| 16. Asphalt felts and coatings | 213 | 38 | 19 | 11,210 | 5.61 | 2,000 |
| 17. Glass products | 2,007 | 354 | 187 | 10,730 | 5.67 | 1,893 |
| 18. Water and sanitary services | 926 | 155 | 94 | 9,850 | 5.97 | 1,649 |
| 19. Stone and clay mining | 965 | 158 | 93 | 10,380 | 6.11 | 1,699 |
| 20. Gas utilities | 5,959 | 848 | 219 | 27,210 | 7.03 | 3,872 |
| 21. Forestry and fishery products | 757 | 91 | 79 | 9,580 | 8.32 | 1,152 |
| 22. Electric utilities | 13,844 | 1660 | 474 | 29,210 | 8.34 | 3,502 |
| 23. State and local government enterprises | 5,218 | 507 | 449 | 11,620 | 10.29 | 1,129 |
| 24. Local, suburban passenger transit | 2,309 | 210 | 274 | 8,430 | 11.00 | 766 |
| 25. Automobile repairs and service | 4,161 | 368 | 557 | 7,470 | 11.31 | 661 |
| 26. Textile goods and floor coverings | 1,038 | 91 | 123 | 8,440 | 11.41 | 740 |
| 27. Railroad services | 8,462 | 676 | 571 | 14,820 | 12.52 | 1,184 |
| 28. Industrial leather products | 236 | 18 | 26 | 9,080 | 13.11 | 692 |
| 29. Motor freight transportation | 11,693 | 854 | 1,201 | 9,740 | 13.69 | 711 |
| 30. Livestock products | 8,735 | 623 | 1,142 | 7,650 | 14.02 | 546 |
| 31. Fiber, yarn, and thread mills | 4,037 | 288 | 580 | 6,960 | 14.02 | 497 |
| 32. Food products | 19,777 | 1319 | 1,737 | 11,390 | 15.00 | 759 |
| 33. Lumber, wood products | 5,308 | 332 | 593 | 8,950 | 15.99 | 560 |
| 34. Rubber and plastic products | 6,512 | 391 | 620 | 10,500 | 16.65 | 631 |
| 35. Medical and educational services and nonprofit organizations | 35,278 | 2033 | 6,785 | 5,200 | 17.35 | 300 |
| 36. New construction | 27,089 | 1518 | 3,153 | 8,590 | 17.85 | 481 |
| 37. Paperboard containers | 2,022 | 102 | 225 | 8,990 | 19.82 | 453 |
| 38. Hotels and personal services (e.g., laundry, beauty and barber shops, funeral services) | 12,872 | 634 | 2,526 | 5,100 | 20.30 | 251 |
| 39. Service industry machines (e.g., vending, laundry, car wash) | 1,484 | 71 | 155 | 9,570 | 20.90 | 458 |
| 40. Agricultural products (e.g., wheat, rice) | 14,958 | 687 | 1,892 | 7,910 | 21.77 | 363 |
| 41. Metal containers | 1,002 | 46 | 77 | 13,010 | 21.78 | 597 |
| 42. Miscellaneous manufacturing (e.g., jewelry, toys, pens, musical instruments, signs) | 3,227 | 142 | 417 | 7,740 | 22.73 | 341 |
| 43. Fabricated metal products (general hardware) | 3,616 | 124 | 329 | 10,990 | 29.16 | 377 |
| 44. Household appliances | 1,595 | 68 | 199 | 8,020 | 23.46 | 342 |
| 45. Drugs, cleaning, toilet preparations | 4,221 | 174 | 263 | 16,050 | 24.26 | 662 |

*In 1958 dollars.

