ENVIRONMENTAL ISSUES OF NATURAL TEMPERATURE DIFFERENCES UTILIZATION

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Keywords: OTEC, AWTEC, Impact, Environment, Effluent

Contents

Summary

In this article the environmental issues of both the energy conversion concepts using the temperature gradients that exist between water masses in the ocean at low latitudes (OTEC) and between sea or river water and air at high latitudes (AWTEC), are examined. Both OTEC and AWTEC use a degraded solar energy resource that does not consume irreplaceable natural resources nor generate specific pollutants. Yet building and operating plants will inevitably disturb the natural environment in their close surrounding and - to some extend - at the regional and global levels. The AWTEC and OTEC threat for the environment depends upon the very processes of the energy conversion themselves, and upon the size and the design of the installations. As for the environmental consequences they are depending upon the characteristics of the site and its surrounding ecosystem.

To make sense, the effects of OTEC and AWTEC operations on the environment should be envisioned within a realistic scheme of their industrial development and compared, where possible, to those of traditional systems of power production.

1. Review of the OTEC and AWTEC Potential Markets and Development Foresight

Whatever could be the results of the international efforts to sober the world population's hunger for energy, the ineluctable increase of the energy demand imposes to diversify and account for all the available resources among which solar resource like OTEC are potentially the most promising. The feasibility of OTEC has been demonstrated but it will take several decades to achieve its industrial development enabling the production of a significant amount of energy to satisfy both the population demands and the economic constraints.

There are several potential markets for OTEC. One is considering the need for electric energy for small isolated communities of few thousands inhabitants - as there are many in the tropical oceans archipelagos. It could be satisfied with small OTEC open or closed cycle electric power plants of few tens MW of capacity. Electricity production shall probably be associated with marine culture and fresh water production. For example few hundreds of such plants could greatly contribute to free many of the small South Pacific States and Territories from fossil fuel dependency, at least for their sector of electricity consumption.

A second opportunity market are the medium size OTEC plants of 50 MW to few hundreds MW to supply electricity and possibly cold water for air-conditioning and other cooling facilities to coastal cities in the tropical region.

Typical of that kind are the shelf-mounted facilities proposed for Hawaii and Puerto-Rico at the beginning of the 1980s, or that of the 20 years Master OTEC Plan proposed in 1994 for the Republic of China (MOPR). In their plan the Taiwanese promoters envisioned to install height plants moored offshore the East coast of the island for a total OTEC electric capacity of 3200 MW. This represents about 8% of the needs for Taiwan's installed capacity as planned for year 2007.

The third potential market - but probably the most important in the long term - is that of fleets of floating plants of hundreds of MW each that will « graze » the solar energy stored in the warm water surface pools that exists in the oceans of the tropical regions to produce transportable fuel to respond to the needs of industrialized countries in the medium latitudes. Calculation shows that four hundred OTEC plants of 200 MW each could produce enough methanol to replace the gasoline used in the US and produced from imported petroleum.

It shall reasonably take a period of twenty to fifty years to fully explore and develop technology allowing OTEC to contribute significantly e.g. up to few hundreds of GW electric power, to the world's energy future demand. This prospect supposes a financial effort that could easily support the necessary research programs indispensable to investigate in detail the OTEC environmental issues and propose solutions.

More theoretical studies and experimental results are necessary to evaluate the technical, the economics and markets of AWTEC. Presently the most probable suitable sites for AWTEC plants are located on the Siberian rivers banks with an estimated thermal energy potential of 25 GW. It could contribute to local economy but any large industrial development for AWTEC within the next decades appears presently a hazardous speculation.

2. Review of the Main Environmental Characteristics of the Potential OTEC Plants Sites

Except in few oceanic regions where « upwelling » or « down welling » occurs, the natural forces induce water circulation patterns in the oceans that most generally limits thermal exchanges between the surface and the deepwater masses. Salient common features of temperature profiles in tropical deep ocean are: a warm homogeneous surface layer, a thermocline region in which temperature falls rapidly and a deep region in which the temperature decreases slowly with depth.

The potential sites for OTEC installation are located in the tropical belt where large temperature differences exists between surface and deep water masses generally separated by a short vertical distance of few hundreds of meters.

To these three zones of the vertical thermal profiles is superimposed the photic zone where the solar radiation can penetrate. It extends from the surface down to imprecise limits depending on the water turbidity. Deep water travels for long periods of time far from the photic zone where the solar radiation supplies energy for the photosynthetic production of living material. During that travel, the time scale of which is of the order of several centuries, the deep water is enriched with the decomposed organic materials that drop from the surface. Thus the characteristics of the water from the depths differ from those of surface water not only because of their physical parameters but also because of their bio-chemical contents and specially their nutrients contents.

