

## A Potential OTEC Power Plant for the Marshall Islands

by James G. Wenzel  
President, Marine Development Associates, Inc.(USA)



\*James Wenzel, President of MDA, Inc.

can provide the basis for new Industry opportunities, such as high-value aquaculture products and unique arid specialized cold water agriculture.

With the above characteristics in mind, plus the availability of low-risk, closed-cycle OTEC technology, the Government of the Marshall Islands elected to conduct a Design, Economic, and Financial Feasibility Study of a 5-10 MW, multi-product OTEC plant, to meet the future energy needs for Majuro. Grant funding for the Study was obtained from the U.S. State Department's Trade and Development Agency (TDA), a competition was conducted, and Marine Development Associates, Inc. (MDA), of Saratoga, California, selected as the study contractor. The Study Industry team included support by Makai Ocean Engineering, Inc. (Hawaii), Fluor Daniel Corporation (Texas), and Pacific International, Inc. (RMI).

### Introduction & Background

Due to the price instability of hydrocarbon fuels, the major impact of such imported fuels on economics, and significant concerns for the environment, many Pacific Island and other developing nations have expressed great interest in finding competitive alternate energy concepts. Ocean Thermal Energy Conversion (OTEC) has been shown to be one of the most promising environmentally benign, alternative energy concepts available for producing baseload electricity in tropical waters. Enormous resources of solar energy are stored in the surface waters surrounding many Island nations, that dwarf the energy required to support and maintain aggressive economic development.

OTEC power plants are also capable of producing multiple products including electricity, fresh water, and cold seawater for meeting critical cooling needs---all fundamental requirements for economic growth. In addition, the cold, nutrient-rich seawater

### Study Objectives

The Study Program's major objectives were as follows:

- § Define a facility design concept, its capital cost, and economic viability, including sale of electricity, fresh water and cold, nutrient-rich seawater, for a reliable and near-term, commercial closed-cycle OTEC plant.
- § Define a Project Financial Plan and establish feasibility of attracting sufficient private investment capital to make this a viable, near-term energy project for the Marshall Islands.

The contracted study began in April, 1993, was completed in April 1994, and is currently being evaluated by the RMI Government.

### Study Approach

The majority of program design activity was spent in optimizing the Power Plant concept for the Majuro site locations, gathering and integrating

basic system cost data. In obtaining component cost data, **MDA** worked directly with multiple suppliers of such major subsystems as heat exchangers, turbine/generators, auxiliary equipment, and the platform to insure and optimize system integration. For example, low-cost, heat exchangers were evaluated, with the varying complexity of installation **piping**, repair and maintenance requirements, to satisfy the demands of a commercial power plant and private financing. This

analysis required full power-system installation layouts, and piping, connection flange, and valve analysis, all of which played a **major** role in selection of a low-risk, off-the-shelf heat exchanger design. Selection of all major power system components has been based on proven designs and technology. A summary of the technology assessment for the principal subsystems is shown in Figure 1.

Figure 1

### Design / Technology Summary Major Components

System Element	Technology Assessment
<ul style="list-style-type: none"> <li>• <u>Power System</u> <ul style="list-style-type: none"> <li>• Turbine/Generator</li> </ul> </li>   <li>• Heat Exchangers</li>   <li>• Mist Separators, Ammonia System - Tanks, Pumps, Valves, Piping, etc.</li>   <li>• <u>Controls, Instrumentation, &amp; Displays</u></li>   <li>• <u>Platform / Barge</u></li>   <li>• <u>Sea Water Svstems</u> <ul style="list-style-type: none"> <li>• Sea Water Pumps</li> </ul> </li>   <li>• Cold Water Pipe</li>   <li>• Warm Water Pipe Mixed Effluent Pipe</li> </ul>	<ul style="list-style-type: none"> <li>• Off-the-Shelf Subsystem, Proven Design</li> <li>• &gt; 4,000 Typical Units Installed World-wide.</li> <li>• Guaranteed Performance. <b>Low risk</b></li>   <li>• Fully Tested at Argonne (DOE). <b>Low risk</b></li> <li>• Life Estimate by DOE &gt; 15-20 years.</li> <li>• Extensive Aluminum Corrosion / Biofouling Tests at NELH-Hawaii.</li>   <li>• Existing and Proven Hardware. <b>Low risk</b></li>   <li>• Available from Existing Power System Applications. <b>Low risk</b></li>   <li>• Existing Deployed &amp; Operationally Proven Structures. <b>Low risk</b></li>   <li>• Operational &amp; Proven, Guaranteed Performance.</li> <li>• Long Operational Life - &gt; 7 years without failure</li>   <li>• Multiple Pipe Fabricators / Available Components, Recoverable for Repair If Required. <b>Moderate Risk</b></li>   <li>• Standard Outfall Deployment &amp; Technology. <b>Low Risk</b></li> </ul>