TABLE 7 *(continued)*
Economic activity, employment, and energy use by industry sector in the United States in 1972 in ascending order of VA/E

| Description of sector | Value added ($/yr)* | Primary energy use ($10^{12}$ Btu/yr) | Employment ($10^3$ persons) | VA/L ($/yr/employee) | VA/E ($/million Btu) | E/L (million Btu/yr/employee) |
|---|---|---|---|---|---|---|
| 46. Paint products | 825 | 32 | 68 | 12,130 | 25.78 | 471 |
| 47. Heating equipment, plumbing fixtures, structural metal products | 3,932 | 152 | 519 | 7,580 | 25.87 | 293 |
| 48. Farm machinery | 1,480 | 57 | 125 | 11,840 | 25.96 | 456 |
| 49. Wholesale and retail trade | 133,299 | 4759 | 17,511 | 7,610 | 28.01 | 272 |
| 50. Engine and turbine manufacturing | 1,207 | 43 | 109 | 11,070 | 28.07 | 395 |
| 51. Miscellaneous electrical machinery, equipment and supplies | 1,071 | 38 | 131 | 8,180 | 28.18 | 290 |
| 52. Screw machine products, stampings | 3,616 | 124 | 329 | 10,990 | 29.16 | 377 |
| 53. Construction, mining, oil field machinery | 2,200 | 75 | 200 | 11,000 | 29.33 | 375 |
| 54. Electrical transmission and distribution equipment | 3,704 | 125 | 387 | 9,570 | 29.63 | 323 |
| 55. Electronic components | 2,972 | 97 | 323 | 9,200 | 30.64 | 300 |
| 56. Household furniture | 2,107 | 67 | 373 | 5,650 | 31.45 | 180 |
| 57. Motor vehicles | 12,479 | 393 | 864 | 14,440 | 31.75 | 455 |
| 58. Electric lighting and wiring equipment | 1,573 | 49 | 222 | 7,090 | 32.10 | 221 |
| 59. Radio and TV broadcasting | 1,629 | 49 | 132 | 12,340 | 33.24 | 371 |
| 60. Federal government enterprises | 5,633 | 167 | 691 | 8,150 | 33.73 | 242 |
| 61. General industry machinery (e.g., furnaces, pumps, bearings) | 3,033 | 89 | 252 | 12,040 | 34.08 | 353 |
| 62. Other transportation equipment (e.g., ships, space vehicles) | 2,677 | 76 | 495 | 5,410 | 35.22 | 154 |
| 63. Other furniture and fixtures | 1,185 | 32 | 126 | 9,410 | 37.03 | 254 |
| 64. Miscellaneous fabricated textile products | 1,053 | 28 | 178 | 5,920 | 37.61 | 157 |
| 65. Materials handling machinery and equipment | 879 | 23 | 82 | 10,720 | 38.22 | 280 |
| 66. Maintence and repair construction | 11,586 | 292 | 1,357 | 8,540 | 39.68 | 215 |
| 67. Machine shop products | 1,905 | 46 | 229 | 8,320 | 41.41 | 201 |
| 68. Special industry machinery (e.g., textiles, paper, printing) | 2,089 | 49 | 160 | 13,060 | 42.63 | 306 |
| 69. Coal mining | 1,967 | 45 | 148 | 13,300 | 43.71 | 304 |
| 70. Metalworking machinery | 3,815 | 86 | 278 | 13,720 | 44.36 | 309 |
| 71. Professional sciences, controlling instruments and supplies (e.g., medical, time, engineering) | 2,594 | 57 | 281 | 9,230 | 45.51 | 203 |
| 72. Amusements (e.g., motion pictures, billiards, commercial sports) | 5,272 | 112 | 702 | 7,510 | 47.07 | 160 |
| 73. Office machines | 2,412 | 48 | 237 | 10,180 | 50.25 | 203 |
| 74. Optical equipment | 2,646 | 50 | 156 | 16,960 | 52.92 | 321 |
| 75. Printing and publishing | 10,096 | 175 | 1,156 | 8,730 | 57.69 | 151 |
| 76. Finance and insurance | 30,186 | 523 | 3,146 | 9,600 | 52.72 | 166 |
| 77. Communications (e.g., telephone, telegraph, teletype) | 17,930 | 308 | 984 | 18,220 | 58.21 | 313 |
| 78. Ordnance | 4,462 | 76 | 230 | 19,400 | 58.71 | 330 |
| 79. Business services (e.g., advertising, data processing) | 30,274 | 497 | 3,089 | 9,800 | 60.91 | 161 |
| 80. Aircraft manufacturing | 8,726 | 137 | 501 | 17,420 | 63.69 | 273 |
| 81. Radio, TV, communications equipment | 6,378 | 99 | 546 | 11,680 | 64.42 | 181 |
| 82. Wooden containers | 241 | 3 | 24 | 10,040 | 80.33 | 125 |
| 83. Apparel manufacturing | 6,995 | 80 | 1,459 | 4,790 | 87.44 | 55 |
| 84. Tobacco products | 2,932 | 27 | 71 | 41,300 | 108.59 | 380 |
| 85. Footwear and leather products | 1,336 | 10 | 278 | 4,810 | 133.60 | 36 |
| 86. Agricultural, forestry, fishery services | 1,397 | 9 | 366 | 3,820 | 155.22 | 25 |
| 87. Real estate services | 82,126 | 448 | 980 | 83,800 | 183.32 | 457 |

