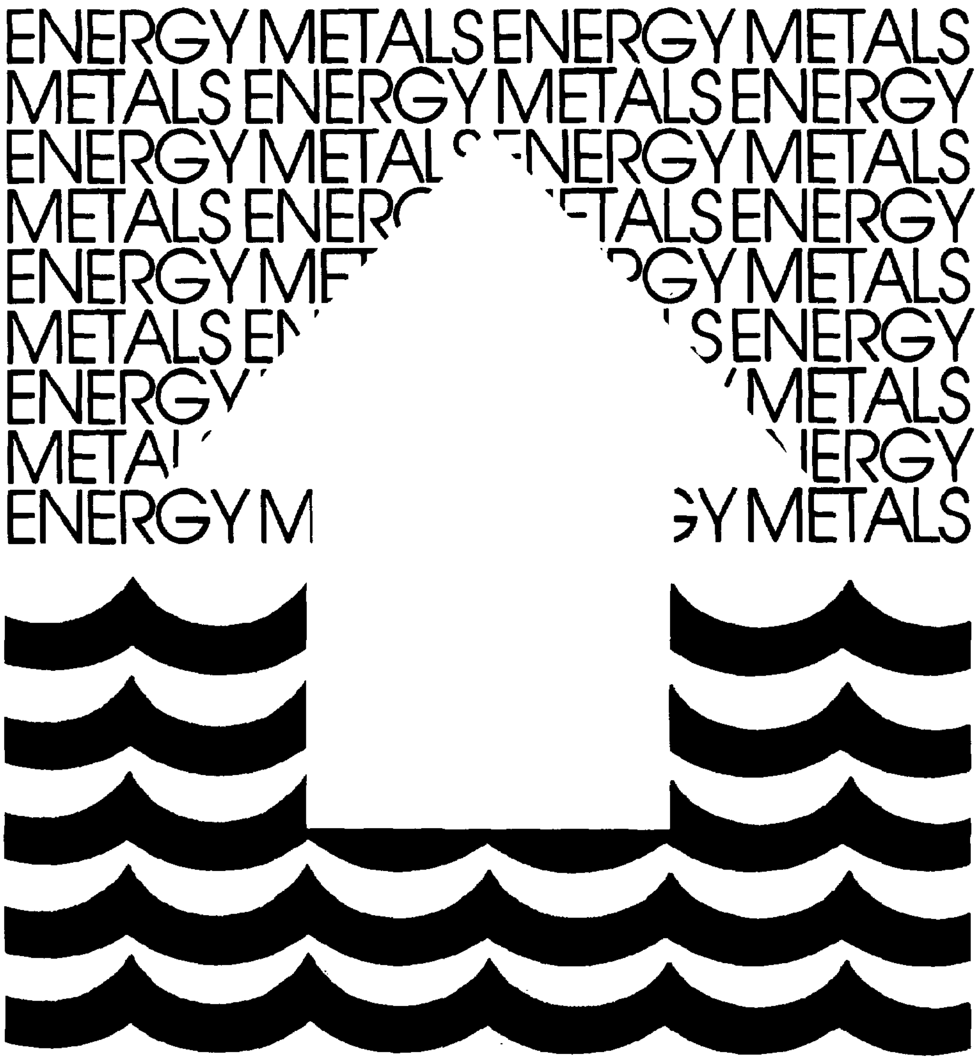

Ocean Thermal Energy Conversion

Report to Congress: Fiscal Year 1981

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Ocean Minerals and Energy
February 1982

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Washington, D.C. 20230

THE ADMINISTRATOR

FEB 1 0 1982

Honorable George H. Bush
President of the Senate
Washington, D.C. 20510

Dear Mr. President:

It is my honor to transmit the Ocean Thermal Energy Conversion Report of the National Oceanic and Atmospheric Administration (NOAA) to the Congress pursuant to Section 405 of the Ocean Thermal Energy Conversion Act of 1980 (P.L. 96-320).

This report describes NOAA's progress in implementing the Act, and our continued development of the OTEC program in a legally sound and environmentally sensitive manner. Also discussed are NOAA's involvement in development of OTEC technology, and our outlook for the future of OTEC.

Sincerely,

John V. Byrne

Enclosure

18110
UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Washington, D.C. 20230

THE ADMINISTRATOR

Honorable Thomas P. O'Neill, Jr.
Speaker of the House of Representatives
Washington, D.C. 20515

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Ocean Thermal Energy Conversion Report to Congress: Fiscal Year 1981

Public Law 96-320

Prepared by:
Office of Ocean Minerals and Energy
2001 Wisconsin Avenue, N.W.
Washington, D.C. 20235

