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Diagnostic Note

Marine Energy/OTEC Pre-Feasibility Assessment for the Bahamas

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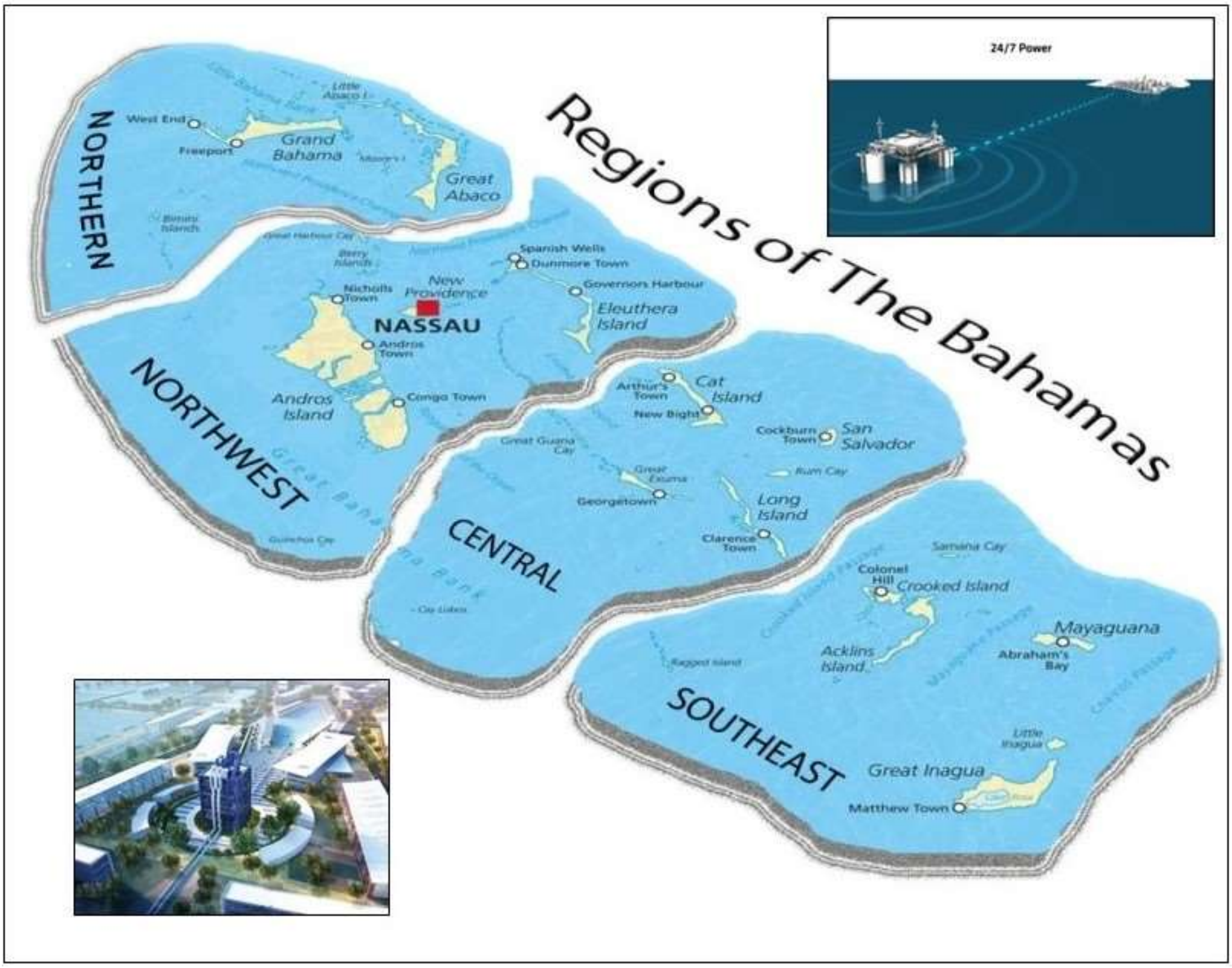

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2. Introduction/Background

2.1. Background to Diagnostic Note and Euroclima Programme for the Bahamas

This work has been undertaken by Ocean Energy Systems Limited (OESL) of Aberdeen, UK. OESL's nominated OTEC Expert, Martin G. Brown, has worked under the guidance of Expertise France in Martinique.

