Potential and Future Prospects for Ocean Thermal Energy Conversion (OTEC) In Small Islands Developing States (SIDS)[1]

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I. Ocean Thermal Energy Conversion Technology

Ocean Thermal Energy Conversion (OTEC) is an energy technology that converts solar radiation to electric power. OTEC system uses the ocean's natural thermal gradient—the ocean's layers of water have different temperatures—to drive a power producing cycle. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C (36°F), an OTEC system can produce a significant amount of power, with little impact on the surrounding environment. The oceans are thus a vast renewable resource, with the potential to help us produce billions of watts of electric power. This potential is estimated to be about 10^{13} watts of base load power generation, according to some experts. The distinctive feature of OTEC energy systems is that the end products include not only energy in the form of electricity, but also several other synergistic products.[3]

II. Sustainable Development in SIDS

Background

The economies and social structure of the vast majority of what is now considered Small Island Developing States (SIDS) were developed under colonial rule. When the majority of these countries became independent nations in the later half of the twentieth century, they inherited economies that were based principally on providing commodities to the former ruling nations. Independence did not bring about any significant change in the nature of the economy or trading relationship, although in some cases there were changes in ownership of land, brought about through purchase, hand-over from ruling country government to newly elected government, and in some cases nationalization.

The trading relationship continued as before and was considered as beneficial to both former ruling country and newly independent state. Periodic meetings were held to reach new agreements on prices and to allocate how the market would be divided among the producing countries. This relationship remained in place until the advent of the World Trading Organization (WTO) in 1994. Under the WTO global rules for "fair" trade, there would no longer be continuation of preferential markets for the commodities from these former colonies beyond an agreed period of time. After that period, between 5 to 10 years in most cases, these former small colonies had to compete with other producers.

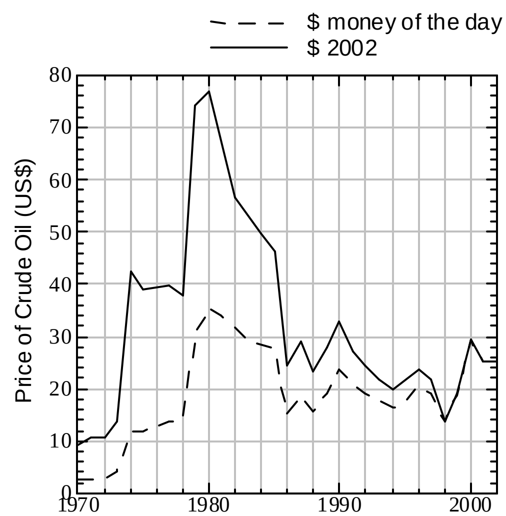

Fig.1 Market Price of Crude Oil
Source: International Fuel Price, May 2003

Prior to being involved in the WTO, these newly independent SIDS were already having great difficulty in the national economy - a major cause was the drastic shock

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1 SIDS (by UN region) is as follows: AFRICA: Cape Verde, Comoros, Mauritius, Sao Tome and Principe, Seychelles; ASIA AND THE PACIFIC: Cook Islands, Fiji, Kiribati, Maldives, Marshall Islands, Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Singapore, Solomon Islands, Tonga, Tuvalu, Vanuatu; WESTERN EUROPE: Cyprus, Malta; LATIN AMERICA & THE CARIBBEAN: Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent & the Grenadines, Suriname, Trinidad & Tobago.

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3 http://www.otecnews.org/whatisotec.html

for their small economies brought about by the escalation in petroleum prices which started in the 1970s, but reached its maximum in the 1980s, as shown in Figure 1. This impact of the escalation in petroleum prices for SIDS is reflected in the changes in the terms of trade. For example, based on a price of US$400 per ton for sugar, the preferential prices paid by the former colonial ruling countries to SIDS in the 1970s through 1980s, a ton of sugar was worth more than a hundred barrels of petroleum. By the mid-1980s, the ratio had declined from greater than 100 to 1 to about 20 to 1. At present, based on the respective world prices for petroleum and sugar, it is about 5 to1.

At the 1992, United Nations Conference on Environment and Developed (UNCED), SIDS were identified as a very special case of environment and development based on the degree of difficulties. Also, in December 1992, the United Nations General Assembly (UNGA), at its 47th Session, adopted Resolution 47/189, giving international designation to SIDS as a special case for environment and development. In May 1994, the designation was followed up by the convening of the United Nations Conference on Sustainable Development of Small Island Developing States and the formulation of the Barbados Programme of Action (BPOA). The BPOA set out the necessary actions that SIDS were to follow as well as the basis for international assistance in helping SIDS to pursue sustainable development. The BPOA was subsequently adopted by the UNGA in late 1994. However, neither the special case designation, nor the adaptation of the BPOA, which should have brought additional and special international assistance to SIDS, has had the intended outcome. Consequently, the economic and environmental conditions in the vast majority continue to deteriorate. In August 2004 in Mauritius, the international community will assemble under the aegis of the United Nations to hear the progress that SIDS have made in implementing the BPOA. The report will not be encouraging; below is a summary of present economic, social, and environmental situation in SIDS.