February 1982

U. S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

Office of Minerals and Energy
James P. Lawless, Acting Director

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Chapter I

Background

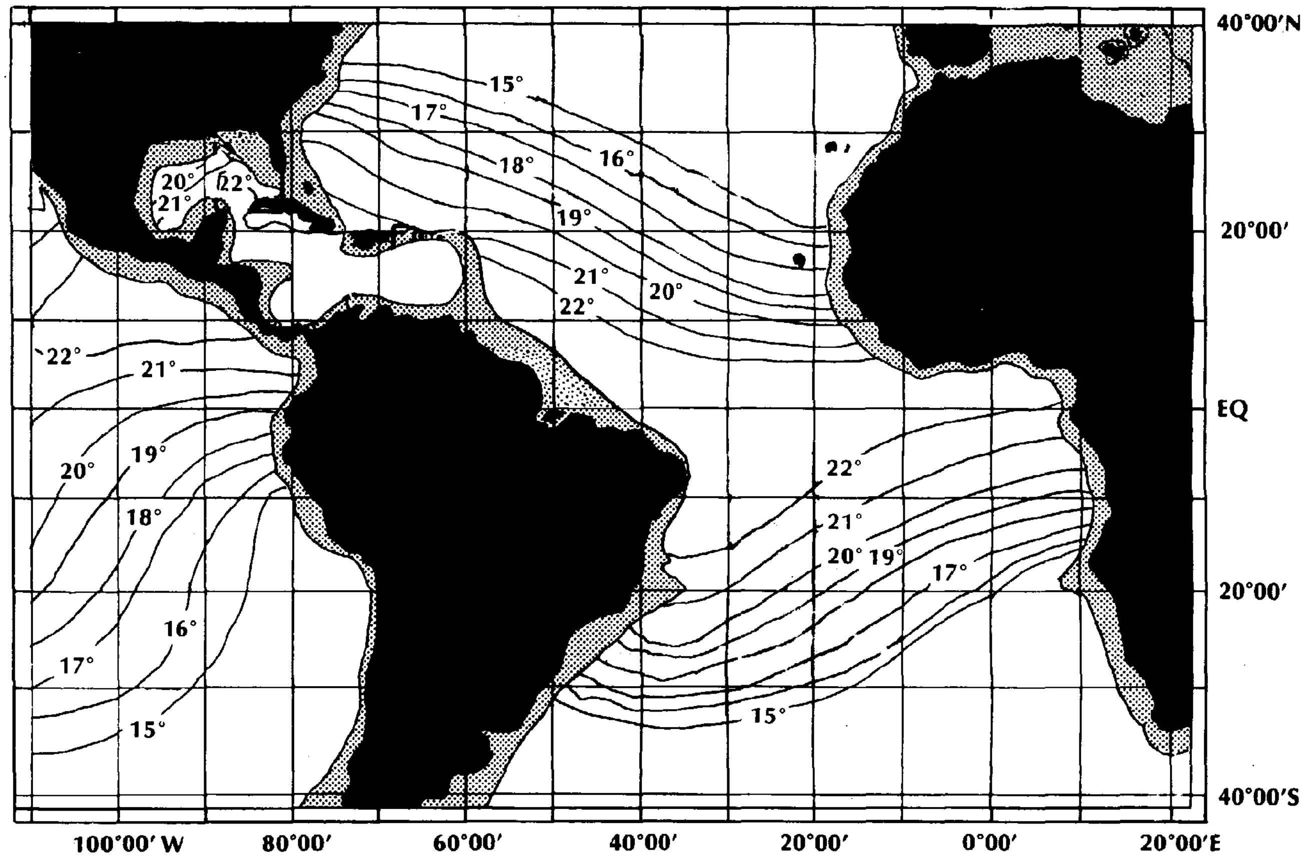
The Resource

In 1881, the French physicist Arsene d'Arsonval published a theoretical article describing a method by which electricity could be generated from the temperature differences between warm and cold water. D'Arsonval suggested that his process could use the temperature differences between water from hot springs and a cold river, or between the warm surface waters and cold deep waters of the ocean.

The efficiency of d'Arsonval's process, now called ocean thermal energy conversion (OTEC), increases greatly with even a small increase in the available temperature difference. Although the process can work at temperature differences of less than 20°C (36°F), that temperature difference is usually used as a minimum standard for the OTEC resource. Deep waters are almost uniformly cold throughout the world's oceans. Thus, the best ocean temperature differences for OTEC are found near the Equator where the surface waters receive the greatest amount of heat from the sun.

Temperature differences of at least 20°C at depths of 1000 meters or less are found in large areas of the ocean between latitudes 30° north and 25° south (Figures 1 and 2). Estimates of the total ocean thermal energy base range from 100 million to 10 billion megawatts. Current electric consumption in the U.S. is about 230 thousand megawatts.

An excellent OTEC resource exists in the Western Pacific Ocean, the Caribbean, the tropical west and southeastern coasts of the Americas, the Indian Ocean, and near both coasts of Africa. This resource lies within 200 miles of the coasts of more than 90 nations and territories.



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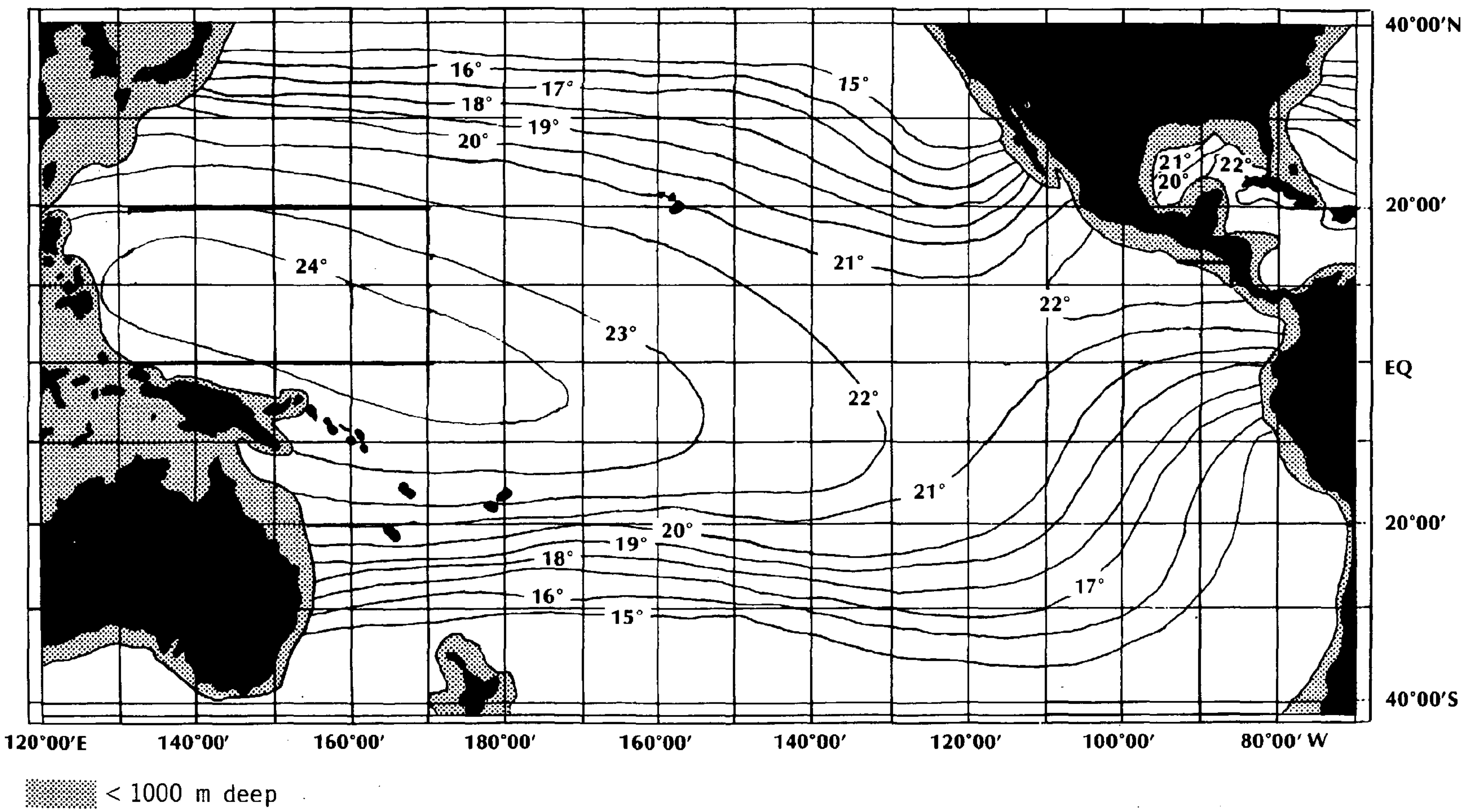
***Contours indicate temperature differential (°C) between surface and 1000 m depth**

Figure 1. The OTEC Thermal Resource Area (Atlantic)



*Contours indicate temperature differential (°C) between surface and 1000 m depth

Figure 2. The OTEC Thermal Resource Area (Pacific)

Potential OTEC areas for the United States include Guam, the Northern Marianas, other Western Pacific islands, Hawaii, Puerto Rico, the U.S. Virgin Islands, and the Gulf of Mexico. The total ocean thermal resource within 200 miles of the United States has been estimated as about equal to total present U.S. energy usage.