Euroclima's Bahamas Country Action Plan (CAP) sets the objective of confirming the energy potential and financial viability of an offshore OTEC facility in the Bahamas putting in place the following activity:

> *"Carry out a comprehensive OTEC prefeasibility study including temperature gradient confirmation, sites identification and eventually cost investment plan".*

This draft Diagnostic Note sets the scene on the present status of OTEC technology worldwide and its high-level potential for the Bahamas archipelago. Brief reference is also made to other potential marine energy sources, but the focus is on Ocean Thermal Energy Conversion (OTEC) and other applications utilising cold deep water, such as freshwater generation and Sea-Water Air Conditioning (SWAC).

A draft revision) Diagnostic Note was circulated prior to an online workshop session on Tuesday the 14th of October 2025 with the following parties to agree an optimum way forward for Bahamas action within the Euroclima programme:

- Interested stakeholders: public and private sector
- Governmental authorities.
- Expertise France
- European Union Delegations (EUDs) in charge of the Bahamas (in Jamaica) EUDs in Barbados
- Commercial companies with expert knowledge either of the Bahamas Archipelago or OTEC/SWAC – post workshop follow up.

Revision 1 (this document) includes feedback received after the workshop.

In addition, after the workshop, a "Bahamas Marine Energy Action Roadmap" will be finalised. With an agreed Roadmap, Terms of Reference (ToR) for a Prefeasibility Study will be developed. The ToR will then be part of the basis of an invitation to tender to companies interested in bidding to undertake the Prefeasibility Study.

This work also reflects Expertise France's Purchase order 25-BC6938 to OESL, which specifies the length and make-up of this Diagnostic Note.

3. OTEC State of the Art Review

3.1. Context Setting for the Bahamas Archipelago

The Bahamas consists of around 16 major islands and is one of the most sought-after tourist destinations in the world. Owing to its significant tourist and finance sector, this island archipelago is one of the richest countries in the Caribbean by GDP per capita, with a GDP of $12 billion against a population of 400,000 people. It is the fifth Wealthiest Caribbean Country[1]. The University of the Bahamas is well established on New Provident Island with a School of Mathematics, Physics and Technology. The Bahamas is land constrained, but has a very significant offshore Exclusive Economic Zone (EEZ). In addition, electricity is very expensive and more than 50% of the country's potable water supply is sourced from seawater reverse osmosis (SWRO). Therefore, the Bahamas is potentially very well placed among Caribbean islands to lead the way in Renewable Ocean Energy for the generation of clean electricity, fresh water and sea-water district cooling including high performance AI computing – see section 5.3.

3.2. What is Ocean Thermal Energy Conversion (OTEC) ?

In the tropical oceans sun light warms the surface layer to more than 25°C depending on location – see Figure 3-1. This causes a boundary between the less dense warm water with the colder and denser deeper ocean water. This oceanographic effect is termed the thermocline and it is illustrated in Figure 3-1 and **Error! Reference source not found.**, which is specific to the Bahamas.

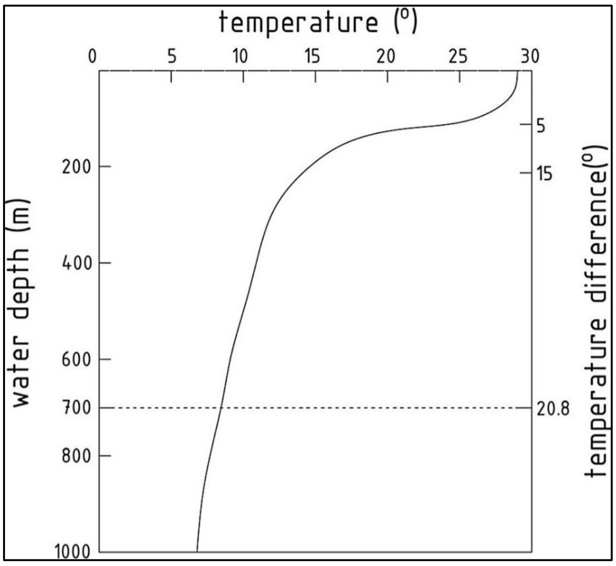

Figure 3-1 – Typical Tropical Ocean Temperature Change versus Water Depth (Thermocline) (Adiputra et al, 2020)