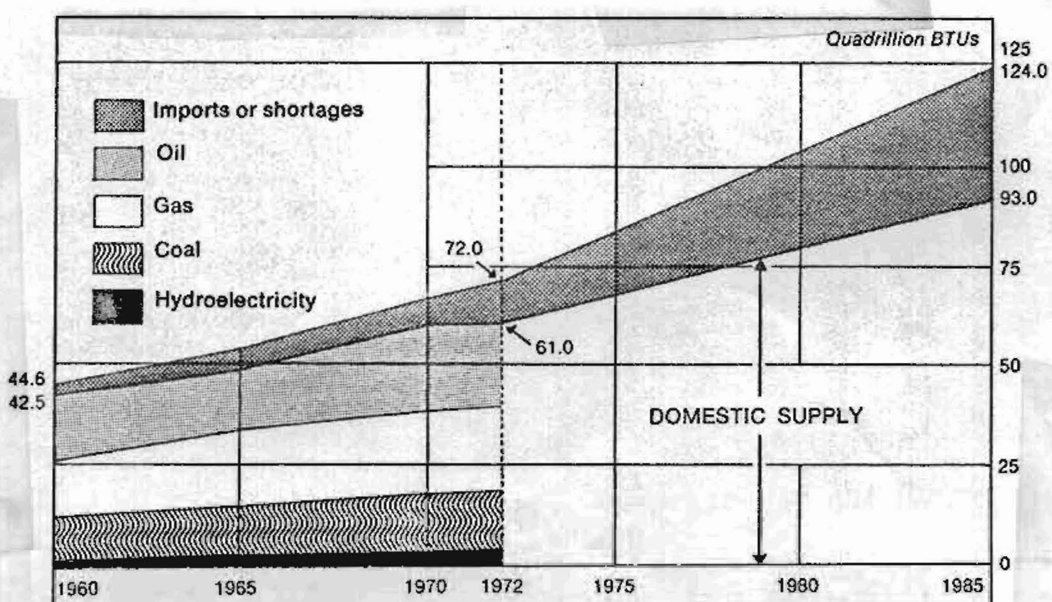
*In 1958 dollars.




*Sources:* Ratio of wholesale price index for fuel and utilities to wholesale price index for all industrials: Bureau of Labor Statistics; Data Resources Incorporated.

Ratio of composite consumer price index for selected energy items to overall consumer price index: Bureau of Labor Statistics (unpublished series); Data Resources Incorporated.

FIGURE 33. RELATIVE ENERGY PRICES (1967 = 1.0)