Present Situation

Economic:

The vast majority of SIDS as represented by the sample in Table 1, are facing severe challenges in finding ways to turn their economies into tourism bases because they found it almost impossible to make their agricultural and manufacturing sector internationally competitive. In this regard, countries like Mauritius, Samoa, and Cape Verde are having some successes. However, tourism is known to be a two-edge sword, in that while it generates national income and foreign exchange and jobs, it also carries negative social and environmental impacts. Additionally, the vulnerability of tourism to internal and

Table 1 GDP and GDP Growth Rate in SIDS

No	Country	GDP (Current US$)			GDP Growth (Annual %)		
		1998	2001	2002	1998	2001	2002
1	Cape Verde	539.5 million	564.1 million	631.1 million	7.4%	3.3%	4.0%
2	Mauritius	4.1 billion	4.5 billion	4.5 billion	6.0%	6.7%	4.4%
3	Samoa	224.1 million	244.4 million	261.2 million	2.4%	6.2%	1.3%
4	Vanuatu	234.4 million	220.6 million	234.4 million	3.0%	-1.9%	-0.3%
5	Fiji	1.7 billion	1.7 billion	1.9 billion	1.4%	4.3%	4.4%
6	Barbados	2.4 billion	2.8 billion	..	4.1%	1.5%	..
7	St. Lucia	619.5 million	661.6 million	659.8 million	2.9%	-3.7%	-0.5%
8	Grenada	350.6 million	398.2 million	414.1 million	9.6%	-4.7%	-0.5%
9	St. Vincent	318.6 million	348.5 million	360.6 million	5.7%	0.2%	0.7%
10	Jamaica	7.5 billion	7.8 billion	8.0 billion	-0.3%	1.7%	1.0%
11	Antigua & Barbuda	620.7 million	682.2 million	709.8 million	4.6%	0.2%	2.7%
12	Cuba	..	..	30.7 billion	1.2%	..	..
14	Papau New Guinea	3.8 billion	2.9 billion	2.8 billion	-2.8%	-3.4%	-2.5%

Source: World Development Indicators database, August 2003,
The World Factbook 2002, USA

external shocks was reinforced by the crises created by "9/11," the Iraq war, and the SARS outbreak. Hence, SIDS will continue to find it difficult identifying sustainable ways to grow their economies. The ongoing difficulties results from a combination of factors that include:

✧ **Loss of Market and Declining Value of Traditional Exports**

As pointed out earlier, as a result of the coming into force of WTO rules, non–LDCs SIDS have experienced loss of preferential access for their exports to developed countries' markets. Preferential access to these markets that paid prices significantly higher than world prices based on historical relationships, were associated with the colonial history of the SIDS and these developed countries. The coming into force of the WTO rules that prohibit preferential access has forced the SIDS to compete in selling commodities at declining prices as shown in Figure 2 and 3, without benefits of economy of scale, very high transportation cost due to geographic location and small freight volumes, among other factors, have resulted in significantly reduced export earnings.

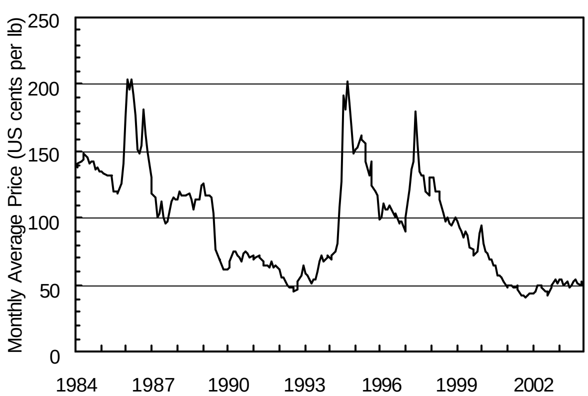

Fig.2 Market Price of Coffee (1984-2002)
Source: International Coffee Organization

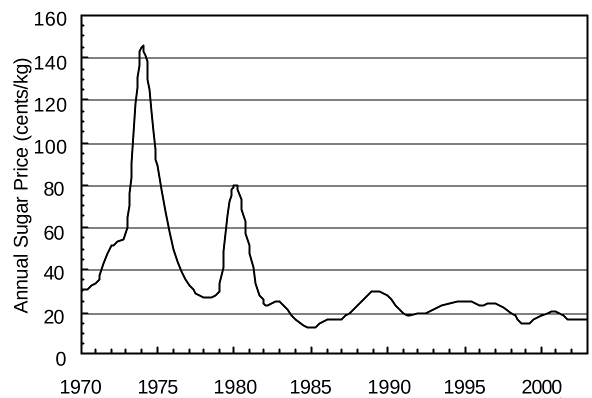

Fig.3 Market Price of Sugar in 1990 US$
Source: FAO

Caribbean SIDS provide a very good example of this. Between 1995, the first year of the WTO, and 2000, the unit value of 7 of the 11 most important exports fell. For 5 of these exports, the decline was greater than 25 %. Consequently, the trade deficit increased from US$1.2 billion in 1994 to US$3.4 billion (almost triple) in 2001[4].