The National Interest

Development of a commercial OTEC industry by the U.S. private sector would provide the United States with: (a) increased energy self-sufficiency, (b) major new international trade opportunities, (c) reduced annual balance of payments deficits, (d) increased investment in manufacturing, construction, and energy-intensive industries, (e) increased regional employment, and (f) continued leadership in new ocean technologies.

The potential power generation market in which U.S.-built OTEC plants could compete has been estimated for approximately seventy of the ninety countries and territories with access to the OTEC resource. The added electric power generation needs of these countries, many of which are lesser developed countries now dependent on imported oil, is large enough to accommodate on the order of 100 10MW OTEC plants, 500 40MW plants, 1100 100MW plants, and 1100 400MW plants (a total of more than 570 thousand MW) between the years 1990 and 2010. Even if U.S. companies are able to supply only ten percent of this potential market, a conservative projection, U.S. exports of OTEC plants would increase U.S. export trade by about $171 billion in 1980 dollars. This would result in major benefits to U.S. employment, industrial activity, and balance of payments.

Meeting a goal of 10,000 megawatts of U.S. OTEC capacity in place by 1999 would free Hawaii, Puerto Rico, and other U.S. islands from dependence on imported oil for their baseload electricity generation, and would reduce U.S. needs for imported oil by approximately 360,000 barrels a day. The cumulative displacement of imported oil by 1999 would amount to a savings of $18 billion. The combination of savings from imported oil and payments for U.S. OTEC plants sold to other countries could result in an improvement in U.S. balance of payments by $5 billion to $7 billion a year during the 1990s.

Because OTEC plants use components and skills from a wide variety of industries, industrial investment and activity would be increased in diverse areas of the U.S. economy, including shipyards, heavy construction, and the manufacturing of concrete, aluminum, turbines, pumps, heat exchangers, and offshore services. It has been estimated that domestic use of OTEC (without counting the additional effects of international trade) by 1997 will increase annual employment by 144,000 workers, personal income by $3.9 billion, retail sales by $1.2 billion, and will generate tax revenues of an additional $600 million to the federal government and $180 million to states and localities.

Commercial OTEC operations will involve extensions and new applications of existing technology. If the OTEC industry emerges strongly in the United States, it will help extend the nation's ability to develop ocean resources in general and will help assure a continuing U.S. role as a leader in ocean engineering and a supplier of high technologies.

Nature of the Industry

A large number of U.S. corporations, varying in size, are involved in development of OTEC technology as potential owners, operators, builders, designers, or parts suppliers. Approximately eight consortia comprising these corporations were formed to bid on a Department of Energy procurement for cost-shared OTEC pilot plants. Another consortium of corporations based in Maryland is exploring the potential for constructing commercial OTEC plants in Maryland for deployment in the Caribbean. In addition, the U.S. Territory of Guam signed a contract in 1980 for construction of a land-based commercial OTEC plant, although work has not yet started. Companies in other countries, principally Japan, France, and Sweden, are also engaged in OTEC development with varying degrees of assistance from their governments.

Chapter II

OTEC Technology

How OTEC Works

Ocean thermal energy conversion is a process for using solar energy stored in the warm surface waters of the tropical and subtropical oceans to perform useful work, either generating electricity for domestic and industrial consumption or providing energy for industrial refining and manufacturing. Several different techniques have been considered as the basis for OTEC power generation. Most experts agree that two of these, closed cycle and open cycle, are the most economically sound and technically feasible in the foreseeable future.

The closed cycle technique (Figure 3) employs a working fluid (most likely ammonia or Freon™) enclosed in a system of piping. This fluid is pumped through a heat exhanger where it is heated by oceanic surface waters that have been warmed by the sun. This vaporizes the working fluid causing it to pass through and drive a gas turbine. The turbine is used to run an electric generator and produce electricity for distribution to industrial and residential users on land or for use directly on site for energy-intensive processing or manufacturing. After passing through the turbine, the working fluid, at this point still a gas, is condensed to a liquid by exposure in another heat exchanger to cold water drawn from the deep ocean. The working fluid is then revaporized by being pumped back through the warm water heat exchanger and the cycle is repeated. This means of power generation does not use any fuel. The system is based on the repeated vaporization and condensation of the working fluid made possible by taking advantage of the temperature difference between the