## Summary and Conclusions

Primary conclusions of the study can be summarized as follows:

- § without question, the design and technical feasibility of the closed-cycle, multi-product OTEC power plant has been defined and established as ready for commercialization.
  - § Consideration of technology advances achieved in heat exchangers and cold water pipe designs, and the associated cost reductions available, have established 5-10 MWe as a viable economic power plant size for Island applications, with costs of electricity competitive with real costs of energy in many developing nations.
  - § The benign impact of OTEC power on global warming, i.e. no hydrocarbon CO<sub>2</sub>, is of significant interest to the U.S. and world governments. The Program has the potential of being declared a "demonstration" program of such an attractive, base-load alternate energy power plant for developing nations.
  - § As an operating 5MW commercial power plant, the proposed facility can play an important role for measurement of environmental impact data, training of OTEC operators, and a test facility for scaled-up components incorporating advanced technology. Modest investment in the RATAK facility could provide major risk reduction for development of larger OTEC facilities, such as the planned Taiwan 500MW power plant.
- 

## A New Book on OTEC

Dr. W.H. Avery of the Applied Physics Laboratory at the Joliet Hopkins University and Dr. Chih Wu of the Mechanical Engineering Department at the U.S. Naval Academy recently (April, 1994) published the book, **Renewable Energy from the Ocean, A Guide to OTEC** in the field of ocean thermal energy conversion (OTEC).

As scientists and engineers around the world strive to develop new sources of energy, one source--OTEC--has aroused considerable interest due to its virtually unlimited potential. This book reviews the status and background of OTEC and presents viable, cost effective means of using the Earth's inexhaustible, tireless thermal engine to generate electricity and other products for man. Theory, application, engineering design, economic, environmental and social impact of various OTEC strategies are all discussed in detailed language.

The book is scientifically sound. The authors have devoted two decades to the OTEC field and, as a result, are widely regarded as the field's premier

authorities. The topics are presented in the proper order, and are equally weighted, as they should be. The material is well organized. The book has been many years in preparation. None of the topics or coverage is superfluous. It will be of interest to a wide range of professionals and students in energy research, power engineering, and mechanical engineering.

With the ever-increasing human burden placed on the planet, it is imperative that cost-effective, environmentally-clean, renewable energy sources be developed today. This book presents a detailed, scientific review of OTEC and has already received accolades in the scientific and engineering communities.

The book, **Renewable Energy from the Ocean, A Guide to OTEC** by Oxford University Press, Inc. at 200 Madison Avenue, New York, NY 10016, USA, is the first book of its kind. The ISBN number of the book is ISBN 0-19-507199-9. The list price of the book is \$65.00.