The amounts of air gases dissolved in seawater are functions of the pressure (i.e. the depth), the salinity, the temperature, and the biological activity. Oxygen and carbon dioxide are the more important as they are determinant for the biological processes in the photic zone. For oxygen the concentration ranges between 5 to 10 ml per liter in the mix layer and is close to zero in the depths. For carbon dioxide the concentration are typically 44 to 50 ml per liter (2 to 2.3 mmol kg^{-1}) at surface and 1000 meters depth respectively.

Some important parameters for surface and deep waters quality at Tahiti (French Polynesia) and at the Natural Energy Laboratory of Hawaii Authority (NELHA, USA), are given in Tables 1 and 2.

Parameters	Surface	At 700 m	At 1000 m
Temperature, °C	28	5.5	4
Density, σ_t = (1000d-1)	23	27.2	27.41
Salinity, °/°°	35 to 36	34.5	34.5
Nitrate, mmol m^{-3}	O.I to 1	12 to 18	25
Phosphate, mmol m^{-3}	0.4 to 0.5	0.7 to 2.5	3
Chlorophyll, mg m^{-3}	0.61	0	0

Table 1. Surface and Deep Ocean Water quality data at Tahiti, French Polynesia

Parameters '	Surface	DOW at 600 m

Temperature, °C	26.19 ± 0.99	8.83 ± 1.18 (a)
Salinity, °/°°	34.74 ± 0.18	34.30 ± 0.03
pH	8.24 ± 0.05	7.61 ± 0.09
Alkalinity	2.31± 0.02	2.36±0.03
$NO_3 + NO_2$ micromolar	0.24 ± 0.18	39.03 ± 1.83
PO_4 micromolar	0.15±0.04	2.89 ± 0.26
Si	2.64 ± 0.95	74.56 ± 4.64
NH_4, micromolar	0.20 ± 0.13	0.06 ± 0.07
Dissolved organic N, mg per liter	5.39 ± 1.27	41.36 ± 2.85
Total organic C, mg per liter	0.68 ± 0.68	0.50 ± 0.47
Total Suspended Solid, mg per liter	0.88 ± 0.96	0.34 ± 0.20

(a : measured in lab).

Table 2. Surface and Deep Ocean Water quality data at NELHA, Hawaii, USA

The regions with potential sites favorable to the installation of AWTEC plants are limited to the Arctic and Antarctic. The Antarctic coast line being presently excluded for political reasons and the only sites that are under consideration are located on the coastline of the Arctic ocean and on the banks of Siberian rivers where few human communities live during the winter period and where a temperature difference between waters - from either seas or rivers - and the ambient air temperature averages 30 to 40°C for about 200 days a year. The ecosystems of these sites are generally considered as biologically rich and environmentally fragile.

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Biographical Sketch

M.Gauthier was born in France in 1935. He holds an Engineer degree from « l'Ecole Nationale Supérieure des Arts et Métiers » (ENSAM, Paris 1957), a Master in Mechanical Engineering from the Illinois Institute of Technology (IIT, Chicago, USA 1958), and a Nuclear Engineering degree from « l'Institut National des Sciences et des Techniques Nucléaires » (INSTN, Saclay 1963).

He served as an Officer in the French Navy (1959-1960). In 1961 he joint the « EURATOM - European Community for Atomic Energy - in Brussels. He came to the «CNES » - Centre National d'Etudes Spatiales in 1963 and worked one year for TWR in Redondo Beach California before joining the CNEXO (Centre National pour l'Exploitation des Ocean) in 1970. (CNEXO became «IFREMER -Institut Français de Recherche pour l'Exploitation de la Mer » in 1984).

In CNEXO/IFREMER he was the head of the Technology and Industrial Department (1970-1975), of the French Deep Sea Mining Project (1976-1979) and head of the Tahiti OTEC project (1982-1986). He served as a consultant for the European Community « Marine Sciences and Technology Programme » (Brussels, 1987- 1990) before becoming the IFREMER Delegate for the Pacific Region (Nouméa, New-Caledonia, 1990-1994). In 1994 he joint the EuroGOOS Secretariat hosted at the Southamptom Oceanography Centre , UK. He retired from IFREMER in 1998.

He was awarded officer of the French «Ordre National du Mérite » in 1986.

He is the acting Chairman of the IOA, International OTEC/DOWA Association, since its creation in 1990.