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Deep Ocean Water as a Catalyst for Economic Development at NELHA (Natural Energy Laboratory of Hawaii Authority)

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In 1973, the world experienced a crisis that had an impact at all levels of the economy. The crisis was named the Arab Oil Embargo and was caused by the conflict between Israel and Arab nations. For island nations like Hawaii and Japan, such an oil crisis had a crippling effect on the local economy as having no oil means not being able to provide the basic services for a community. Fortunately for the State of Hawaii, the top government officials had a vision to reduce the vulnerability of Hawaii by generating its own source of energy. Just one year after the Arab Oil Embargo, Governor John Burns commissioned a project to Dr. John P Craven who was in charge of the Polaris Nuclear Submarine program during the cold war. The project was to create the Natural Energy Laboratory of Hawaii on the Kona coast of the Big Island of Hawaii to research how electricity can be produced by the temperature difference of the warm surface seawater and cold seawater from the deep. And that process is called OTEC or Ocean Thermal Energy Conversion (Claude 1930). While OTEC was developed in 1881 by a Frenchman named Jacques D'Arsonval and attempted to be proven by his student George Claudes, it was not until 1979 at NELHA that for the first time in history, OTEC was proven a success with NET power output. This project was a closed cycle OTEC plant performed just off-shore from NELHA on a barge and did 15kW of NET electricity production. The success of this project led to the start of an Open Cycle OTEC project at NELHA from 1992 to 1998 where not only electricity was created, but also fresh water, which is also a valuable commodity for the dry West Hawaii (Vega 2001).

In 1981, the State of Hawaii installed two pipelines to pump both warm surface water and cold, deep ocean water. Later in 1984, two more pipelines were installed with larger capacity. Then in 2001, to allow for a 1 MW OTEC plant to be built, the State of Hawaii installed two new pipelines of surface and deep seawater at a $25 million cost. These two new pipelines pump 21,000 gallons of seawater per minute using HDPE pipes (140 cm in diameter) where the deep water is being pulled up from 915 meters deep and is 5℃ in temperature (Table 1).

NELHA's ability to pump warm surface water and deep cold water was not just an asset for electricity through OTEC production but also proved to be the ideal location for the growing of seafood which helps with the food security issue. The chemistry of deep seawater pumped at NELHA was shown in Table 2 with data of surface seawater for comparison. In fact, the ability to fine tune the temperature of the

Table 1. Diameter, intake depth offshore pipe length and pumping capacity of deep and surface seawaters pumped at NELHA (Website: http://www.nelha.org/about/facilities.html)

Seawater	Pipe inside diameter (cm)	Intake depth (m)	Offshore pipe length (m)	Pumping capacity (m^3/s)
Deep seawater	100	674	1,916	0.84
	45	628	1,884	0.19
	140	915	3,124	1.80
Surface seawater	71	21	163	0.61
	61	10	81	0.34
	140	24	165	2.56

seawater for aquaculture purposes creates a most favorable environment for high productivity among farms. Fortunately, NELHA's location allows it an almost constant temperature for the surface water making it much easier for farms which do not have to make adjustments in water use from winter to summer. Finally, the amounts of nutrients including nitrate, nitrite, silicate, phosphate and dissolved organic nitrogen are found to be high enough to make ideal water for fish farming and when coupled with the high insolation make for an ideal situation for plant growth. Today, 70% of the aquaculture in the State of Hawaii is being done on Hawaii Island.

More recently, NELHA has utilized its seawater pipelines for energy related projects, allowing it to go back to its original intent on developing natural energy initiatives. A project called Keahole Solar Power uses concentrating solar collectors to focus the sun's heat to create thermal energy generation using an organic rankine cycle generator. Like OTEC, organic rankine requires a large temperature difference to provide the pressure needed to drive the turbines. Normal locations which do not have access to deep ocean water would need some way to provide cold temperature, however, the project at NELHA uses existing deep ocean water to create the Delta T needed for efficient power generation.

Table 2. Water chemistry comparison between surface and deep seawaters pumped at NELHA (Website: http://www.nelha.org/about/seawater_data.html)

Parameter	Surface seawater (SSW)	Deep seawater (DSW)
Temperature	24-28.5℃	5-8℃
Salinity	34.7‰	34.3‰
pH	8.3	7.6
Alkalinity	2.31	2.36
Nitrate/Nitrite	0.24 μm/l	39.0 μm/l
Phosphate	0.15 μm/l	2.89 μm/l
Silicate	2.64 μm/l	74.56 μm/l
Ammonia	0.20 μm/l	0.06 μm/l
DON	5.39 μm/l	41.36 μm/l
DO	6.87 mg/l	1.24 mg/l
TOC	0.68 mg/l	0.50 mg/l
TSS	0.88 mg/l	0.34 mg/l

One of the most useful ways NELHA and their tenants use the cold temperature of the deep ocean is in heat transfer applications where a heat exchanger replaces the traditional refrigerant coolant. This technique allows for an 80% reduction in electrical cooling costs.

Finally, one of the more interesting uses of the seawater has been to grow microalgae. The algae itself is grown in freshwater with sodium bicarbonate additive but the deep seawater nutrients are used to fertilize the algae. Then during the harvesting process, the deep seawater is used to 'air-condition' the drying environment thus speeding up the drying process (Fig. 1). In January of 2009, some of the algae were used to create an aviation biofuel which was used on a one hour test flight from Houston

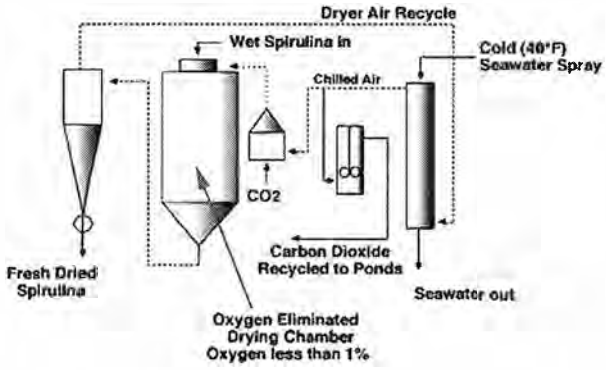

Fig. 1. Use of deep seawater as a air-conditioner for drying cultured *Spirulina*.

by Continental Airlines.

To summarize, the combination of cold deep ocean water and warm surface water pumped at NELHA has proven to be a winning combination for economic development in Hawaii. By growing business in sustainable technologies involved with food, water, energy and health, NELHA adds $30-40 million to the States GDP each year while reducing the vulnerability of the island's food and energy security.

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