# Rick Dworsky: A Warm Bath of Energy -- Ocean Thermal Energy Conversion

Posted by Prof. Goose on June 5, 2006 - 5:14pm
Topic: Alternative energy
Tags: energy conversion, ocean energy, otec [list all tags]

**[editor's note, by Prof. Goose]** This is a guest piece by Rick Dworsky--he has been involved in environmental conservation and energy issues for over 30 years in government and private industry.

In 1870, in Twenty Thousand Leagues Under the Sea, Jules Verne wrote: "I owe all to the ocean; it produces electricity, and electricity gives heat, light, motion, and, in a word, life to the Nautilus."

Indeed, the Earth has an enormous natural solar collector - the tropical oceans. "On an average day, 60 million square kilometers (23 million square miles) of tropical seas absorb an amount of solar radiation equal in heat content to about 250 billion barrels of oil."(1) Energy "equivalent to at least 4000 times the amount presently consumed by humans."(2) If we can tap into this renewable source, considering thermodynamics and entropy, approximately 1% of it could provide the entire current worldwide demand for energy. More than enough energy is available, we only need a way to get it - in a practical, cost effective, ecologically safe and sustainable way.

Ocean Thermal Energy Conversion (OTEC) is a technology that can extract useful work from solar energy stored in the sea. Since the sea IS the energy storage medium, OTEC offers 'always on' baseline supply -- during bright clear days and dark nights, in still air and ferocious wind storms -- without the expense and complications of artificial energy storage systems.

---

In 1881, eleven years after Verne -- 125 years ago -- Jacques Arsene d'Arsonval, a French physicist, conceived OTEC. It operates on the temperature differences between warm surface and cold deep waters - using a heat engine built for the purpose. Wherever a 20 degree Centigrade (36 degree Fahrenheit) difference or greater is readily obtainable between warm surface and cold deep waters, the process can be put to work. In 'Open Cycle' systems, lowering the pressure above warm water turns it into a vapor, effectively 'steam', which runs a turbine before it is recondensed by cold water. In 'Closed Cycle' systems and hybrids, the water heats and cools -vaporizes and recondenses- an intermediary fluid/gas that powers a turbine within a closed sub-system, which enables much larger energy outputs. Basic heat engine physics. The concept, at least, for OTEC had arrived. But the idea preceded the materials technology and manufacturing methods required to make it, and further, make it competitive with fossil fuels.

In 1930 Georges Claude, d'Arsonval's student, built the first experimental OTEC system in Cuba. It produced a gross output of 22 kilowatts (kW) of electricity. Five years later he built a floating OTEC generator in Brazil. Both of these pioneering efforts were destroyed by weather and high seas. High capital investment costs and cheap fossil fuels prevented the further development of OTEC until fairly recently. In 1979, off the coast of Hawai'i, a tiny OTEC generator produced, for the first time, a net output - of 18 kW. A system efficient enough to meet the power requirements of it's pumping systems and provide additional useable energy had been created. A plant which continuously produced more than 50 kW soon followed.

Design and material advances have now reduced the capital investment costs of OTEC to a competitive position in suitable locations, given the expected price of oil over a minimum 25 year life cycle. OTEC facilities can probably be maintained -sustained- far longer than that, perhaps 'forever' - if we reserve enough surplus bio-mass to replace ingredients currently made from petroleum, such as fiberglass resins (synergy with OTEC would return better ERoEI than burning). Currently the Indian Ocean, Caribbean, South Pacific and Hawaiian regions present cost effective scenarios for landed OTEC facilities. If a major OTEC industry develops, costs are expected to fall low enough to justify implementation world wide - at least wherever the process will work - an ocean belt spanning approximately 20 degrees to the north and south of the equator. Land based plants are contracted or under construction in the Cayman Islands and Mauritius. A Japanese company built a 1 megawatt plant in India. Hawai'i has a leading edge OTEC laboratory where working models have been proven, a deep cold water pipe is already in place - better funding could be put to good use.

Large floating OTEC platforms have been designed which would drift and 'graze' warm tropical seas, harvesting the energy, using it to extract hydrogen from sea water, to be picked up by transport vessels and delivered where it is needed. Ammonia, methanol and other compounds could also be produced. At the moment however, only terrestrial and undersea cable transmission of electricity is cost effective - limiting OTEC to land and near shore installations close to waters with sufficient temperature differences.

In no case would critical working parts need to be exposed directly to the ravages of the sea - high and dry on land or safe above sea level on floating platforms larger than super tankers, only the tubes to draw in water would need to endure the difficult ocean environment. The United States has already completed design, production and testing of the required durable cold water intake tubes and their attachment to vessels. The U.S. Navy has proven the use of OTEC generators shipboard.