✧ **Declining Domestic Food production and Increasing Imports.**

The WTO requirement for reduced tariffs on imports, along with overproduction of agricultural products for the export in the developed countries, are negatively affecting food production in SIDS. Local farmers cannot compete with the price of imported products, subsequently, they have to either stop or significantly reduce production. Therefore, SIDS are experiencing increasing levels of food imports. In Caribbean SIDS, the cost of food imports increased by 47 % between 1994 and 2001.[5]

Table 2 Foreign Direct Investment in SIDS

No	Country	Foreign Direct Inevstment (Current US$)	
		1998	2001
1	Cape Verde	8.8 million	0.7 million
2	Mauritius	12.2 million	-47.5 million
3	Samoa	3.0 million	1.2 million
4	Vanuatu	20.4 million	18.0 million
5	Fiji	107.0 million	-2.6 million
6	Barbados	15.8 million	17.5 million
7	St. Lucia	83.4 million	50.9 million
8	Grenada	48.7 million	34.3 million
9	St. Vincent	89.0 million	35.7 million
10	Jamaica	369.1 million	613.9 million
11	Antigua & Barbuda	..	..
12	Cuba	..	..
13	Papau New Guinea	109.6 million	62.5 million

Source: World Development Indicators database, August
The World Factbook 2002, USA

[4,5] Extracted from statement of the Secretary General of the Caribbean Community Secretariat to the SIDS Meeting, Bahamas January 2004

✧ **Difficulty Attracting Foreign Direct Investment.**

The prevailing theory of economic development is for national governments to create an enabling environment and international investment will follow. Under the direction of the World Bank (WB) and the International Monetary Fund (IMF), the majority of SIDS have done so, but the level of foreign direct investment (FDI), which they have been able to attract is very limited, have been overwhelmingly in tourism and in the purchasing of utilities like electricity and telecommunications.

✧ **Increasing Cost of Petroleum Relative to Value of Traditional Exports.**

The price of petroleum, in addition to being very volatile which acts to severely disrupt the economy of SIDS, continues to increase relative to the value of traditional exports as can be seen by comparing Figure. 1, 2 and 3. The high cost of petroleum is increasingly resulting in the reduced ability of SIDS to compete internationally in the production of goods and services. As a consequence, there is ongoing relocation of manufacturing jobs and loss of economic activity.

✧ **Reduction in Official Development Assistance (ODA).**

As pointed out previously, in 1992, the United Nations General Assembly (UNGA) passed a resolution making SIDS a special case for the environment and development. With such a designation, the international community were expected to provide increased support to help these countries pursue sustainable development as set forth in the BPOA. As shown in Figure 4, rather than an increase, the assistance has declined by 50% during the decade since the adaptation of the BPOA by the UNGA.

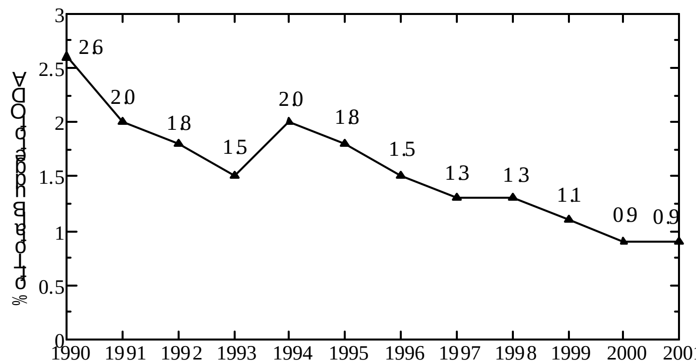

Fig.4 Percentage of ODA for SIDS

Source: OECD

As a consequence of these and other developments, including reduction in tourism caused by the terrorist attacks on the USA in September 2001, SIDS are experiencing increasing external debt (See Table 3), and limited economic growth, with the exception of SIDS such as Cape Verde and Samoa, and this is so because of their Least Developed Country (LDCs) status, thereby enjoying preferential treatment. Given the economic difficulties experienced by SIDS during the decade of the 1990s, when the World Bank Report of July 2001 described as the period of greatest economic expansion in history, the population of the vast majority of SIDS faced an uncertain future.

Social:

Economic difficulties and increasing population are leading to reduced quality of life reflected in education, health, housing, and nutritional status. Limited employment opportunities and chances for career advancement are leading to emigration of professionals to OECD countries and with it, loss of capacity. While emigration of professionals benefits the SIDS through repatriated earnings, which contributes significantly to lessening the economic pressures, the ongoing loss of experienced professionals weakens the human resource pool and makes SIDS more dependent on high cost expertise from developed countries.