[1] https://www.globalcitizensolutions.com/which-caribbean-country-makes-the-most-money/

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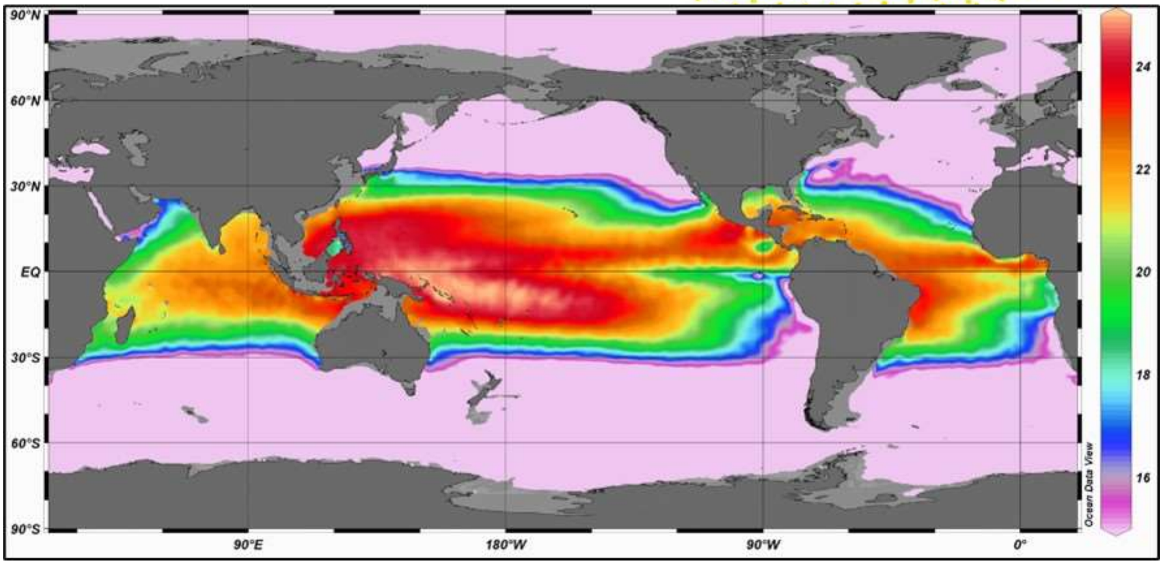

Figure 3-2 - Mean annual temperature difference between the typical OTEC depths of 20 and 1000m, see coloured temperature key on RHS (Nihous, G.C., 2010)