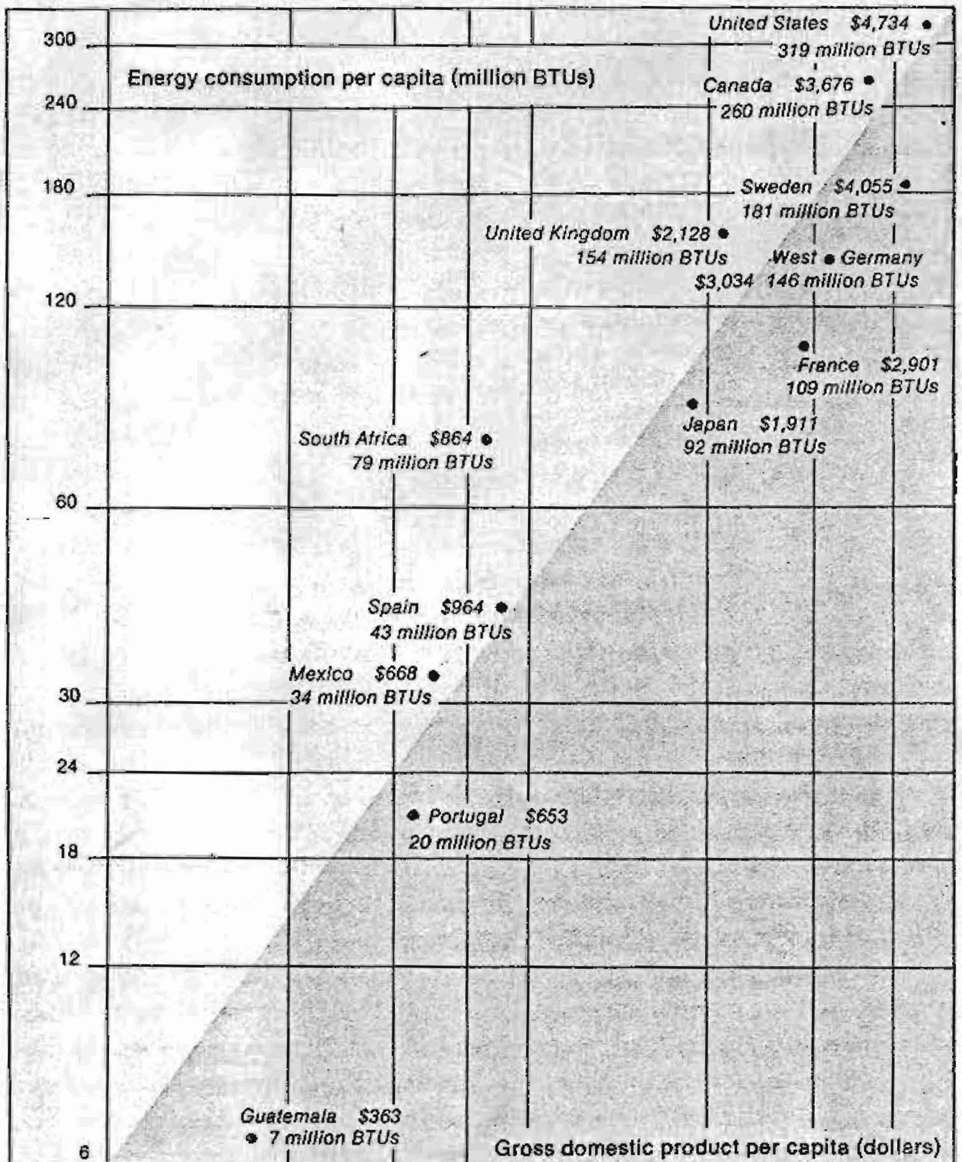

*Source:* U.S. Congress. Joint Committee on Atomic Energy. *Understanding the "National Energy Dilemma"* (Washington, D.C.: U.S. Government Printing Office, 1973), foldout "L."

FIGURE 34.

U.S. ENERGY GAP PROJECTED TO 1985, BASED ON SUPPLY AND DEMAND TRENDS PRIOR TO OIL BOYCOTT

FIGURE 35.

ENERGY USE AT DIFFERENT LEVELS OF GROSS DOMESTIC PRODUCT, PER CAPITA, SELECTED COUNTRIES, 1970




*Source:* U.S. Bureau of the Census, *Statistical Abstract of the United States, 1972* (Washington, D.C.: U.S. Government Printing Office, 1972), tables 1329, 1333.

FIGURE 36.

