Context

Island and coastal communities face increasing challenges from global-scale changes such as sealevel rise and warming. As logistics chains and traditional energy sources become more expensive and unreliable, there is increasing demand for climate resilient local solutions for water, energy, food, economic, and social regeneration. Deep Ocean Water (DOW) is a local resource available to more than 90 countries that can enable communities to create their own local power, farm and fish more reliably, cool buildings with less electricity, and provide environmentally friendly desalination for water security.

Solution

In Japan, existing DOW intake on Kumejima, Okinawa provides the water resources for more than $24million a year in revenue from a variety of industries as well as a 100kW Ocean Thermal Energy Conversion (OTEC) demonstration facility. The island's plan for its future, a combination of OTEC and DOW industries, where water can be used multiple times and supplied to users with the varying temperatures as required is coined the "Kumejima Model." This concept is particularly attractive for small islands and near-shore communities such as Palau.

Ocean Water Intake

Water intake and distribution is approached as a separate infrastructure project as it serves various industries and can be self-supporting from ocean water sales. It supplies the basic resource seawater for energy, water, food, and economic regeneration.

OTEC

OTEC operates as an independent power producer, providing power 24/7 with no fuel costs, while also providing various benefits to the intake system. It provides firm and rotating (turbine driven) power for grid stability and resilience.

DOW Industries

Together, OTEC and DOW Intake make ocean water resources available at various useful temperatures and water qualities for other separate follow-on projects such as seawater air conditioning (SWAC), desalination, aquaculture, agriculture, cosmetics, coral management, tourism, food production, data center cooling, etcetera.

PROJECT SUMMARY

PROJECT NAME:

Deep Water Intake Infrastructure powered by MW-scale OTEC

CAPITAL COST:

Ocean Water Intake and Distribution Cost: $40~110 million (site/method dependent).
OTEC Cost: $24 million (@1MW)
DOW Industry Costs: Each Separate Project

DEVELOPER:

Japan Industrial Academic Consortium including Institute of Ocean Energy Saga U. (IOES) and Xenesys Inc.

PROJECT HOST:

Palau, RMI, etc.

GEOGRAPHICAL LOCATION:

Palau, Oceana, etc.

TYPE OF PROJECT:

Energy

PROJECT TIMELINE:

4 year development, 40+ year operation

Technology

Ocean Water Intake

Around the world there are at least 45 deep water intakes of various scales providing communities with local resources. DOW Intake provides a long-term solution from high density polyethylene (HDPE) materials that do not corrode and can last tens of years or more. This proposal's inclusion of OTEC as a companion improves the environmental impact and economic efficiency of the DOW intake as infrastructure concept as currently employed worldwide. OTEC baseload power generation with ocean water resources provide for a variety of industries that regenerate local industry. The pipe materials allow for an operational life of 37 years or more, as demonstrated at the Natural Energy Laboratory Authority of Hawaii (NELHA) where intakes have been in use since 1987. NELHA is a DOW water intake and distribution facility with the world's largest intake and largest industrial use.

OTEC

OTEC is a type of renewable power generation where warm surface water, heated by the sun, is used to vaporize a low-boiling-point working fluid in a heat exchanger. The vapor drives a turbine to create power, then the vapor is condensed back into a liquid with deep ocean water for reuse in a continuous cycle. For OTEC, the low temperature difference results in a theoretically low efficiency, which is offset by the vast and renewable warm and cold-water resources freely and locally available in the ocean. Technological advances in Japan through 50+ years of research have resulted in advanced cycles, heat exchangers, and knowhow to effectively deploy OTEC economically. The basic technologies have been demonstrated long-term in Okinawa since 2013. The novel approach inspired by Kumejima is to connect DOW industry and OTEC to increase efficiency and benefits to all users through multiple use of the water resource.

DOW Industries

In general, DOW is a resource that supports various existing technologies (not a new technology) that uses the cold, cleanliness, and nutrient salts from deep water. There is a track record in the private sector for SWAC, aquaculture, agriculture, etc. There are a variety of industrial ocean water technologies and techniques available for implementation depending on the final site and local characteristics. As a model, the available menu of options can be tailored to each subsequent implementation. On Kumejima, where water is plentiful, the main DOW industries are aquaculture, however, desalination, seawater air conditioning, or even chilled-soil agriculture may be added in to fit local needs. The most successful DOW Industry implementations improve or expand existing operations.