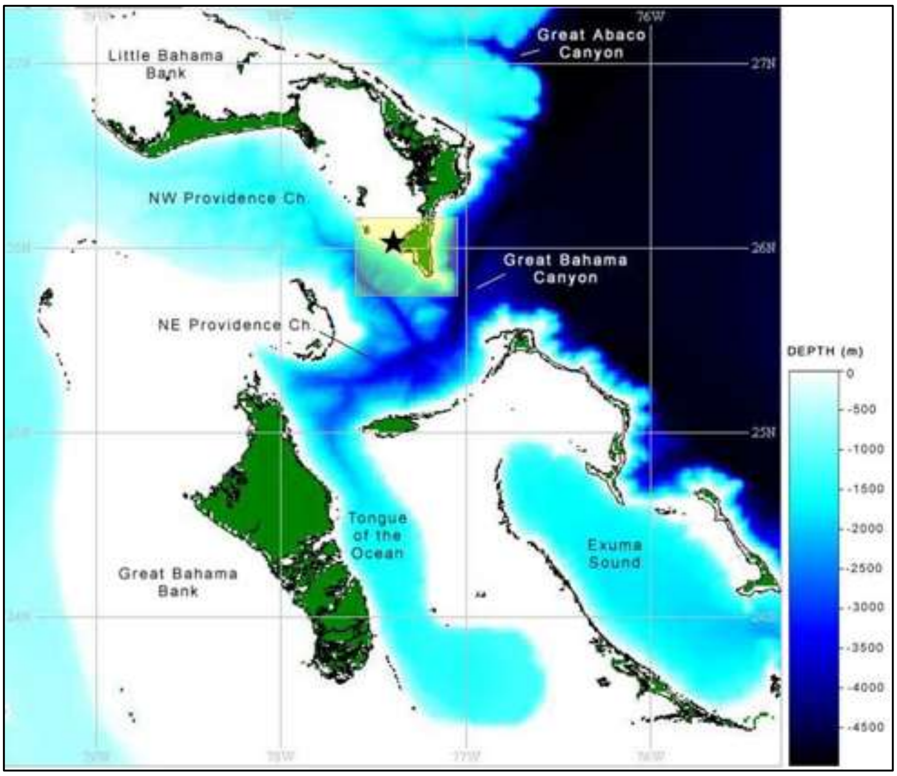

Figure 3-3 - Proximity of Deep Ocean water to some of the Islands in the Bahamas – Depth Key on Right

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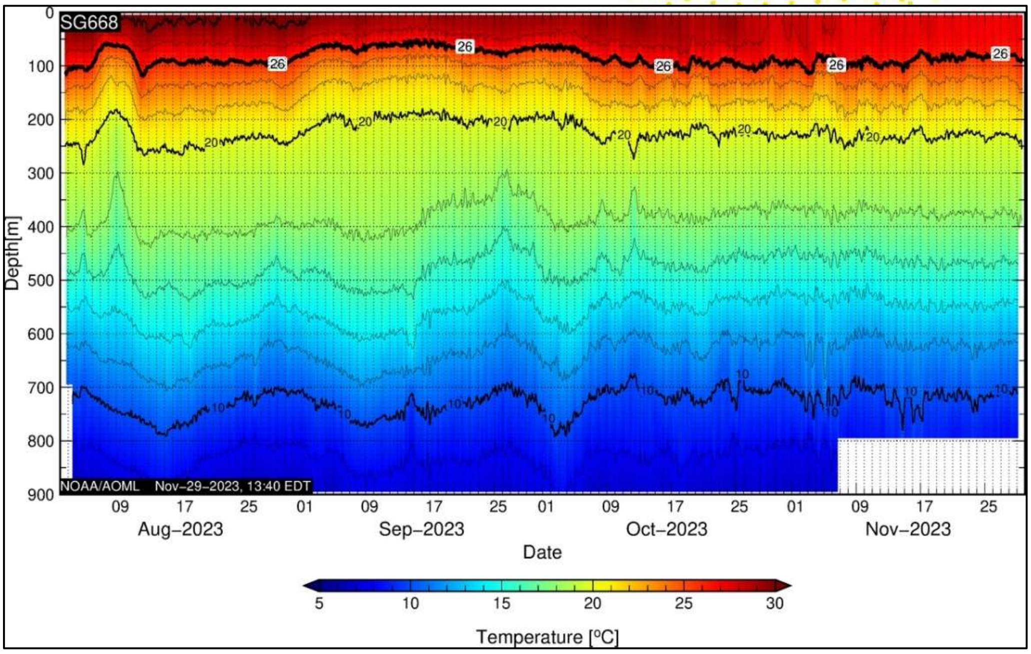

Figure 3-4 – Sea Glider SG 668 Track east of Eleuthera, Temperature versus Depth Profile, Four Months during 2023, courtesy John Bowleg