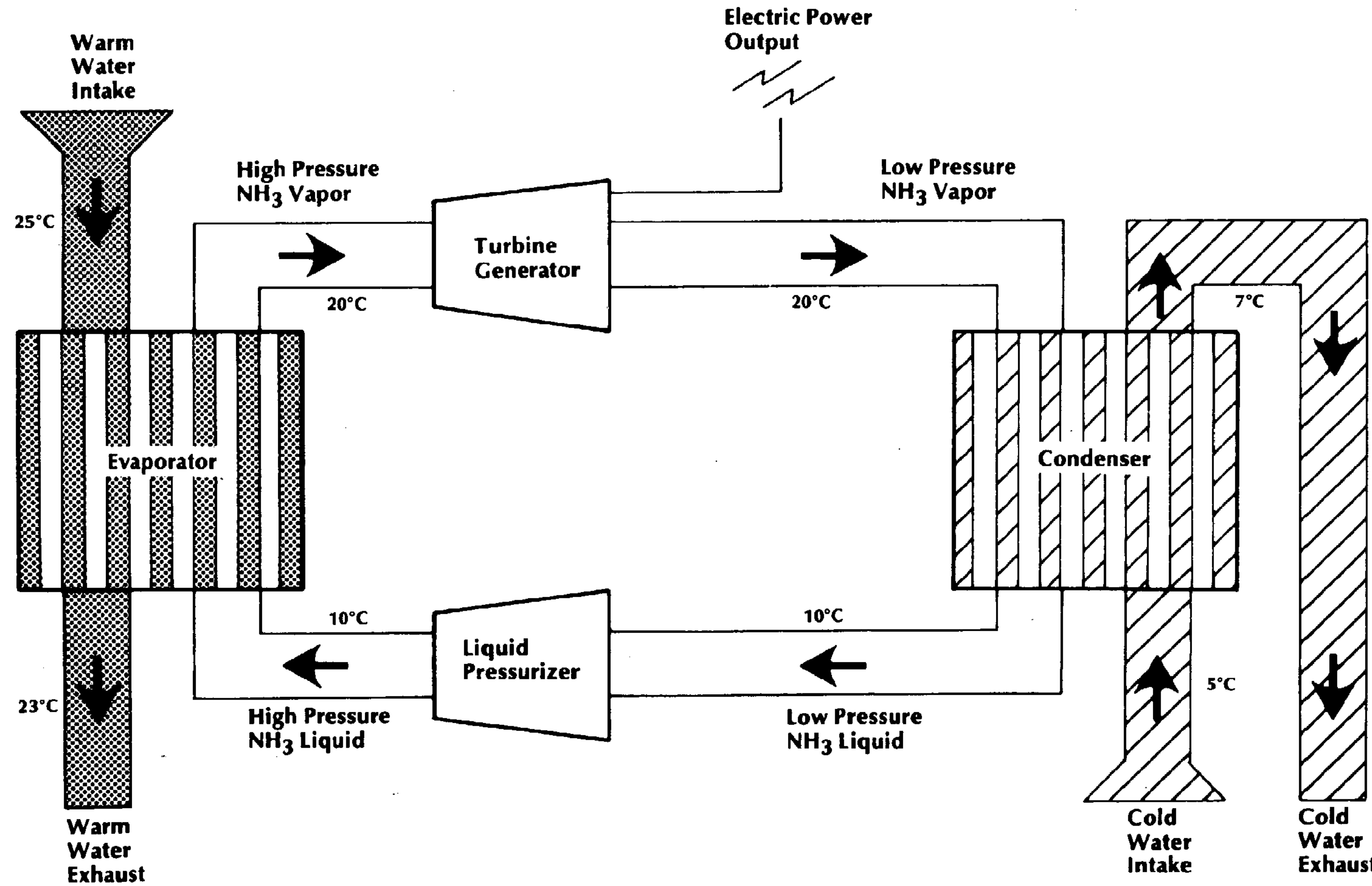


Figure 3. Schematic Diagram of a Closed-Cycle Power System

sun-heated surface waters and the perpetually cold deep waters of the tropical oceans. Even the pumps used to draw in the warm and cold water do not need conventional fuel. They are powered by a part of the energy produced by the process itself.

The open cycle system is, in most ways, quite similar to the closed cycle system. However, in the open cycle system seawater itself is the working fluid. Warm surface water is pumped into an evaporator in which the pressure is reduced to the point where the seawater boils. This produces steam that passes through and drives a low-pressure turbine to generate electricity, like the closed system. After leaving the turbine, the steam is cooled and condensed by exposure to cold, deep water in a heat exchanger. The open cycle technique has the advantage that the dissolved salts do not accompany the surface water when it forms steam. Thus, a valuable byproduct, fresh water, results when this steam condenses.

The earliest commercial applications of the OTEC principle are expected to use the closed cycle process. There is also, however, considerable interest in open cycle applications because of the additional benefit of its fresh water production.

Generation of electricity is expected to be the first commercial application of the OTEC process, with early commercial plants beginning operation by the mid-1980s. The facilities will probably be moored to or mounted directly on the ocean floor, or located partly on land with their intake and discharge pipes extending out into the ocean. The electricity from moored or bottom-mounted facilities will be brought to shore by submarine electrical transmission cables. Land-based OTEC facilities would be in areas where deep water is found very close to shore. Such sites exist in Hawaii, Guam, and other U.S. islands. OTEC facilities are expected to vary in size from about 10 megawatts (a size suitable for small islands) to about 400 megawatts (about the size of a conventional plant serving approximately 60,000 households).

Another possibility for implementation of the OTEC process is to use the electricity directly on the site for production of energy-intensive products such as hydrogen, ammonia or methanol, or for energy-intensive activities, such as aluminum smelting.

Such onsite manufacturing or processing could take place on facilities situated on or close to shore, or on roving plantships. For the facilities near shore, the product would be moved ashore by a product pipeline or by vessels. Self-contained plantships that would use OTEC techniques to obtain the energy needed to run onboard manufacturing or processing activities could float unmoored or move slowly under their own power as they sought out optimum thermal gradient conditions. Vessels would be used to transport OTEC plantship products to their destinations. Such plantships are expected to employ closed cycle systems.

Technology Development

The first experimental application of d'Arsonval's OTEC theory was by one of his students, Georges Claude, who in 1930 built a plant at Matanzas Bay, Cuba. The facility, destroyed by a storm shortly after its completion, actually consumed more electricity than it produced. Because other sources of energy were still viewed as unlimited and inexpensive, Claude's accomplishment was regarded at the time as more of a scientific curiosity than the early development of a major source of renewable energy.

Renewed interest in OTEC as an energy source came about in the 1970's as a result of fossil fuel shortages and the increasing uncertainty associated with foreign sources of supply. In 1972 the National Science Foundation began work on OTEC technology. As this work continued, it was transferred to the Energy Research and Development Administration (ERDA) and then to the Department of Energy. In the United States, particular interest in OTEC developed in Hawaii, Puerto Rico and Guam due to their almost total dependence on imported oil for electrical power.

While Department of Energy efforts to develop large-scale commercial technology continued, private industry and the State of Hawaii undertook a small-scale demonstration of the at-sea feasibility of the OTEC principle. This effort was initiated independently of the federal technology development program and was financed largely by Hawaii, Lockheed Missiles and Space Company, and the Dillingham Corporation. Their activities resulted in deployment and successful operation of Mini-OTEC, a 50-kilowatt gross output plant, off the Kona Coast of the island of Hawaii in 1979. Mini-OTEC produced a net power output of more than 10 kilowatts, exceeding design expectations. The Mini-OTEC project was the world's first actual demonstration that OTEC technology could produce net electrical energy.

Since late 1976 NOAA has been providing ocean engineering and technical management assistance to the Department of Energy's OTEC research and development program. This work has been conducted by NOAA's Office of Ocean Technology and Engineering Services (OTES). The program's major accomplishments during FY 1981 are described in the next section.

Ocean Engineering Research and Development Program

NOAA's OTES office has supported the Department of Energy in developing a number of concepts and components for OTEC plants including systems relating to platforms, cold water pipes, sea water, anchoring, mooring, and foundations. Most of the effort before 1981 emphasized floating OTEC systems. However, in the past year interest in shelf-mounted systems has accelerated. Some of the significant factors associated with shelf-mounted systems are:

- Installation and protection of bottom-mounted pipes;
- Greater loading forces due to the structure, cold water pipe, and power plant components;
- Slope stability and associated foundation design and installation; and
- Influence of near-shore circulation on discharge pipe design and installation.

The FY 1981 ocean engineering program managed by NOAA was redirected in mid-year to emphasize technology related to the pilot plant or "proof of concept experiment" conceptual designs while maintaining a well balanced approach toward satisfying the technical problems of floating systems and the newly introduced shelf-mounted systems.