---

Major emphasis has also been given to the most sensitive technology requirement for a viable OTEC plant, namely, a reliable, low-cost and low-risk cold water pipe design. The power plant design concept, which has emerged from these analyses, can be summarized in general as follows:

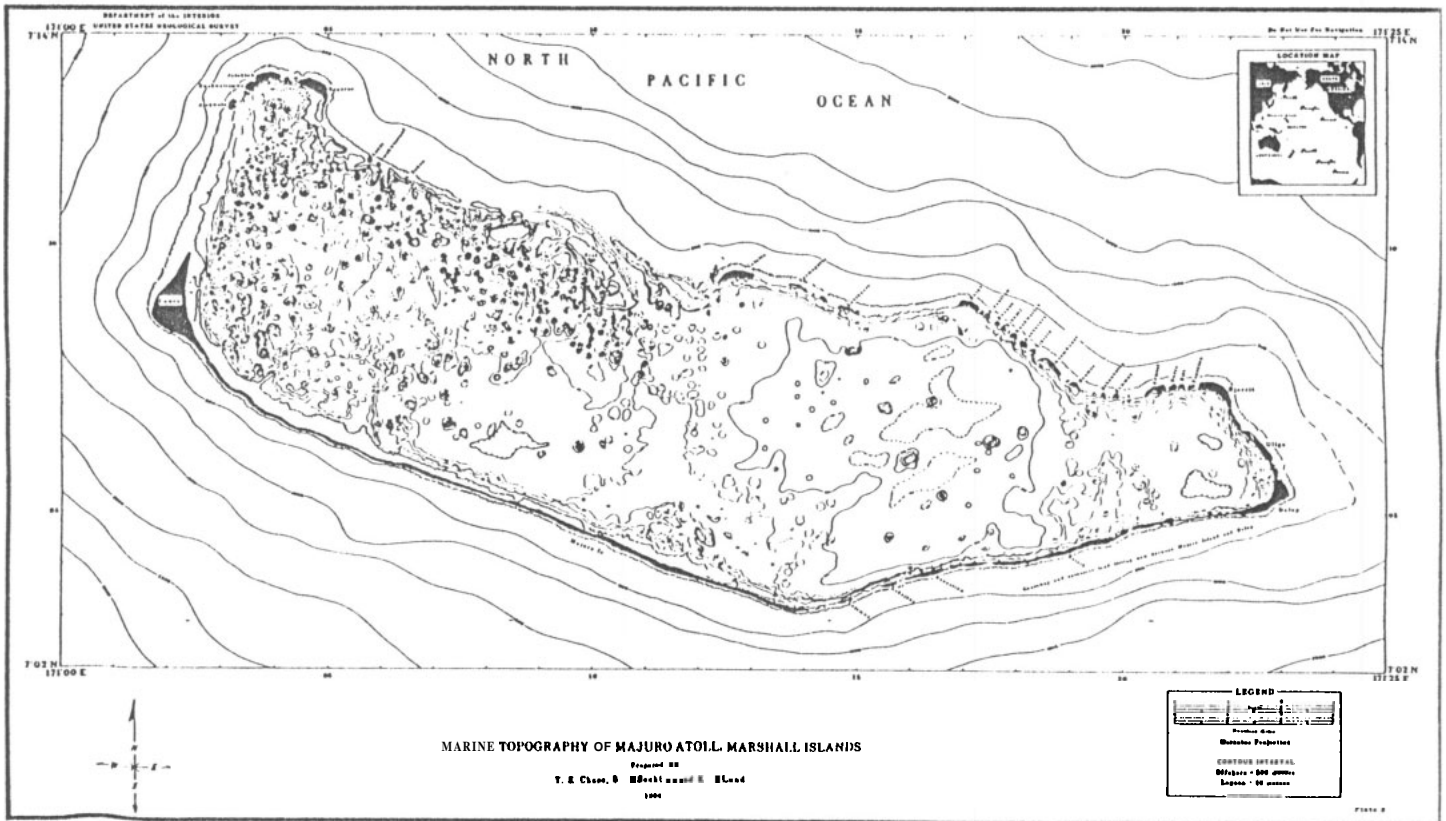
- § A modular, closed-cycle, OTEC plant, utilizing aluminum heat exchangers, and incorporating automated controls and instrumentation.
- § A concrete, floating (but sinkable) platform, into which the power system can be installed and operated in a controlled environment, tested, transported to **Majuro**, and installed on a prepared, lagoon-shore site.
- § A low-cost cold water pipe design, based on MDA's semi-rigid "soft pipe" concept, and installed on the seafloor in a manner to minimize

the impact of typhoon-type storms. The CWP design also includes the capability of recovering the pipe from the seafloor, to minimize capital risk and permit repairs should damage occur in a typhoon.