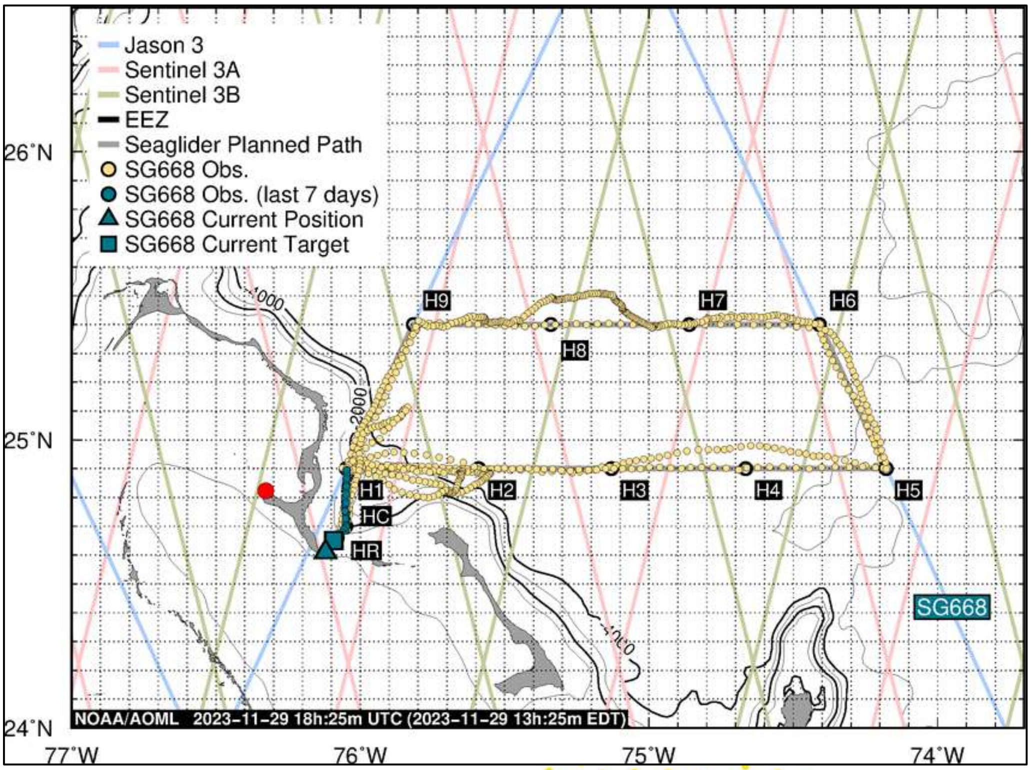

Figure 3-5 – Sea Glider SG 668 Track east of Eleuthera, courtesy John Bowleg

OTEC has some similarities to solar power, however, the technology does not require solar panels over the sea surface, since the process makes use of the heat absorbed by sea water not by a panel. Thus, OTEC does not obstruct the oceans with vast arrays of solar panels which, depending on design and location, may be vulnerable to storms.

3.4. Past OTEC Projects

Table 3-1 shows past OTEC projects around the world including power rating.

No.	Organisation (Country)	Year, Location	Power Rating (kW)	
			Gross	Net
1	Claude (France)	1930, Cuba	22	-
2	Mini OTEC (US)	1979, Hawaii	53	18
3	OTEC-1 (US)	1980, Hawaii	1000	-
4	Toshiba & TEPC (Japan)	1982, Nauru	120	31.5
5	Saga University (Japan)	1984, Saga	75	-
6	NELHA (US) Open Cycle	1992, Hawaii	210	100
7	Saga University (Japan)	1995, Saga	9	-
8	NELHA (US)	1996, Hawaii	50	-
9	NIOT (India)	2000, Tuticorin (incomplete)	1000	-
10	DCNS (Naval Group, France)	2012 onwards, La Reunion Island	15	
11	KRISO (South Korea)	2012, Goseong	20	
12	Okinawa Prefectural Government (Japan)	2013/2016, Kumejima, Okinawa prefecture, Japan	100	
13	Makai Ocean Engineering, Hawaii USA,	2015, Kona, Hawaii	100	-
14	K-OTEC1000 Barge, (KRISO) South Korea	2019. Floating unit.	338 to 1,000	

Table 3-1: Summary of Key OTEC Research and Development Projects -see Reference 3

3.5. Recent Relevant Projects

An OTEC plant built by Makai Ocean Engineering became operational in Hawaii in August 2015 – see Figure 3-7. This is the first closed-cycle OTEC plant to be connected to a U.S. electrical grid. It is a demonstration plant capable of generating 105 kilowatts, enough to power about 120 homes.