Plantship Vessels and Offshore Platform Systems

Prior to FY 1981 OTEC engineering was concentrated on floating vessel concepts--either moored barges or spars with an electrical cable leading to shore, or mobile, "grazing" vessels producing energy-intensive products such as ammonia. Studies of alternative concepts using fixed-tower technology developed by the offshore oil industry were begun in late FY 1980 and are continuing.

NOAA ocean engineering findings in 1981 concerned with plantship and offshore platform technology are described below:

- o Model basin tests and other studies have shown that seakeeping characteristics of OTEC barge-type vessels can be significantly improved using standard naval architecture techniques.

- o Marine concrete is a practical material for plantships.

- o Attachment of the cold water pipe directly to a plantship complicates the vessel's motion in a seaway and makes survival difficult during severe weather. A moored pipe that decouples the motion of the vessel and the cold water pipe and also permits detachment of the plantship from the pipe during severe storms was found to be feasible.

- o Design, installation, deployment, inspection, maintenance, and repair of shelf-mounted platforms and cold water pipes have been analyzed. Conceptual designs are being developed to identify tower and platform arrangements for model basin tests.

- o Preliminary classification and technical requirements for the inspection, maintenance, and repair of plantships, cold water pipes, and mooring systems were developed. These studies showed that it is possible to optimize both initial and long-term costs, and thus minimize lost income from operational downtime, without compromising safety.

- o Baseline designs for a 40 MW OTEC pilot plant were found to be feasible and in general agreement with ship classification society regulations.

Cold Water Pipe and Seawater Systems

The cold water pipe draws cold water from a depth of about 1,000 meters (3,300 feet) to the power plant condenser. A suspended cold water pipe for a 40 MW floating plantship would be about 1000 meters long and 9 meters (30 feet) in diameter. The cold water pipe for a shelf-mounted platform would lie on the sloped ocean bottom. During FY 1981, several important tests on cold water pipes were conducted. They included:

- A 1/50 scale test to collect valuable design data on the stress associated with towing and deploying cold water pipes during installation. Results indicate that a system in which the pipe is towed to the plant location and then "flipped" into its vertical position is feasible.

- A 1/110 scale mooring test of a platform and cold water pipe showed that the pipe was sufficiently strong during severe weather. Fiberglass reinforced plastic, cable-reinforced elastomer, and articulated steel cold water pipes were tested.

- Two analytic models of the dynamic and structural behavior of the cold water pipe, platform, and moorings were developed. These computer programs will be used in subsequent design and development efforts.

- A 1/3 scale cold water pipe test program was started in FY 1981. This program will produce information on the performance of fiberglass-reinforced plastic pipes; establish design and construction procedures; quantify dynamic response during deployment and exposure to environmental loads in both normal and severe sea conditions; and help validate the analytic models.

- An analytical computer program that integrates dynamic and thermal-hydraulic responses of the flow of water in piping systems was developed and evaluated.

Mooring and Foundation Systems

The mooring system comprises the wires, chains, lines, anchors, hardware, and deck handling equipment. Foundations are the footings for tower structures, slope-mounted pipes, and anchor pilings for mooring systems.

A study to evaluate the performance of various anchoring systems on a sloping sea floor showed that gravity and embedment anchors are ineffective on slopes over 15 degrees. The study also showed that at a Hawaiian site the best anchoring systems would use drilled and grouted anchor piles. At a Puerto Rico site, gravity embedment anchors could be used in deep water where heavy sediment exists. However, drilling and grouting of anchor piles would be required near shore where the bottom is mostly rock.

Chapter III

The Legal Regime

The Ocean Thermal Energy Conversion Act of 1980

The successful, Mini-OTEC demonstration off Hawaii in 1979 captured the imagination of executives at industrial concerns and of lawmakers, thus setting the stage for legislation to encourage development of a commercial OTEC industry. Private industry and utility companies believed some kind of federal law was necessary to remove legal and regulatory barriers that would otherwise prevent U.S. companies from building and operating commercial OTEC plants. These barriers consisted largely of legal and regulatory uncertainties, which, if left unresolved, could have deterred potential investors. These uncertainties consisted primarily of:

- Lack of any clear statement that OTEC activities are legal under national or international law;
- Lack of any law or regulation assuring continued access to the ocean thermal resource being used by a particular OTEC plant;
- Lack of clarity as to whether admiralty, land-based, or some other body of residual and common law would apply to activities on OTEC platforms located on the high seas beyond the normal coverage of national laws;
- Uncertainty about whether OTEC operations might be declared illegal or partially restricted in the future; and
- Lack of clarity as to which federal agency regulations might apply to

OTEC operations in U.S. waters, and how those existing regulations would be interpreted when applied to OTEC operations.

The overall effect of those uncertainties, if not dealt with by clear legislation, would have been to make finanacing and insuring of commercial OTEC operations essentially impossible.

The first formal response to these uncertainties was the introduction of H.R. 6154, the Ocean Thermal Energy Conversion Act of 1980, on December 14, 1979. A similar Senate bill, S. 2492, was introduced on March 27, 1980. Committee action on this legislation began early in the second session of the 96th Congress. Extensive hearings on both bills were held, with thirty-six witnesses appearing during three days of hearings on H.R. 6154 during January and February 1980 before the Oceanography Subcommittee of the House Committee on Merchant Marine and Fisheries. Hearings on S. 2492 were held in Honolulu and Washington, D.C., in April and May 1980 by the Senate Committee on Commerce, Science and Transportation. During these hearings, witnesses representing private industry, utility companies, state governments, and private citizens reiterated the need for federal legislation to clear the way for commercial OTEC development.

S. 2492 was reported by the Senate Commerce Committee on May 15 and passed the Senate on July 2, 1980. The Merchant Marine and Fisheries Committee reported H. R. 6154 on May 16. There were only minor technical differences between the two bills. As a result, after passing H.R. 6154 on July 21, the House of Representatives vacated passage of that bill and passed S. 2492. On August 3, 1980, the Ocean Thermal Energy Conversion Act of 1980 (Public Law 96-320) was signed into law.

The principal provisions of the Act were:

- o Establishment of United States jurisdiction over (a) OTEC facilities located in the U.S. territorial sea or connected to the United States by pipeline or cable, (b) OTEC plantships owned or operated by U.S. citizens, and (c) OTEC facilities or plantships documented under U.S. law;

- o Specification of which federal and state laws are to apply to OTEC facilities and plantships under U.S. jurisdiction; and

- o Creation of a fair and expeditious licensing system to assure compliance by U.S. OTEC facilities and plantships with both U.S. and international law.

The license processing system in the Act is designed to yield a single federal decision representing all involved departments and agencies without the protracted delays that can occur in other governmental licensing processes. The overall licensing system is administered by the National Oceanic and Atmospheric Administration. The Act required promulgation of final licensing regulations by August 3, 1981. The Act also contains several provisions related to financing of OTEC plants, to be implemented by the Transportation Department's Maritime Administration.