The loss of jobs resulting from contraction of the manufacturing and agricultural sectors is not being compensated by creation of jobs in other areas in

Table 3 The Value of External Debt in 2001

No	Country	Value of Debt in 2001 (Current US$)
1	Cape Verde	231.3 million
2	Mauritius	1.7 billion
3	Samoa	142.0 million
4	Vanuatu	36.6 million
5	Fiji	174.9 million
6	Barbados	739.3 million
7	St. Lucia	229.2 million
8	Grenada	190.2 million
9	St. Vincent	155.8 million
10	Jamaica	5.4 billion
11	Antigua & Barbuda	231.0 million
12	Cuba	12.3 billion
13	Papau New Guinea	2.2 billion

Source: World Development Indicators database 2
The World Factbook 2002, USA

numbers significant to cope with displacement and population growth. As a result, the percentage of population living below the poverty line remains high, is some SIDS above 30%.

Environmental:

Unable to find sustainable means of growing the economy to absorb growing population, increasing numbers of the population have no option but to derive their livelihood from the natural environment by any means possible. Government, lacking the resources to provide proper training or effective enforcement, is limited in ability to reverse the trend to any significant degree despite increasing public awareness. As a consequence, there is ongoing significant loss of biodiversity both terrestrial and marine. Principal causes include bad agricultural and fisheries practices and pollution due to agro-chemical run off and improper waste disposal. Lack of or inadequate sanitation and improper waste management are polluting precious fresh water resources. Degradation of critical ecosystems like coral reefs, resulting from a combination of the above actions and the loss of forest including mangroves to provide household energy represent other critical environmental issues.

Table 4 Populations and Population Growth Rate in 2001

No	Country	Population	Population Growth Rate (annual %)
1	Cape Verde	446,400	2.6
2	Mauritius	1.2 million	1.0
3	Samoa	174,000	1.3
4	Vanuatu	201,200	2.2
5	Fiji	817,000	0.8
6	Barbados	268,200	0.4
7	St. Lucia	156,700	1.2
8	Grenada	100,400	1.3
9	St. Vincent	115,900	0.7
10	Jamaica	2.6 million	0.9
11	Antigua & Barbuda	68,490	0.7
12	Cuba	11.1 million	0.3
13	Papau New Guinea	5.3 million	2.3

Source: World Development Indicators database 2003

The failure to develop the economy to create jobs, combined with limited public sector capacity is taking a devastating effect on both the population and the fragile natural environment, and many critical systems will soon suffer from irreversible damage in a number of SIDS.

The Overall Situation

As part of the preparation for the World Summit of Sustainable Development (WSSD) held in Johannesburg, South Africa, in August 2002, the United Nations Development Programme (UNDP) convened an expert group of professionals from the SIDS to make an assessment of the sustainable development progress. The report "*Vulnerability of Small Island Developing States,*" published in the *United Nations Development Policy Journal*, August 2001, stated that during the decade of the 1990s, the overall vulnerability of the SIDS has significantly increased as a result of many factors including the difficulty that these countries were having in fostering economic growth, increasing external debt, migration of professionals, and difficulty attracting foreign direct investment.

The Vulnerability Report called for SIDS to take innovate steps in order to build resilience and better position their countries to address the future threats of climate change and sea level rise. Some SIDS may not be able to survive the combination of economic stress and climate change, and whole countries or parts of multi-island/atolls may be lost in the future if the present trend continues. The principal recommendation from the expert group for resilience building in SIDS was to reduce the dependency on imported petroleum.

III. OTEC Potential Contribution to Sustainable Development in SIDS

OTEC has the potential to contribute to the sustainable development of SIDS in a number of ways, which are described below.

Cheap Secure and Unlimited Source of Commercial Energy

SIDS, with the exception of Trinidad and Tobago, Papua New Guinea, Sao Tome and Principe, and to a limited extent Cuba and even more limited extent Barbados, have no petroleum resources. Also with few exceptions (Barbados – solar water heaters) and the sugar producing SIDS (Barbados, St, Kitts, Fiji, Mauritius, Jamaica, Dominican Republic, Cuba, Trinidad and Tobago) that use biomass for electricity generation, during the sugarcane harvesting season, there is no meaningful development of the abundant renewable energy resources that exists in SIDS. The dependency on imported petroleum, which results in very high electricity price ranging between US$0.13 per kWh in the case of Jamaica, to more than US$0.30 in the islands of the Pacific, is a constraint to development in a number of ways.