## POSSIBLE PATTERN OF U.S. ENERGY SUPPLY AND DEMAND IN 1985 TO HOLD IMPORTS TO 10 PERCENT OF TOTAL USE (quadrillion BTUs)

| | *1972* | *1985* |
|---|---|---|
| **DEMAND** | | |
| Residential and commercial[a] | 13.5 | 15.5 |
| Industrial[a] | 17.5 | 23.5 |
| Transportation[a] | 18.0 | 25.0 |
| Electric utilities | 18.5 | 31.0 |
| Nonenergy uses (e.g., plastics) | 4.5 | 8.0 |
| Synthetic fuel production | — | 2.0 |
| TOTAL | 72.0 | 105.0 |
| **DOMESTIC PRODUCTION** | | |
| Oil | | |
| Conventional[b] | 23.0 | 28.5 |
| Synthetic | — | 2.0 |
| Gas | | |
| Conventional | 22.5 | 26.5 |
| Synthetic | — | 1.5 |
| Coal[c] | 12.0 | 21.5 |
| Nuclear | 0.5 | 10.0 |
| Hydroelectric, geothermal, solar | 3.0 | 5.0 |
| TOTAL | 61.0 | 95.0 |
| **IMPORTS** | | |
| Oil | 10.0 | 8.5 |
| Gas | 1.0 | 1.5 |
| TOTAL | 11.0 | 10.0 |
| **TOTAL SUPPLY, DOMESTIC PRODUCTION AND IMPORTS** | 72.0 | 105.0 |

*Note:* One quadrillion British thermal units (BTUs) equals the amount of energy produced by 172 million barrels of oil, 1 trillion cubic feet of natural gas, or 41.6 million tons of coal.

[a]Excludes electricity.

[b]Includes natural gas liquids.

[c]Direct use plus energy for synthetic fuel production.

*Sources:* Data for 1972: Data Resources Incorporated Energy Databank; U.S. Department of the Interior, Bureau of Mines, March 13, 1974, news release.

Data for 1985: A. H. Packer, S. Park, and W. Flaherty, "The Cost of Self-sufficiency," CED staff paper (available upon request).

available, and the economic activity and energy use sector.

## THE TECHNOLOGICAL GAP

There is a recognized technological gap between the developed nations and the developing nations; additionally, there is a lag between developed countries in certain areas of technology. Technologically, the United States falls behind other countries in certain industries:

West Germany leads in chemical industry.

Great Britian leads in Vertical Take-Off and Landing Systems (VTOLS)-Airplanes

France leads in construction technology.

Sweden excels in long-line electrical engineering.

Japan excels in manufacture, motorcycles, cameras, and ship building. The United States creates most of the leading technology in the computer field, in military electronics, in space technology, and in nuclear technology. Additionally, the United States commits more of its resources to research than western Europe. There is no gap in theoretical technology, but there is a gap between applied and commercial distribution. The American industry excels in fast application- it has the ability to move a scientific discovery from the laboratory through the development states and onto the market jlace in a short period of time.

TECHNOLOGY, MILITARY PROBLEMS, AND MARINE AFFAIRS

As each milestone in ocean techniques are uncovered, new ones must develop; let us take SOSUS (Sound Surveillance Systems) for instance- at the inception of this program in 1957, noise levels were analyzed by hand- this was gradually superseded by computer analysis (the computer had been built) to sort out submarine noise from the background noise of 3000 ships on the Atlantic Ocean at any given moment. In the 1960's, new sounds appeared at any given moment; these came from oil exploration vessels operating on the outer continental shelf with subbottom profiling apparatus, air guns, propane-oxygen flexible wall explosive devices, pneumatic imploders, hydrophones on long cables anchored on the sea floor, magnetometers for dettcting archeological artifacts. The navy needed information as to place and time of surveys, as well as the tppe of sound sources, but this was proprietary technology- available only to the companies controlling the technology such as to allow for tee highest bidder of an offshore oil and gas lease.

The Navy found it necessary to expand its technological know how to new signal processing methods of identifying and pinpointing new sound sources- each technological step requires added technology to keep ahead; the impact on national and international affairs is inescapable.