OTEC Licensing Regulations

NOAA immediately took action to respond to the Act's mandate for OTEC licensing regulations. Proposed regulations were issued on March 30, 1981, just six months after the Act became law. Final regulations governing the licensing process were published in the Federal Register on July 31, 1981. These regulations carry out the purposes of the statute by eliminating legal uncertainties and providing for a coordinated, efficient licensing process. They are flexible enough to allow the experimentation and innovation required for OTEC to advance from the developmental stages into a commercial reality.

The regulations are designed to be readily usable by those seeking a federal OTEC license and include a voluntary review process to ensure more rapid processing of an application than is required by the Act. The regulations described:

1. Who is required to apply for an OTEC license and the procedures for submitting an application.
2. Procedures for conducting optional pre-application consultations with NOAA prior to actual submission of an application.
3. The financial, technical and environmental information that must be submitted with an application to enable NOAA and other federal agencies to make licensing decisions.
4. An explanation of the Act's requirements for processing an OTEC license application and of special processing procedures available at the applicant's request.
5. The criteria for approval or denial of an application, and the terms and conditions that may be included in a license.
6. Procedures for formal hearings on a license application, should they become necessary.
7. The post-licensing enforcement procedures.

There was general agreement during development of the regulations that site evaluation and preconstruction testing regulations were unnecessary at present. Thus, the final regulations did not address these matters. It was also apparent that current scientific understanding and projected development schedules did not justify immediate establishment of upper limits on the number or total capacity of OTEC facilities and plantships to be licensed. Accordingly, that issue was reserved for future rulemaking, should establishment of such limits become necessary.

As part of the process of developing the licensing regulations, NOAA prepared a regulatory impact analysis. The possible approaches to a licensing regime fell into three categories: detailed, moderate, and minimum regulation of OTEC activities.

In considering which of these alternatives would be most appropriate, NOAA was guided by the principle that maximum flexibility should be allowed for development of a domestic OTEC industry while providing a degree of certainty sufficient to encourage private financing of commercial OTEC projects. The choices involved the following considerations:

1. Detailed regulation of OTEC activities

This general approach would involve regulations containing detailed provisions specifying the design of OTEC plant components and requiring use of specific operating procedures. The information required to make application for a license would of necessity be voluminous, and detailed design of the plant would have to be completed prior to making application.

Because adoption of this alternative would yield a low probability of obtaining the benefits to society that would accrue from OTEC development and would impose high costs on both potential OTEC owners and on the government, it was not seriously considered.

2. Moderate regulation of OTEC activities

Under the moderate approach, regulations would not contain detailed provisions specifying design of OTEC plant components or plant operating procedures. The regulations would, however, contain detailed guidelines and performance standards applicable to all OTEC facilities and plantships in order to ensure adherence to overall regulatory goals. A license applicant would be required to prove that the intended plant design and approach met each of the detailed guidelines and performance standards included in the regulations.

The use of specific guidelines and performance standards is a common approach to regulation of relatively mature and stable industries where many facilities already exist and the nature of the technology used and its impacts are well known. However, when applied to a nascent industry such as OTEC, this approach would limit the design and technical flexibility needed to evolve systems that best meet the combined goals of sound engineering and economics and of protection of societal values. For this reason, this alternative was not selected for the licensing regime.

3. Minimum regulation of OTEC activities

Under the minimum regulation alternative, NOAA would include in the licensing regulations only the general guidelines and performance standards specified in the Act. Detailed guidelines and specifications would not be provided in advance in the regulations. They would be introduced if deemed necessary on a site-specific, case-by-case basis to prevent significant adverse effects on the environment or to prevent other results contrary to law. The information submitted to NOAA with an application would include details of the proposed site, descriptions of the operating features of the plant, and assessments of the potential impacts of construction and operation. Thus, application for a license could be made before detailed design of the

OTEC plant was completed. NOAA would examine the applicant's assessments of the nature and potential magnitude of the impacts from construction and operation of the proposed project, and analyze in detail only those impacts that appeared to pose significant problems.

Under this approach, the incremental administrative costs to NOAA to process each application would be relatively modest, on the order of two to three person-years and $250,000. Maximum design flexibility would be afforded OTEC project sponsors, consistent with reasonable protection of societal values.

Most persons who commented on the proposed OTEC licensing regulations favored the minimum regulation alternative. NOAA's detailed analysis of potential regulatory impacts of various licensing regimes, prepared as part of the regulation development process, confirmed that the minimum regulation approach was the most cost-effective one that would satisfy the stated goals of the Act. Accordingly, it was adopted as the basis for the final licensing regulations issued by NOAA.

The Licensing Process

NOAA's regulations establish the procedures for applying for and processing OTEC licenses. In addition, they make specific provision for consultations between NOAA and potential applicants in advance of actual submission. This arrangement fosters early and productive dialogue between NOAA and potential OTEC license applicants and can save potential applicants from wasting effort gathering information that NOAA will not need.

Reflecting requirements of the OTEC Act itself, NOAA's licensing regulations provide that the application to NOAA constitutes application for all necessary federal agency actions, other than Coast Guard inspections and approvals. Provisions are made in the regulations for insuring that all involved federal and state agencies receive copies of an application in timely fashion. Provision is also made for NOAA to prepare an environmental impact statement on the application, to cover all federal agency actions relating to OTEC project. Extensive provisions are made in the regulations for public involvement in the application review process.

The regulations impose rigid time constraints on the OTEC license application review process, as required by the Act itself. An initial determination as to the completeness of the application must be made within 21 days after its receipt. Review of the application for anti-trust implications must be completed by the Attorney General within 90 days after receipt of a copy of the application by the Justice Department. NOAA must issue a draft environmental impact statement not later than 180 days after giving notice of receipt of a complete application. Public hearings on the application must be completed not later than 240 days after notice of its receipt in complete form.

Other involved federal agencies must complete reviews within their areas of responsibilities and make their recommendations to NOAA regarding approval or denial not later than 45 days after completion of public hearings.

Finally, NOAA must make a final decision on approval or denial of the license application not later than 90 days after completion of public hearings. Thus, under the deadlines imposed by the Act and NOAA's implementing regulations, the entire license application review process will be completed in slightly less than one year after receipt of an application.

Early in the process of developing regulations to govern OTEC licensing, NOAA recognized the need to provide applicants with the option of a more coordinated, efficient review process than the minimum required by the Act. A model exists for such a coordinated approach to multiple agency licensing and permitting decisions on a single project in the form of the Joint Review Process developed by the Colorado's Department of Natural Resources for use in federal and state permitting of major energy and natural resource development projects. Drawing heavily on the concepts used in the Colorado process, NOAA developed the Consolidated Application Review (CAR) process provided for in the licensing regulations. The process involves early designation of federal, state, and local government members to serve, with the applicant, on a CAR team for the application. NOAA will chair the CAR team, and its primary responsibility will be to coordinate the scheduling of each government agency's review process for the application, including necessary hearings and decision points, so that a prompt and unified decision can be reached on the application.