Although SIDS are characterized by limited land and land based natural resources, they have 20 to 25 % of the world's ocean in their EEZs. This most productive part of the oceans, with all-year warm water above 25 degrees Celsius due to the high level of solar radiation drives the photosynthesis supporting large quantities and diversity of marine life. It is estimated that on average, daily direct solar radiation is equivalent to about 25,000 to 30,000 barrels of oil, equivalent/per hectare. On an average day, 60 million square kilometers (23 million square miles) of Tropical Ocean absorbs an amount of solar radiation equal in heat content to about 250 billion barrels of oil[6]. The ocean geology of SIDS is primarily characterized by steep continental shelves, so that the distances from shore from the deep water, with temperatures of 4 to 6 degrees Celsius, are within less than 10 kilometres in the majority of SIDS (See Table 5).

Table 5 Countries with Ocean-Thermal Resources 25 km or Less from Shore

Country/Area	Temperature Difference (°C) of Between 0 & 1,000 m	Distance from Resource to Shore (km)
Latin America and the Caribbean		
Barbados	22	1~ 10
Cuba	22-24	1
Dominican Republic	21-24	1
Grenada	27	1~ 10
Haiti	21-24	1
Jamaica	22	1~ 10
Saint Lucia	22	1~ 10
Saint Vincent	22	1~ 10
Trinidad and Tobago	22-24	10
Indian and Pacific Oceans		
Comoros	20-25	1~ 10
Cook Islands	21-22	1~ 10
Fiji	22-23	1~ 10
Kiribati	23-24	1~ 10
Maldives	22	1~ 10
Mauritius	20-21	1~ 10
Samoa	22-23	1~ 10
Seychelles	21-22	1
Solomon Islands	23-24	1~ 10
Vanuatu	22-23	1~ 10

Source: National Renewable Energy Laboratory, USA

The combination of high year-round sea surface temperature, relatively short distance from shore and excellent thermal profile of the oceans as shown in Figure 5, represent the ideal conditions for OTEC. While there are other renewable energy resources such as solar photovoltaic (PV) and wind power in SIDS, these cannot compete with the potential of OTEC. The wind power, for example, is limited in the amount of energy because of site requirement; PV is very costly for SIDS, and available only during sunny daytime. Neither wind power nor PV can provide reliable base load power compared to OTEC. Additionally, they have no direct linkage with water and food production. Clearly, OTEC is in a class by itself as the best renewable energy resource for SIDS.

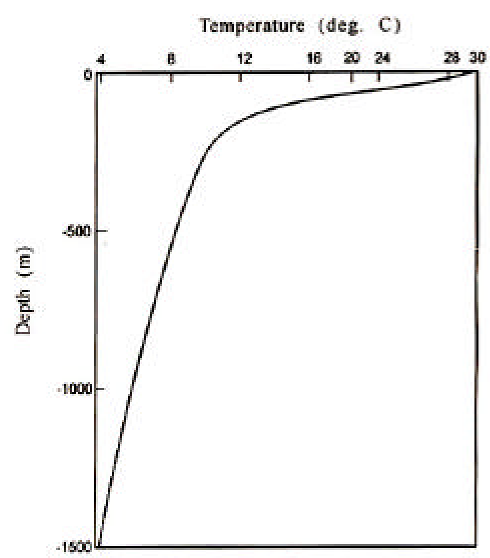

Fig.5 Ideal Temperature Profile for OTEC

Transportation Fuel

Transportation cost in SIDS are the most expensive, as it is based on automobiles powered by petroleum fuels (gasoline, diesel and in a few very limited application LPG) because the petroleum fuels

6 NREL website

are shipped in relatively small volumes. Only in Vanuatu, and to a limited extent in the Marshall Islands, there is any substitution of renewable based liquid fuel such as coconut oil for petroleum. Cuba is the exception, where there are some passenger railroads. In Cuba, Jamaica and Fiji, railroads are used to a limited extend in industry. In Jamaica, the railway is used by the bauxite and alumina industry and in Fiji by the sugar industry. This points to the great potential for fuel cell vehicles as the foundation of transportation in SIDS in the future using the hydrogen produced by OTEC plants.

Increasing Fresh Water Availability

With few notable exceptions - Papua New Guinea, Dominica, Samoa, Fiji, Cuba and Jamaica - SIDS have very limited fresh water resources. Even in a number of these countries, the location of population and fresh water resources are not matched up. Additionally, with economic and population growth, the fresh water resources become less available and droughts have greater impact than in the past. Based on the Global Climate Change Models developed by the IPPC[7], which projects the declining precipitation over the tropical ocean, many SIDS are likely to experience the extended period of reduced fresh water availability, thereby aggravating present situation. This means that SIDS will increasingly have to desalinate seawater and consequently, increasing opportunity for OTEC as the desalination technology of choice, given its projected cost advantages over thermal or reverse osmosis desalination technologies.