Business Model

We propose a water supply and distribution business for deep water management, and a separate power generation business.

Ocean Water Intake Project

Simply, once installed, this ocean water intake will operate as an ocean water sales business. As an infrastructure project it is almost the same as water supply or industrial water businesses. The intake operation and maintenance are paid for through water sales to businesses. The intake has low maintenance needs. Follow-on industries buy water, sell products, and contribute to economic growth. The capital cost of an intake system depends on the exact location as the length of the pipe will change. The cost of water to businesses can be set based on use to encourage specific industry development.

For Palau, a Feasibility Study will select the best intake location in terms of cost and benefits. Past studies indicate an onshore intake will cost on the order of $50~110 million USD depending on the installation method, distance to desired depth, final pipe size, and other factors. Once installed, the Intake will provide water resources to various users including OTEC. In the case of Kumejima, a 2017 study by the Okinawa General Bureau Cabinet Office of Japan estimated an expanded DOW Intake Facility would cost 8.4 billion JPY (67.2 million USD when 1USD =125JPY) and revenue from DOW Industries would reach 8 billion JPY/year ($64 million USD/year). There are many sites that would have much lower costs from shorter pipelines and advantageous environmental factors.

Ocean Thermal Energy Conversion Facility

The OTEC facility, likely installed as a separate, complimentary project, acts as an anchor tenant, providing renewable energy at costs lower than diesel in many cases, and decreasing the energy use for pumping by industries. Research performed in Japan based on detailed design and actual demonstration expects a commercial OTEC plant at 1MW-scale to cost $24 million USD with O&M cost per year of $156,000. This results in a rough power generation cost of $.145/kWh.

Ocean Water Industrial Use Projects

There are a variety of options for use of the ocean water resources enabled by the Ocean Water Intake Project and OTEC Project. Each additional use will have its own associated cost and benefits, and may include desalination, agriculture, aquaculture, nursery (including corals) and research, and other commercial applications.

Financing

The significant capital cost of DOW intake, despite low operating and maintenance costs, the ocean environment, and long operational life are risks that makes traditional financing difficult. As the intake provides resources to multiple industries, it is appropriate to approach as public infrastructure. This is the method for deployment at NELHA, where the impact of NELHA on the State's output was $103.6 million in 2018.

For OTEC, advantageous financing can allow reduced power generation costs, which maximizes the paradigm shift from fossil fuel to renewable local energy. As an independent power producer, it may operate as a private sector project.

Results

As a supply of local resource for economic development, ocean water intake provides an adaptable base for decarbonization and development of existing industries, plus new job opportunities and industrial diversification at various economic levels. It is expected that deep ocean water and OTEC would be an essential enabler for the MARES framework.

Lessons Learnt

Deep Ocean Water Intake is now an established technology with a track record of 37 years of operation in Hawaii and multiple sites in Japan being established from 1989. Among them, the Kumejima intake established in 2000 has recently had accelerated action towards larger-scale implementation due the need for more renewable energy, the decrease in natural fishery resources, and increase in agricultural instability due to climate change. Concerning OTEC, autonomous continuous operation has been confirmed through operation of the demonstration facility since 2013.