The CAR process is intended to assure early and continuous coordination among all involved federal, state and local agencies and to provide a focal point for applicants in their dealings with all involved agencies. Participation in the CAR process is voluntary on the part of an applicant and the agencies other than NOAA, because the Act does not explicitly require use of this degree of integration in the review process.

In developing the CAR process, NOAA has had extensive discussions with the other pertinent federal agencies, and all have made a commitment in principle to use the CAR process if requested to by an applicant. NOAA is now identifying information requirements and decision schedules related to all other government authorizations and permits necessary for location, construction, and operation of OTEC facilities and plantships. If an applicant chooses not to use the CAR process, NOAA will still provide the information on other agency procedures and information requirements to assist the applicant in direct interactions with those agencies. In any case, the extensive ongoing consultations that NOAA is conducting with the U.S. Army Corps of Engineers, Coast Guard, Department of the Interior, Environmental Protection Agency, and Department of Justice, among others, will create a sensitivity and commitment among the involved agencies that will benefit an OTEC license applicant whether or not the CAR process is used.

The licensing process developed by NOAA and specified in the final regulations is intended to provide the orderly, timely, and efficient review of OTEC proposals envisioned by the drafters of the Act. As the licensing process is implemented, NOAA will monitor it carefully, and make adjustments where necessary to assure that it in fact contributes to early development of a U.S. commercial OTEC industry.

Chapter IV

Environmental Considerations

OTEC Environmental Issues Discussion Paper

To provide for an early and open process to determine the scope of the environmental issues associated with development of OTEC licensing regulations, NOAA published a paper addressing environmental issues within a month of the signing of the OTEC Act. The discussion paper described the Act and OTEC in general, gave several OTEC commercial development scenarios, and highlighted environmental issues associated with OTEC development.

The discussion paper was not a draft environmental impact statement, but rather a brief introduction to OTEC so that interested parties could better work with NOAA in identifying the environmental issues and the more significant questions to be answered in the process of formulating regulations to implement the OTEC Act.

Environmental Impact Statement (EIS)

NOAA prepared an Environmental Impact Statement analyzing the environmental consequences of OTEC development up to the year 2000 under the legal regime established by the OTEC Act. The EIS also evaluated regulatory alternatives for mitigating adverse environmental impacts associated with construction, deployment, and operation of commercial OTEC plants.

The EIS concluded that although commercial OTEC development might have some affect on the atmosphere, the terrestrial environmental, the marine ecosystem, and various human activities in the vicinity of deployment and operation sites, the net environmental impact from OTEC development would be minimal compared to the impacts from fossil fuel and nuclear power production. However, the uncertainties associated with the redistribution of intake waters must be better assessed. The EIS also concluded that minimal regulation of OTEC activities, an approach that depends primarily upon existing regulatory provisions, is the preferred strategy for licensing OTEC plants.

Potential effects from commercial OTEC plants, although less than those from equivalent fossil fuel plants, include climatic disturbances resulting from releasing carbon dioxide and cooling the sea surface. Significant atmospheric effects are not expected as a result of single-plant deployments. However, large scale deployment could result in carbon dioxide releases and sea-surface cooling of a magnitude that may affect climate. Local air quality is not expected to be significantly affected by emissions from industrial OTEC plants producing energy-intensive products such as aluminum or ammonia. Building land-based OTEC plants, like any heavy industrial construction, may destroy terrestrial habitats and increase noise levels and air pollution locally.

The majority of environmental effects caused by OTEC development center on the marine ecosystem, since it is the source of evaporating and condensing waters and the receiver of effluent waters used by the plant. The effects can be put in three categories: (1) major (those that might cause significant environmental impacts), (2) minor (those causing insignificant environmental disturbances), and (3) potential (those occurring only during accidents).

Source	Potential Major Effect
o Platform presence	o Biota attraction
o Withdrawal of surface and deep ocean waters	o Organism entrainment and impingement
o Discharge of waters	o Nutrient redistribution resulting in increased productivity
o Release of biocide	o Toxic to marine life

Source	Potential Minor Effect
o Release of protective hull-coating	o Toxicity and bioaccumulation of hull-coating constituents
o Power cycle erosion and corrosion	o Toxicity and bioaccumulation of released metals
o Installation of cold water pipe and transmission cable	o Habitat destruction and turbidity during dredging
o Production of low-frequency sound	o Interference with marine life
o Discharge of surfactants	o Toxic to marine life
o Operation of open-cycle plant	o Alteration of oxygen and salt concentrations in downstream waters

Source	Potential effects from Accidents
o Release of working fluid from spills and leaks	o Toxic to marine life
o Releases of oil	o Toxic to marine life

Nekton populations (i.e., free-swimming organisms) will increase near the plant because they are attracted to the structure itself and its lights. Populations may decrease in downstream areas, as a result of entrainment of eggs and larvae and impingement of juveniles and adults. Plankton populations (i.e., floating organisms) may also be reduced immediately downstream of OTEC plants, because of entrainment and release of biocides. However, these effects may be offset by the redistribution of nutrient-rich deep water into the photic zone, stimulating plankton productivity and ultimately increasing plankton populations and the numbers of fish that feed on the plankton. Benthic community effects will center primarily on their planktonic larval stages, possibly reducing recruitment stocks and adult benthic populations downstream of the plant. The cumulative effect of OTEC development near islands may significantly affect threatened and endangered species at some sites. However, this effect is not expected to be a problem for commercial OTEC plant operation in open ocean regions.

The magnitude of potentially adverse impacts can be reduced by changing the plant's location or its equipment. Siting OTEC plants away from commercially important, ecologically sensitive, and biologically productive areas will reduce the effects of biota attraction, organism impingement and entrainment, and biocide release. Organism attraction to OTEC plants can be minimized by reducing lights and noise on the platform. Organism impingement and entrainment may be reduced by locating intake structures where the least number of organisms are found or by inducing horizontal intake flows which fish tend to avoid. Adverse environmental effects resulting from biocide release, sea-surface temperature alterations, and nutrient redistribution may be reduced by discharging the effluent waters below about 250 feet. Employing alternate biocide concentrations, alternate biofouling control measures, and release schedules will minimize the effects of biocide release.

Technical Guidance Document

NOAA published a Technical Guidance Document in September 1981 to help industry meet the environmental requirements of the regulations for licensing commercial OTEC plants. To a large degree, these environmental requirements are based on those developed by the Department of Energy (DOE) for OTEC pilot plant proposals. In spite of the similarities, however, NOAA believed that there may be other valid approaches to meeting the requirements. Accordingly, NOAA recommended that potential applicants avail themselves of the pre-application consultations provided for in the regulations so that the specifics of the environmental assessment needs can be discussed and resolved for site-specific situations.