MARINE TRANSPORTATION

As a result of the "technology of scale" (bigger and better), and the continued dependence of the United States on oil imports- the oceans and seas have become further impacted with the huge vessels of transport and the hugh oil-carrying tankers. Additionally, this has necessitated the building of superports- terminals designed to service the huge vessels which have been built since the end of World War II, and used primarily to carry petroleum products.

Since World War II, deadweight (dwt) of the largest tanker afloat has increased 10-fold every 20 years, and its draft has almost doubled in the process. Ten years ago, 100,000 dwt was the largtst vessels anywhere in the world- today there are more than 200 tankers over 200,000 dwt, and vessels of 500,000 dwt are being built with an anticipation of a million dwt for the future. These larger vessels require greater depths of water than the smaller vessels; 75 feet of water us required for 250,000 dwt, and 90 ft. for 326,000 dwt. In the 1970's, the U. S. Coastal ports had channel depths limiting tankers to size of 65,000 to 85,000 dwt- the deepest channel depth for harbors on the U. S. Atlantic and Gulf Coast was 45 feet; in Los Angeles and Long Beach on the Pacific Coast the depte was 51 feet. The alternate idea to deep water terminals has been a suggestion to construct off-shore deep water terminals. However, no matter what is provided, there is the necessity for some constructing and installation on the ocean to provide a terminal which is connected tr the shores by pipelines or by feeder ships.

The oceans have also been suggested as a potential site for offshore airports because of the congestion in air travel- greater energy uses means more leisure times- which means greater necessity for quick transport to vacation spots.

FISHERY TECHNOLOGY

The 200- mile fishing limit which has been imposed by many nations, including the United States, has impacted on the size and nature of vessels and instruments, and the methods of fishing. More sophisticated and faster methods of securing and marketing fishery resources is a continuing quest of the fishermen- from fish processing- to freezers- to meal and oil plants; from fish finding and navigation equipment- to echo sounders- to sonar; from propulsion vessels- to trawlers of 4,000 gross registered tons (grt)- to pump fishing; each of these has a major impact on the oceans and marine affairs.

Inasmuch as the Coast Guard is given the responsibility to monitor and regulate the vessels of the 200-mile limit, the Coast Guard like the Navy has had to exjand its technological know-how. The Coast Guard has established Vessel Tmaffic Services (VTS) requirements for some congested ports and marine traffic areas; it has constructed new LORAN-C stations for expanding services to the West Coast; it has cosntructed new endurance cutters, and purchased shortqrange recovery Helicopters. The flexibility and responsiveness of the Coast Guard's multi-mission facilities and personnel has left the service short-handed at the time of need to do more in the marine environment and toward controlling inflation.

COMMUNICATIONS

Any stepped-up requiremtnts in Weapons, Vessel Size and design increases the requirement for monitoring devices to assure use and safeey of technology's innovations. Thus, communication methods are becoming more sophisticated, and create their own impact on Marine Affairs- from the Giant Satellites that occupy air space to the mrnitoring hydrophones of ocean space- global affairs are impacted. Perhaps the culmination of our technological skills in communications will be reached when AT&T designs the ultimate in communications instruments- AT&T visualizes an ultimate communication system which will equip every one anywhere in the world with a two-way telephone worn as a watch to contact any other person in the world; when you can't reach the person, it is reasonable to conclude that the person is dead!

Constructing facilities that impact on ocean space require domestic legislation to determ.ne the impact on adjacent coastal states- it requires as well- international legislation- the 1958 Geneva Convention did not have superports et al in mind when it drafted the law of the Sea regulations. Technology's expansion has left a basic need- the need to enhance maritime waterways as transportation systems of equal stature with railways, highways, and airways.

## TECHNOLOGY'S IMPACT ON LAND

The relationship between energy and land use patterns is as important as the use of energy in individual (vehicles) structures. Unfortunately, it is often overlooked. Because of the patterns of urban development that have developed over past years, a built-in component of the demand for energy has been created. Because of the location of particular structures housing a number of urban activities, transportation and infrastructure networks have developed that assure a certain level of energy- preferences... imply particular levels of energy consumption. Because of presently rising energy prices and future energy shortages, there will be alterations to the design and location of buildings, etc. These will have to take account of changes in both the price and the availability of increasingly scarce energy supplies. No area of interest, no people anywhere in the world, nor any activity is free of the impact of the use of energy to fuel our technological innovations (Table 8).