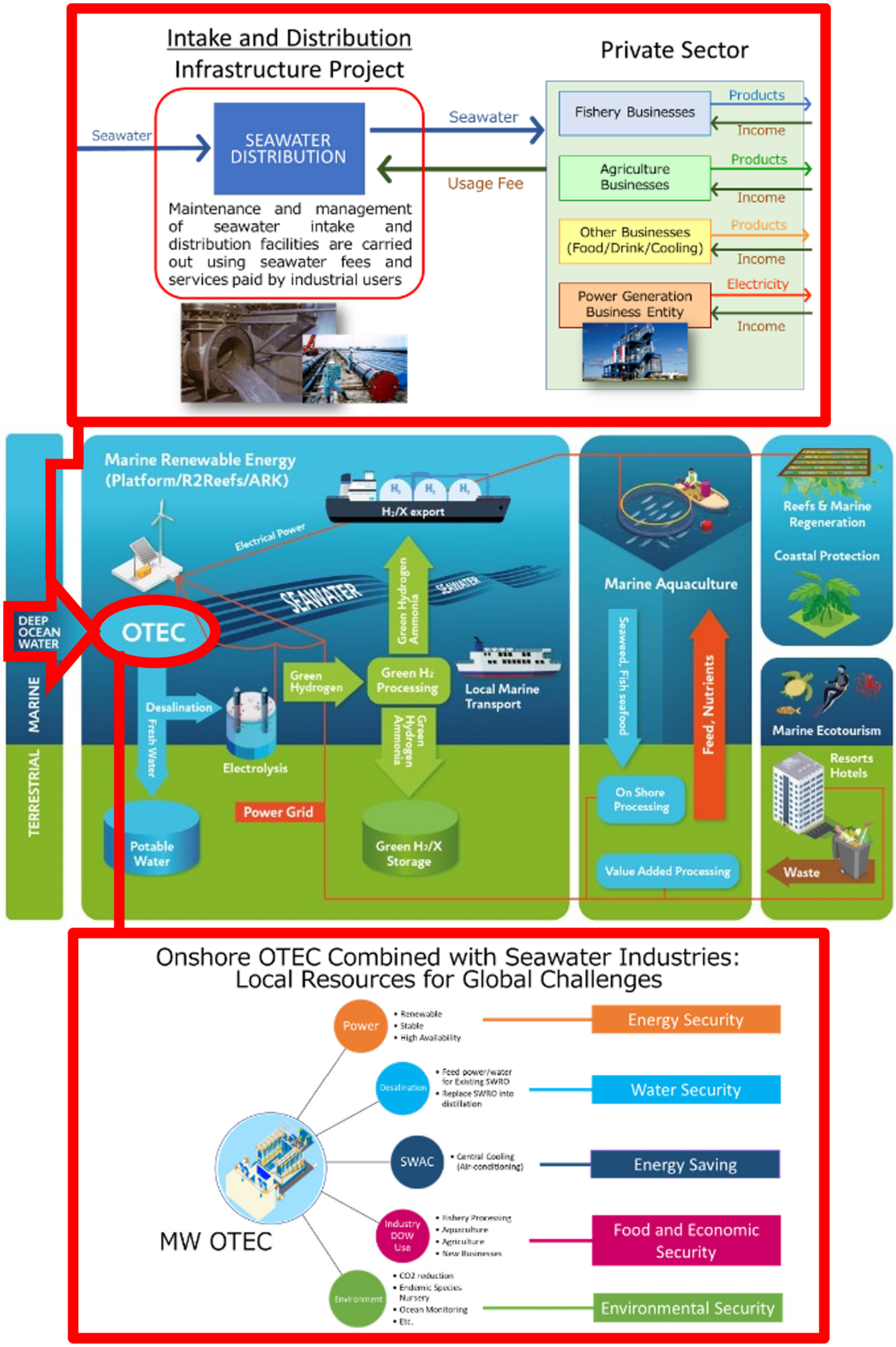
Developer

An industrial and academic consortium centered on the Institute of Ocean Energy Saga University (IOES) in Japan has more than 50 years of experience in OTEC research and development. Among the organizations with experience and knowhow in implementing such projects, Xenesys Inc. has focused on research and development of Ocean Thermal Energy Conversion with core capabilities including the design and construction management of power generation systems and the manufacture of heat exchangers.

References

Institute of Ocean Energy, Saga, Xenesys Inc, OTEC PreFS Study Conducted for CTCN on Nauru, FY2017 Study by Okinawa General Bureau (in Japanese), Economic Impact of NELHA tenant on Hawaii in 2018