Capital costing of the above configuration and its installation at Majuro proved to be very encouraging. Economic analyses have shown that, under the Financial Plan developed by MDA for this first commercial OTEC power plant, a return of over 15% on private capital required can be realized, with a price of electricity less than the current real cost of diesel-electric power at Majuro. With OTEC being one of the very few alternate energy concepts that become less expensive per kW of electricity produced with increasingly larger generating units, this result was very significant.

7°02'N to 7°14'N  
171°00'E to 171°25'E

## Majuro Atoll - Marshall Islands



# 》 MEETING OF INTEREST TO IOA ‹

## **TECHNO-OCEANS'94**

Place: Kobe International Exhibition Hall (port Island, Kobe)

Date: 26-29 October, 1994

Contact: Kobe International Association,  
Trade Fair Division,  
11-1, 6-Chome, Minatojimanaka-machi, Chuo-ku, Kobe, 650 Japan  
Fax: 81-78-302-1870

Contact: Prof C.C. Liu, Workshop on Deep Ocean Sea Water Applications, National Taiwan University

1, Roosevelt Rd., Sec. 4, Taipei, Taiwan, ROC  
Fax: 886-2-362-6092

## **Major IOC Conference**

**"Towards Sustainable Use of the Ocean and Coastal Zones"**

Place: Lisbon, Portugal

Date: 7-12-23 November, 1994

Contact: J. Lopes Serrado, Exec. Sec. Comissao Nacional da UNESCO, Av. Infante Santo 42, 50, 1300 Lisboa, Portugal  
Fax: 351-1-396-9064

## **COSU '95**

Place: Yokohama, Japan

Date: 30 May to 2 June, 1995

Contact: Yutaka Miyaji,  
Port and Harbours Bureau,  
2-1-3 Kasumigaseki,  
Chiyoda-Ku, Tokyo 100 Japan  
Fax: 81-3-3580-1593

## **SINO-US**

Place: Taipei, Taiwan

Date: Nov. 14-18, 1994

## **DEEP FOUNDATIONS and GROUND IMPROVEMENT SCHEMES**

Place: Bangkok, Thailand

Date: 21-24 November, 1994

Contact: Prof. A.S. Balasubramaniam,  
Geotechnical & Transportation Eng. Program  
School of Civil Engineering, AIT  
G.P.O. Box 2754 Bangkok 10501, Thailand  
Fax: (66-2) 516-2126

---

## **IOA Newsletter**

**Vol.5 NO. 3 / Autumn 1994**

The IOA Newsletter is a quarterly publication by the IOA secretariat Office. We welcome any contributing articles highlighting the technologies of ocean thermal energy conversion and/or deep ocean water applications including research, new product announcements and information about meetings, symposia and workshops. Please send the articles to:

### **THE EDITORS**

#### **IOA NEWSLETTER**

Bldg. 64, 195, Chung-Hsing Rd., Sec. 4, Chutung, Hsunchu, Taiwan 31015, R.O.C.  
Tel: 886-35-916305, Fax: 886-35-916310

#### **IOA SECRETARIAT OFFICE**

3F-1, 285, Fu-Hsing South Rd., Sec.2, Taipei, Taiwan, R.O.C

Tel: 886-2-704622 1, Fax: 886-2-7046206.

### **EDITORIAL STAFF**

#### **EDITORIAL COMMITTEE**

Ling-Yuen Clien (R.O.C.) (Editor-in-chief)  
Yasuichiro Matsunaga (Japan)  
Don Lennard (U.K.)  
Andrew Trenka (U.S.A.)  
Christian Habault (French Polynesia)

#### **CONTRIBUTING EDITOR**

Carrie Matsuzaki (U.S.A.)

#### **EDITORS**

Jin Chung and Jennifer Lin (R.O.C.)