As NOAA gains experience with OTEC operations, and as information is developed through environmental research, NOAA will provide additional guidance to license applicants.

Environmental Research Plan

Section 107 of the OTEC Act requires NOAA to initiate a program to assess:

(1) any short-term and long-term effects on the environment which may occur as a result of the operation of ocean thermal energy conversion facilities and plantships;

(2) the nature and magnitude of any oceanographic, atmospheric, weather, climatic, or biological changes in the environment which may occur as a result of deployment and operation of large numbers of ocean thermal energy conversion facilities and plantships;

(3) the nature and magnitude of any oceanographic, biological or other changes in the environment which may occur as a result of the operation of electric transmission cables and equipment in the water column or on or in the seabed, including the hazards of accidentally severed transmission cables; and

(4) whether the magnitude of one or more of the cumulative environmental effects of deployment and operation of large numbers of ocean thermal energy conversion facilities and plantships requires that an upper limit be placed on the number or total capacity of such facilities or plantships to be licensed under this Act for simultaneous operation, either overall or within specific geographic areas.

Furthermore, a plan must be prepared and submitted to Congress for carrying out this program.

NOAA and DOE both have mandates to assure the environmental compatibility of OTEC technologies. However, NOAA's responsibilities focus on licensing and facilitating commercial development of OTEC, whereas DOE's responsibilities focus on development of the technology. Although these responsibilities are clearly distinguishable from each other, the environmental research that is required under each is not so clearly differentiated. Thus the plan by NOAA for OTEC-related environmental research is designed to complement ongoing and planned DOE studies so that the two programs together will meet their respective needs most cost-effectively. The plan stresses the following research areas critical to NOAA's licensing decisions:

- o Interference of one OTEC plant with another,
- o Effects of entrainment and impingement,
- o Long-term cumulative and interactive effects (including biocide effects), and
- o Monitoring environmental effects.

Chapter V

International Impact and Future of OTEC

International Trade

While OTEC can play a major role in the generation of electricity and the manufacture of energy-intensive products in the United States, OTEC's potential for generating new international trade is even greater.

Over 90 countries and territories are located within the OTEC resource area, that is, within 200 miles of waters with a 20°C. temperature difference. Many of them have little or no domestic oil, coal, or hydropower for baseload electricity generation, and as a result depend on imported oil. The total electricity need of a large number of these countries and territories is too small for use of commercial-sized nuclear plants. For those countries, OTEC is the technology most likely to be chosen for generating baseload electricity to meet future increases in electrical demand and, in some cases, to replace existing, costly plants.

Development of an active OTEC plant export business by U.S. private industry would serve to open up substantial international trade relationships with countries that are not now major U.S. trading partners. Initiation of trade relationships through OTEC could broaden accessability of foreign markets for U.S. manufactured and consumer goods, and strengthen economic and political relationships with countries that are sources of strategic and non-strategic raw materials.

Unlike the United States, foreign countries have concentrated their efforts in the export market because they have relatively few domestic sites for OTEC plants. However, U.S. industry still has a technological lead on the foreign competition. Once U.S. companies have built initial commercial OTEC plants, they are expected to begin more aggressive pursuit of export markets.

The major competition for OTEC export markets is from Japan, Sweden, and France. In 1979 the Pacific island republic of Nauru signed a contract with Japanese interests for OTEC development. A demonstration test of a 100 kilowatt net land-based OTEC plant on Nauru began in October 1981. The pilot plant was built by the Tokyo Electric Power Company. Most of the equipment was supplied by Toshiba. The plan is to operate the pilot plant in a testing mode for one year to gain information on technical problems, and then to build a small commercial plant to supply baseload power for the island. The pilot plant is subsidized by the Japanese government.

A Swedish OTEC group, which consists of several Swedish companies with government support, is performing site evaluations in Jamaica prior to construction of an OTEC pilot plant. The reported plans are for a pilot plant approximately 1 megawatt in size, followed by a commercial plant.

France was involved in the post-World War II period in OTEC work in the Ivory Coast and Guadeloupe, although both projects were apparently dropped before they produced commercial power. More recently, a French engineering company is performing OTEC studies for the Government of the Ivory Coast. The Centre National pour l'Exploitation des Oceans (CNEXO), which is owned by the French government, is performing site studies in Tahiti that are expected to lead to construction of a small, land-based commercial OTEC plant.

International Law

The Ocean Thermal Energy Conversion Act of 1980 is firmly grounded on concepts of national jurisdiction that are widely recognized in international law, and the Act requires U.S. OTEC licensees to abide by the provisions of international treaties to which the United States is a party. The draft treaty currently under consideration at the Third United Nations Conference on the Law of the Sea is not expected to raise any new barriers to OTEC development by U.S. corporations. In fact, the draft text confirms each coastal nation's jurisdiction over OTEC activities within 200 miles of its coastline. Consequently, the domestic and international legal regimes under which OTEC development can take place in a secure investment climate already exist, and international law does not pose a barrier to the OTEC industry.

The only gap in international legal arrangements that might cause difficulty for OTEC development is the lack of stated rules to prevent one moving OTEC plantship from interfering with the thermal resource being used by another moving plantship. The U.S. law contains provisions for handling this situation between plantships licensed by the United States, so the potential conflict could arise only between an OTEC plantship licensed by the United States and a plantship licensed by another country. At the present time, the United States is the only nation considering development of OTEC plantships. Therefore, this problem is not likely to arise in practice in the next ten to fifteen years. If another country does begin development of OTEC plantships, bilateral arrangements to prevent this problem could be initiated at that time.

Recommendations for Amending the OTEC Act

At the current time no amendments to the Act are recommended. NOAA is analyzing several areas in which technical amendments would clarify the original intent of the Act. The most significant of these relates to the specific requirements for issuance of OTEC licenses for facilities that are located partly on land and partly in ocean waters. This type of facility is often called a "land-based" OTEC facility.

NOAA believes it is clear that the OTEC Act requires a license from NOAA for ownership, construction, or operation of a land-based OTEC facility whose input or discharge pipes are located in the territorial sea of the United States. Section 101(c)(7) of the Act prevents NOAA from issuing an OTEC license if the OTEC facility or plantship will not be documented under the laws of the United States. This provides protection against operation of OTEC facilities and plantships under foreign flags of convenience. However, the specific wording of section 101(c)(7) causes a problem that may, if not corrected, prevent issuance of licenses for land-based OTEC facilities because of the difficulty of documenting these facilities under existing U.S. vessel documentation laws administered by the Coast Guard. This problem was discussed in the preamble to NOAA's publication of final rules for Licensing Ocean Thermal Energy Conversion Facilities and Plantships (46 Federal Register 39388, July 31, 1981).

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