Appendix


Intake and Distribution
Infrastructure Project
Seawater
SEAWATER DISTRIBUTION
Maintenance and management of seawater intake and distribution facilities are carried out using seawater fees and services paid by industrial users
Seawater
Usage Fee
Private Sector
Fishery Businesses
Products
Income
Agriculture Businesses
Products
Income
Other Businesses (Food/Drink/Cooling)
Products
Income
Power Generation Business Entity
Electricity
Income
Marine Renewable Energy (Platform/R2Reefs/ARK)
H2/X export
Electrical Power
SEAWATER
Green Hydrogen Ammonia
DEEP OCEAN WATER
OTEC
MARINE
TERRESTRIAL
Desalination
Fresh Water
Electrolysis
Green Hydrogen
Green H2 Processing
Local Marine Transport
Green Hydrogen Ammonia
Power Grid
Potable Water
Green H2/X Storage
Marine Aquaculture
Seaweed, Fish seafood
Feed, Nutrients
On Shore Processing
Value Added Processing
Reefs & Marine Regeneration
Coastal Protection
Marine Ecotourism
Resorts Hotels
Waste
Onshore OTEC Combined with Seawater Industries:
Local Resources for Global Challenges
MW OTEC
Power
• Renewable
• Stable
• High Availability
Energy Security
Desalination
• Feed power/water for Existing SWRO
• Replace SWRO into distillation
Water Security
SWAC
• Central Cooling (Air-conditioning)
Energy Saving
Industry DOW Use
• Fishery Processing
• Aquaculture
• Agriculture
• New Businesses
Food and Economic Security
Environment
• CO2 reduction
• Endemic Species Nursery
• Ocean Monitoring
• Etc.
Environmental Security

	Construction/Development			Operation→										(Thousands USD)	
Item	Year -3	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9		Year 39	Year 40
Marine Renewable Energy															
Capital Cost		$ (12,000)	$ (12,000)												
Total Capital Cost				$ (24,000)											
Revenue - OTEC@$.20/kWh				$ 1,697	$ 1,731	$ 1,766	$ 1,801	$ 1,837	$ 1,874	$ 1,912	$ 1,950	$ 1,989		$ 3,602	$ 3,674
Costs				$ (156)	$ (161)	$ (166)	$ (170)	$ (176)	$ (181)	$ (186)	$ (192)	$ (198)		$ (480)	$ (494)
OTEC Cashflow				$ (22,459)	$ 1,571	$ 1,600	$ 1,631	$ 1,662	$ 1,693	$ 1,725	$ 1,758	$ 1,791		$ 3,123	$ 3,180
Intake and Distribution															
Capital Cost	$ (5,000)	$ (23,000)	$ (22,000)												
Total Capital Cost				$ (50,000)											
Revenue - Seawater				$ 543	$ 1,385	$ 1,662	$ 1,939	$ 2,216	$ 2,493	$ 2,716	$ 2,824	$ 2,937	...	$ 12,613	$ 13,117
Costs				$ (1,400)	$ (1,442)	$ (1,485)	$ (1,530)	$ (1,576)	$ (1,623)	$ (1,672)	$ (1,722)	$ (1,773)		$ (4,305)	$ (4,434)
High-end Aquaculture															
Capital Cost					$ (1,000)							$ (500)			
Revenue - Seagrapes					$ 200	$ 800	$ 1,600	$ 2,400	$ 3,200	$ 4,000	$ 4,800	$ 5,600		$ 13,655	$ 13,928
Costs					$ (1,457)	$ (1,976)	$ (2,495)	$ (3,014)	$ (3,533)	$ (4,052)	$ (4,421)	$ (4,790)		$ (13,149)	$ (13,543)
Co- Benefits															
Jobs (pax)				12	40	70	90	110	130	150	175	200		360	363
Carbon Reduction (TCO2e)				408,000	408,000	408,000	408,000	408,000	408,000	408,000	408,000	408,000		408,000	408,000
Total Cashflow				$ (73,315)	$ (743)	$ 601	$ 1,145	$ 1,688	$ 2,230	$ 2,717	$ 3,239	$ 3,265		$ 11,937	$ 12,249

Total Capital Cost	$ (75,000)
OTEC IRR - 5% (20 year)	5%
Combined IRR-5% (20 year)	1%
Combined NPV-5% (40 year)	$14,580

Combined OTEC/ Intake Financials

Notes:

1. Figures indicated reflect a potential scenario for Palau based on experience and estimates from Kumejima Town, Japan as an image. Reference only.
2. OTEC O&M costs reflect experience from the Okinawa OTEC Demonstration Facility
3. Intake Revenues include a gradual increase in demand for seawater use. Costs include contingency funds.
4. Aquaculture includes additional future capital outlays for gradual expansion of production
5. More than one ocean water industry (seagrapes) would be expected to significantly contribute to the overall project economics, a single example is included for simplicity. Options include SWAC, Desalination, other aquaculture industries, etcetera.