OTEC can be built with non-exotic materials which do not require expensive secure disposal. While some designs (Uehara Cycle) require titanium, it has also been shown in other designs that the heat exchangers can be made of common aluminum without excessive corrosion problems.

At this time OTEC appears to offer an environmentally neutral energy source. The intermittent injection of minimal amounts of chlorine to prevent bio-fouling of the warm water intakes, and the leaching of metal particles and other materials via erosion/corrosion would probably be environmentally insignificant. Large storage tanks for chlorine would not be necessary - small amounts could be generated 'live' as required to manage the danger to personnel. No bio-fouling within the cold water intake tube has occurred. Although a 100% kill rate for small organisms such as phytoplankton that get drawn into the warm water intakes is probably inevitable, it is believed that this can be mitigated by the pumped 'upwelling' of cold deep fertile waters and the outfall effluent. Only extensive monitoring of an installed mid-size test facility can enable a comprehensive environmental assessment, and find the balance point between bloom and bust. Adjustments of the outfall depth may be necessary, according to local conditions. It may well be the case that OTEC can target some of the energy that causes damaging and catastrophic storms and redirect it into useful work, if large mobile floating platforms become a reality. We should carefully consider when a location can host the process and remain within it's normal temperature gradient range, this would be similar to concerns about the energy absorption effects of solar panels and windmills. OTEC appears to be a vast, renewable, sustainable, safe, 'always on' energy source that does not emit $CO_2$ or nuclear waste.

Landed OTEC facilities could also provide cold outfall water for reuse in air-conditioning, refrigeration and sea water agricultural projects - 'mariculture'. Some OTEC designs and add on modules produce copious volumes of safe distilled drinking water, a much needed commodity in increasing demand in many tropical locations where OTEC could be based.

Given all the fantastic promise OTEC presents, the amount of useful energy that can be obtained from each cubic meter of sea water is relatively small. The quantity of water that would have to be processed to produce a significant amount of useful energy would be enormous. Deep cold water intake tubes 11 meters (36 feet) in diameter with pumps of the same scale are proposed for 100 megawatt units. "The discharge flow from 60,000 MW (0.6 percent of present world consumption) of OTEC plants would be equivalent to the combined discharge from all rivers flowing into the Atlantic and Pacific Oceans (361,000 m3 s-1)."(3) OTEC is a technology of oceanic magnitude. To ameliorate the enormous problems of Global Warming, Peak Oil, Fresh Water, and Food supplies, we are going to need proportionally large solutions. Our task would be easier if we could reverse Human Population pressures.

OTEC may be one of our best hopes for the environmentally clean, sustainable solutions we need to solve our global energy and environmental problems - or at least a substantial chunk of them. In combination with other renewable sources, efficiency gains, conservation and adequate voluntary population management, we may be able to maintain a semblance of world civilization.

Perhaps we can still save our Nautilus.

Footnotes:

1. http://www.cogeneration.net/ocean_thermal_energy_conversion.htm
2. http://www.otecnews.org/articles/vega/01_background.html [Note: The seemingly high percentage (1%) of required renewable energy inputs to meet world demand through OTEC is due to entropy and thermodynamics - a basic physical constraint. The theoretical maximum OTEC efficiency is about 8%, but for various practical reasons 3% is more typical.]
3. http://www.otecnews.org/articles/vega/02_tech_limitations.html

A few links for further research:

National Renewable Energy Laboratory (U.S.) http://www.nrel.gov/otec/what.html
Department of Energy (U.S.) http://www.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50010
National Energy Laboratory of Hawaii Authority (U.S.) http://www.nelha.org/
OTEC News (U.S.) http://www.otecnews.org/
Wikipedia http://en.wikipedia.org/wiki/OTEC
Sea Solar Power (U.S.) http://www.seasolarpower.com
Marine Development Associates, Inc. (U.S.) http://www.marinedevelopmentinc.com/ocean_energy
Cogeneration Technologies (U.S.) http://www.cogeneration.net/ocean_thermal_energy_conversion.htm
World Energy Council (U.N.) http://www.worldenergy.org/wec-geis/publications/reports/ser/ocean/ocean.asp
Xenesys, Inc. (Japan) http://xenesys.com/english/index.html

Wired Article http://www.wired.com/wired/archive/13.06/craven.html
The National Institute of Ocean Technology (India) http://www.niot.res.in/m1/otec.htm