TABLE 8.

## Energy Usage Required to Construct a Typical Single-Family House*

| Item | BTUs Per Board Feet, Square Feet, Cubic Yards and Pounds | Board Feet Square Feet, Cubic Yards and Pounds Per House | Total BTUs Per House | Total Gallons Needed Per House (#2 Fuel Oil) | Total Cost @ 70c/Gallon (#2 Fuel Oil) | Total Gallons Needed Per House (Petroleum) | Total Cost @ 85c/Gallon (Petroleum) |
|---|---|---|---|---|---|---|---|
| Lumber | 14,400/BF | 9,775/BF | 140,760,000 | 1,019 | $ 713.30 | 1,108 | $ $941.80 |
| ⅝" Particle Board | 415/SF | 14,800/SF | 6,142,000 | 45 | 31.50 | 48 | 40.80 |
| 4" Brick Veneer | 65,000/SF | 360/SF | 23,400,000 | 170 | 119.00 | 184 | 156.61 |
| ⅝" Plywood | 9,600/SF | 4,288/SF | 41,164,800 | 298 | 208.60 | 324 | 275.50 |
| ½" Gypsum Board | 8,800/SF | 6,280/SF | 55,264,000 | 400 | 280.00 | 435 | 369.75 |
| Concrete Foundation | 2,600,000/CY | 19/SF | 49,400,000 | 358 | 250.60 | 389 | 330.63 |
| Concrete Block Walls | 38,000/CY | 415/SF | 15,770,000 | 114 | 79.80 | 124 | 105.40 |
| Concrete Flat Work | 2,600,000/CY | 24/CY | 62,400,000 | 452 | 316.40 | 491 | 417.35 |
| Flat Glass | | | 5,241,600 | 38 | 26.60 | 41 | 34.85 |
| Single Glaze | 15,600/SF | 94/SF | | | | | |
| Double Glaze | 15,600/SF | 121/SF | | | | | |
| Aluminum Siding | 153,000/LBs | 60/LBs | 9,180,000 | 67 | 46.90 | 72 | 61.20 |
| Hardboard Siding | 6,320/SF | 202/SF | 1,276,640 | 9 | 6.30 | 10 | 8.50 |
| Insulation Board(1) | 7,000/SF | 432/SF | 3,024,000 | 22 | 15.40 | 24 | 28.23 |
| Gypsum Board(1) | 8,800/SF | 115/SF | 1,012,000 | 7 | 4.90 | 8 | 6.80 |
| Fiberglas(2) | 10,700/LBs | 450/LBs | 4,815,000 | 35 | 24.50 | 38 | 32.30 |
| Foam(2) | 7,900/SF | 202/SF | 1,595,800 | 12 | 8.40 | 13 | 15.29 |
| **Subtotal** | **N/A** | **N/A** | **420,445,840** | **3,046** | **$2,132.20** | **3,309** | **$2,825.01** |
| Other (estimate)** | N/A | N/A | N/A | 900 | $ 630.00 | 978 | 831.30 |
| Construction*** | N/A | N/A | N/A | 2,000 | $1,400.00 | 2,174 | $1,847.90 |
| **Grand Total** | **N/A** | **N/A** | **N/A** | **5,946** | **$4,162.20** | **6,461** | **$5,504.21** |

(1) Sheathing
(2) Insulation
* The typical single family house has 1,640 square feet; the estimates of BTUs used to produce the said amount of building materials does not include the transportation of raw materials to the factory site or the transportation of the finished product to the construction site.
** Because the list of items is incomplete, an estimate of 900 gallons of #2 fuel oil and 978 gallons of petroleum was used for the following items: paint, steel beam(s), plumbing fixtures, electric wiring, appliances, heating, excavation, roofing, tiule and millwork, and hardware.
*** Includes erecting the house plus land development, site improvements, streets, utilities, landscaping, etc.