In the Caribbean, for example, a number of countries are already utilizing desalination processes for the production of potable water, countries include: Antigua and Barbuda, that produces in excess of 6 million litres per day; Barbados produces between 12 and 16 million litres per day from a plant commissioned in February 2000; British Virgin Islands, where production in 1994 exceed 1 billion litres; Trinidad and Tobago, which has the largest facility in the region, providing water for industry, produces approximately 40 million cubic metres per year. Desalination plants are also operating in Anguilla and Belize. In the Cayman Islands, Curacao, Turks and Caicos Islands, and the US Virgin Islands, a number of smaller units are operated by hotel to meet their demand.

The cost of desalinated water is very high as all these facilities utilize reverse osmosis using electricity generated from petroleum. In the Bahamas, prices range from US$4.40 - $6.60 per cubic meter. In the British Virgin Islands, the capital cost is in the range of US$1190.00 – $2642.00 per cubic meter per day, and the costs is US$3.40 –$4.30 per liter. With growing population, expanding tourism and the threat of climate change reducing the availability of fresh water, there are significant opportunities in the SIDS for OTEC to provide potable water in addition to electricity.

Food Security in SIDS and the Potential of OTEC

In the majority of SIDS, particularly the smaller islands, the limited availability of land with fertile soil and limited water availability severely constrains food production. All SIDS depend on imports of food to meet both domestic and tourism needs. Food security for SIDS is therefore an issue of having the foreign exchange availability to import the grains, milk and protein sources that they are either unable to produce or cannot produce in adequate quantities for their demand. With growing population and increasing tourism, the majority of SIDS will have no option but to increase importation of essential foods.

OTEC has the potential to contribute to food security in SIDS in many ways. First, direct contribution is the utilization of large volumes of nutrient rich cold water, which would be discharged from an operating facility at about 10 degrees Celsius, for Mari-culture production. This application is demonstrated in Hawaii, US. Feasibility studies conducted by the University of the West Indies Centre for Environment and Development (UWICED), based on the Hawaiian experience, showed that the gross return per unit of land used for Mari-culture[8] would be more than ten times greater than which accrued

[7] Third Assessment Report of the International Panel on Climate Change, UNFCC 2002.
[8] The feasibility study was done on a system that would produce a range of product including Abalone, Lobsters, Crabs, Salmon, Tilapia

from growing bananas for export, and more than thirty times sugar earning. The employment generated was 300% greater than for bananas and more than 600% for sugar. Therefore, the first potential contribution by OTEC to food security would be a combination of enhanced domestic protein production and foreign exchange earnings.

The second potential contribution would be through increased availability of fresh water as a co-product from the OTEC plant, which would be available to support hydroponics farming. The third potential contribution would be using some of the cold seawater discharge to regulate greenhouse temperature and thereby maximize yield. The fourth potential would be based on the use of the water discharged from the plant to regulate the temperature of reefs to maximize photosynthetic activity and increase natural marine production in the coastal areas and beyond. The final potential contribution would come from the significant reduction in the vulnerability of SIDS to the escalating and volatile prices for petroleum, thereby significantly increasing the availability of foreign exchange available to import food supplies.

Enhancing Environmental Security

The BPOA pointed out that the sustainable development of SIDS, in the vast majority of cases, would be linked to extracting services and products from the environment. If SIDS were able to do so in a sustainable manner, i.e., without destroying or degrading the natural environment, their development would be sustainable.

As pointed out earlier, the significant degradation of the natural environment in all SIDS, because of their relatively small size and isolation, represents a serious threat to future survival of the present and future population. To a large extent, the ongoing environmental degradation is the combination of bad practices driven by the limited availability of options to find means of livelihood for a growing population. The situation is compounded further by the limited training and understanding of how to manage the natural environment and their limited resources. If the trend continues in the long-term, the impact will be irreversible damage. A particular case is coral reefs, which are the most critical ecosystem for SIDS. They are the basis of the tourism industry, which is the largest means of livelihood for the SIDS population, a principal source of food (protein), which is a major export for many SIDS, and the natural defence mechanism protecting the coastline, where the bulk of SIDS infrastructure and human settlements is usually located, and also protection from the raging tidal force driven by tropical cyclones/hurricanes. Degradation or destruction of coral reef ecosystems would therefore have dire consequence for many SIDS. An excellent example is presented by the Maldives.

The Maldives' economy is based primarily on fishing and tourism; consequently, it depends on the extensive coral reef ecosystem. During 1999 to 2001, there was a two degree Celsius increase in the average temperature in the Indian Ocean. As a result, there was a significant ongoing reduction in the marine catch, as shown in Figure.6. This reduction in catch is due to the physiology of the coral reef ecosystem in which a number of symbiotic relationships exist between different biological organisms. An increase in temperature by a few degrees changes the relationships and the coral's ability to convert sunlight into biomass, which provided the energy for the entire ecosystem including fish. This phenomenon is described as coral bleaching and this ends only when the seawater temperature returns to normal range. Recovery, also shown in Figure 6, takes much longer. OTEC takes heat from the surface as well as bring the cold water to the surface, so this could be utilized to help control bleaching of critical coral reef systems, potentially giving SIDS an option that is now not available.