Source: NAHB Economics Division

SUMMARY

If the 20th Century can properly be called tee "Era of Science", then it must also be called tee era when Science's "cauldron"- Technology- gained preeminence- for science and technology go hand-in-hand. Technology applies the principles of science- utilizes nature's materials to develop products for man's continued affluence and existence in this materialistic world. Science may be described as the method by which man determines the exttnt of his universe, probing and unlocking unknown areas, and defining the kinds of energy sources and processes (heat and force) that provide motion to the Universe. It is technology, however, that utilizes this energy and the processes involved-- without the continuing innovations and developments related to technology, it is reasonable to assume teat there would be no energy crisis, nor would man be expending continuing time and effort to provide further energy resources to stem the tide of inflation. This tide of inflation has developed as a result of the technology needed to develop new energy forms- of technology needed to minimize the effect of technology's use of energy- of technology needed tr maximize the use of new technological concepts- of technology needed tr ease the crunch of energy used to support technology.

The world faces an energy crisis at a time when the high cost of technological development makes questionable the idea of developing as new energy sources nature's own free and renewable energy:

Tidal Power
Solar Power
Wind Power
Water (Thermal) Power

The cost of harnessing the Tides has increased many-fold since the idea was proposed by Dexter P. Cooper more than 40 years ago. Nevertheless, Tidal

Power Plants have been developed on the La Rance River, St. Malo, France, and on Kislaya Guba, in the White Sea area of the U.S.S.R. The United States is presently determining the feasibility of developing a tidal power plant in the area of Cobscook Bay- Bay of Fundy, and supplemented by a hydroelectric plant at Dickey-Lincoln School Lakes on the Upper St. John's River.

Long range plans have been proposed by President Carter to develop Solar Power and other renewable sources of energy as the requirement to satisfy future needs.

Technology has developed sophisticated weaponry of war and instrumentation and vehicles necessary to walk on the moon, but no grand scheme is available for harnessing renewable sources of energy without expenditures of great capital outlays and requiring technology not presently developed in large scale measure.

Basically, technology appears to have chosen a path all its own- neither accounting for its wastefulness, nor accountable to those who seek to depend on its as the ultimate solution to all of society's ills. Stewart Udall et al states in ENERGY BALLOON -

> "Because we are a society that revel in the superlatives, the most representative relics of our t.me will not be found in the Smithsonian ..., it will be found in the ravaged landscapes - the polluted waterway, the vanglorious space of ocean vehicles and machines we've left behind.
>
> Future generations will undoubtedly marvel at our extravagance- taller buildings- longer and heavier autos- bigger and faster airplanes- super tankers- super submarines- super ocean bases- a 20th-Century America, bigger and better in everything. And to fuel this giddy go-go philosophy of super consumption, huge quantities of imported and domest.cally produced energy and raw materials were used in wanton disregard for those who follow after us."

The premise of this paper is that full scale funding should be provided immediately to the research and development of renewable energy sources to meet the requirements of future needs for energy. If this is not done, and if technology continues on its errant path of crunching massive energy resources to sustain its existence, society may eventually exact a price. The price may not be paid in full by the generation presently in existence, but it may result in the return of future generations to a wilderness shorn of its resources and plucked clean and polluted by the greed of a generation that lost its brakeshoes in a technological tap dance.

ENERGY EQUIVALENTS

British Thermal Unit (BTU) - Amount of heat required to raise one pound of water 1°F.

| | |
|---|---|
| Barrel of crude oil | = 5,800 BTU |
| Residual Oil | = 6,100,000 BTU |
| Ton of Coal | = $22 \times 10^6$ BTU |
| Cubic foot of gas | = 1,025 BTU |

Uranium liberated in 1 lb. - if all atoms disintegrate = $39 \times 10^9$ BTU.

Building a 1970 automobile = $1.23 \times 10^8$ BTU. To build a bicycle = 150 BTU.

Fuel consumption of a vehicle varies as the cube of its speed.

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