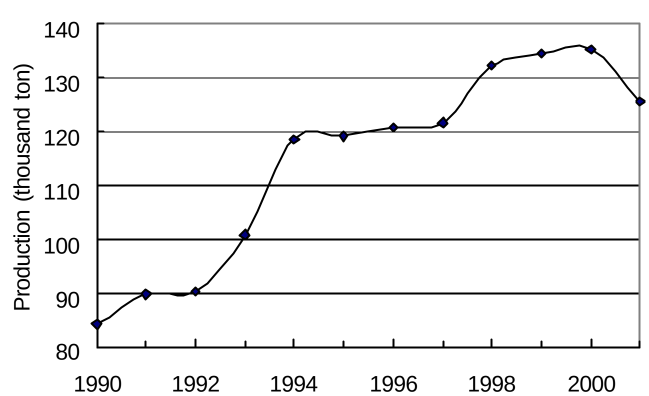

Fig.6. Marine Capture Production in Maldives

Source: FAO Statistical Databases

An emerging threat to environmental security in SIDS is the phenomena of climate change and sea level rise, which is likely to become significantly more serious at present, and in the medium to long-term. A principal concern, which is the increasing sea surface temperature, could have the most serious impact on the ecosystem in SIDS, particularly coral reefs, which are already under severe stress in a number of SIDS from sedimentation, pollution and improper fishing and maritime activities as outlined in recent reports[9].

Therefore, OTEC has the meaningful potential to assist SIDS by:

- Increasing employment through the lowering of energy costs, increasing competitiveness in providing goods and services in the global markets.
- Reducing the amount of outflow of foreign exchange, which is some SIDS exceed 20 % annually, thereby increasing the financial resources for the investments that creates new employment.
- New products for export as discussed in the section on food security.
- Direct and indirect contribution to reduce local pressure on the terrestrial and coastal environment.
- To begin the development of its largest undiscovered natural resources in the tropical ocean.

IV. Challenges to Realizing the Potential

Despite French Scientist Jacques D'Arsoval laying out the OTEC system almost 120 years ago, there has been very slow progress in developing the engineering systems that would make it possible to realize the enormous potential of this renewable energy technology. Early in the 21st Century, thanks to a dedicated team of researchers at institutions such as Saga University, Japan, National Renewable Energy Laboratory of the United States, and the efforts of private groups such Sea Solar Power, OTEC engineering has made tremendous advances in the last 25 years.

Based on engineering progress, in particularly the development of the Uehara cycle with a thermal efficiency of about 5 %, compared to earlier efficiency of about 3 %, has made the technology ready for commercialization. Ongoing research and development in institutions such as the Institute of Ocean Energy, Saga University (IOES) promises continued improvement over time.

A 30 kW experiment plant at Imari, in the Saga Prefecture, part of the Institute of Ocean Energy, Saga University, which is the only facility of its kind in the world, provides hard evidence of technological viability. There is no OTEC plant that is operating at the commercial scale equivalent to conventional power plants or wind and mini-hydro renewable energy plants. Absence of OTEC plants in the commercial scale remains due to questions of the technical and economic viability of the entire system as well as environmental impacts.

Technical Viability of the OTEC System

The OTEC system, at its simplest, consist of three components: an energy supply source component represented by the warm and cold water, pipelines, as well as the return pipelines that provides the thermal gradient; the desalinization system; and the energy conversion system. Advances in ocean engineering that allows for modelling of tidal and wave movements, have led to successful deployment of deep water pipelines in Hawaii, which provided the proof of the technical ability and feasibility of this component.

However, for the other two components, there is no evidence of successful operations at commercial scale, at present. Consequently, there is a valid question of technical viability of the entire system. Addressing this will require the commissioning of a commercial scale facility; the soon to be commissioned 1 MW capacity OTEC barge[10] will provide critical confirmation of technical viability at

[9] Reefs In Peril, World Resources Institute, USA, 2002

[10] The 1 MW barge is a research and demonstration facility being developed by the National Institute of Ocean Technology, India (NIOT) with technical support from Institute of Ocean Energy, Saga University (IOES).

close to commercial scale. The 1 MW facility will, however, not address economic viability, financing mechanism, or environmental impact of shore based OTEC plants.

Economic Viability and Financing

The first issue of economic viability arises from the high level of initial investment. This is the most easily understood in the context of energy efficient lighting in poor households. It is well known that poor households pay the highest cost of electricity per unit of service received, be it cooling, heating, lighting or refrigeration. This is a result of limited income, which serves as an obstacle to the acquisition of energy efficient and use appliances. Let us consider the case of light bulbs. It is generally accepted that a 70-75 watt incandescent light bulb will give as much lighting as a 20-25 watt compact fluorescent bulb, while using less than a third of the electricity, and also has a much longer life time, and use of the compact fluorescent bulb would bring about significant saving on electricity bills, making it a much better bulb to purchase, despite being more costly. However, with very limited disposable income, the poor household has no option but to purchase the cheaper bulb and pay the higher electricity bill.

An Innovative electric company, recognizing the economic benefits of end user efficiency develops a partnership with the household, and finances the cost of the efficient light bulb, and recovers the cost in the monthly utility bill. In that way, both the utility and the household realize economic benefits from the reduction in the amount of energy that is wasted by the bulb. Overcoming the obstacle of high initial investment required for an OTEC plant will require innovative financing partnerships similar to that used to finance efficient lighting. Such partnerships are tried by the US-based OTEC Company Sea Solar Power.

The second challenge is the relatively high degree of variability of overall initial cost estimation compared to petroleum-based systems. While a conventional energy developer can say very early what will be the cost per megawatt of diesel or fuel oil power plant at any location in SIDS with a significant degree of certainty, this is not yet possible with OTEC. This does not, however, represent a technical weakness, but rather a reflection of the site-specific nature of the most renewable energy technologies.

Environmental Impact

As discussed earlier, the environmental considerations are very important in SIDS and will become even more so in the future because future survival is directly linked to environmental preservation. While the OTEC system is potentially the most environmentally friendly development technology, there in no experience of the environmental impact assessment of the system.

The primary concern raised by environmentalist and also the Science and Technology Advisory Panel of the United Nations Environmental Programme (UNEP) in the January 2000, on the assessment of OTEC technology, is the management of the outflow water streams. As discussed earlier, rather than being a problem, the cold water outflows from the OTEC plant show potential for new commercial ventures like Mari-culture and horticulture, as demonstrated in Hawaii, USA, the extensive coastal-based fisheries and a potentially unique means to protect critical ecosystems from the negative consequences of increased ocean temperatures.

However, this potential will most likely be realized in the medium to long-term, after OTEC has proven its commercial scale as an energy system. There is need to show that the system can be used without the negative environmental impact. Based on deep-water simulation research at the IOES, the way to prevent

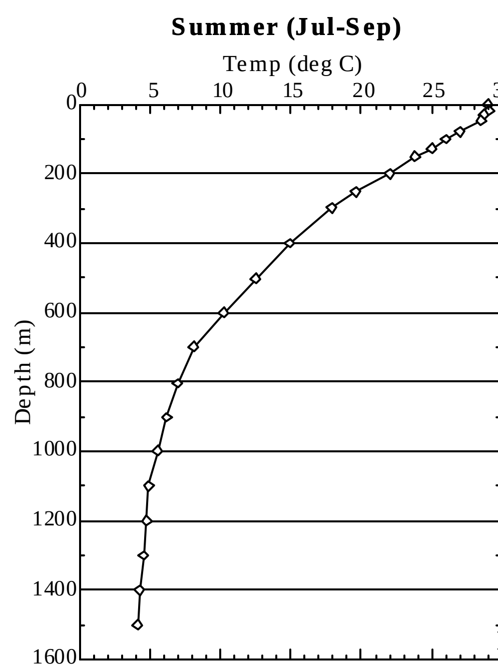

Fig.7 Temperature Profile in Jamaica

negative environmental impacts will be to design the pipeline system that will return the outflow from the OTEC plant to the appropriate ocean depth that coincided with the temperature of the combined water outlet from the plant. For example, in the case of a 10-megawatt plant using the Uehara cycle, such a plant would have an output of about 29 tons per second of water at about 23 degrees Celsius, and about 30 tons per second at about 10 degrees Celsius. The combined outflow would be about 59 tons and at a temperature of about 16 degrees Celsius. Based on its temperature and depth profile shown in the island of Jamaica in Figure.7, the return pipe would be placed at a depth of between 350 and 400 meters. However, this has to be demonstrated before OTEC will be given a positive Environmental Impact Assessment.

Reliability of System

While there is great interest at the policy level and among the sustainable development community in SIDS regarding OTEC, there is not the same degree of interest by the leadership of electric utilities. The leadership of the electric utilities are highly sceptical about endorsing new technologies, and unlikely to endorse any technology until it has been proven and they can get hard performance reliability and cost data. If the new energy technology is to be considered as the base load capacity, then the leadership become even more demanding about the data. The best way to convince this critical segment of the SIDS professionals is by having an OTEC plant on commercial scale, operating under conditions similar those in their country.

Limited Capacity

One of the defining socia l characteristics of SIDS is the limited scientific and technical capacity in order for this not to be an obstacle against commercialisation. It will be necessary for the development of specially designed initiatives to help these countries to develop the capacity for the effective management of this technology. One possible option will be through the collaboration between Saga University and the regional universities in the Caribbean and the Pacific, such as the University of the West Indies and the University of the Southern Pacific respectively.