In 2013/2016 in Japan, a 100 kW OTEC demonstration facility was established by Okinawa Prefecture with technical assistance from Saga University through subcontract to IHI Plant Construction, Yokogawa Electric, and Xenesys Inc. This is a grid connected unit, which is still operational – see Figure 7-3 and Figure 7-4. Construction seems to be underway to expand the facility up to 1MW capacity – see Figure 3-8.

Figure 3-7 – Makai Closed Cycle Test Facility in Hawaii, copyright Makai

Figure 3-8 – Expansion Underway of the Kumejima OTEC Facility

3.6. Sea Water Intake and Discharge Options – Shelving Sea-Bed Plus Vertical

Robust warm and cold water sea-water intake systems are vital for a reliable OTEC power plant. It is informative that the 1 metre (40 inch) diameter Cold Water Pipe (CWP) that was installed at the

Natural Energy Laboratory in Hawaii (NELHA) in 1988 is now approximately 37 years old – see Figure 3-9. During this unusually long period of time the pipeline has been reliable in operation and withstood the major Kiholo Bay earthquake in2006. The pipeline's originally evaluated design life was only 10 years. It is still in use today.

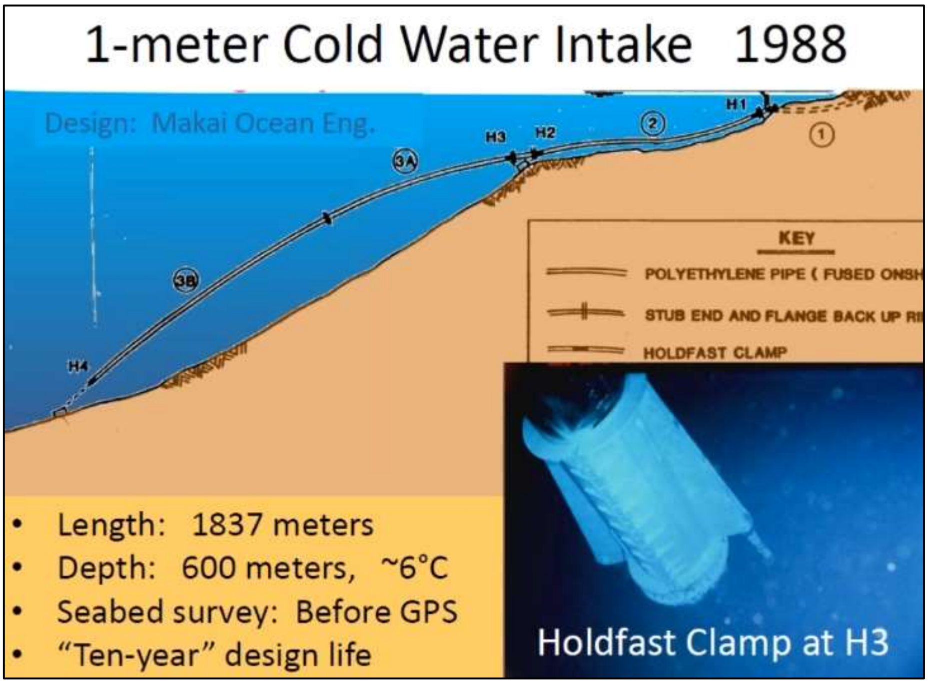

Figure 3-9 – Elevation View of the 40 inch or 1m Diameter CWP at NELHA – courtesy Pat Grandelli

Larger diameter pipes have recently been installed in other regions – see for example Figure 3-10.

Figure 3-10 - Deployment of 3m La Taboada Sea Outfall Pipeline in Lima, Peru, note the size of people

3.7. Vertically Drilled Sea-Water Intakes/Boreholes

An interesting alternative to a marine CWP which follows a steeply shelving sea-shore is to utilise one, or more, vertically drilled boreholes – see Figure 3-11. There is a limit to the maximum diameter of boreholes that can be drilled, hence the need to drill more than one to achieve the required flow rate. John Bowleg (Sr. Hydrologist, Consultant for Hydrology & Marine Energy Renewables reporting to the Office of the Prime Minister (OPM)) has described that the Bahamas are effectively land sitting on a porous sponge, whereby cold deep water is accessible beneath the land – see Figure 3-12.

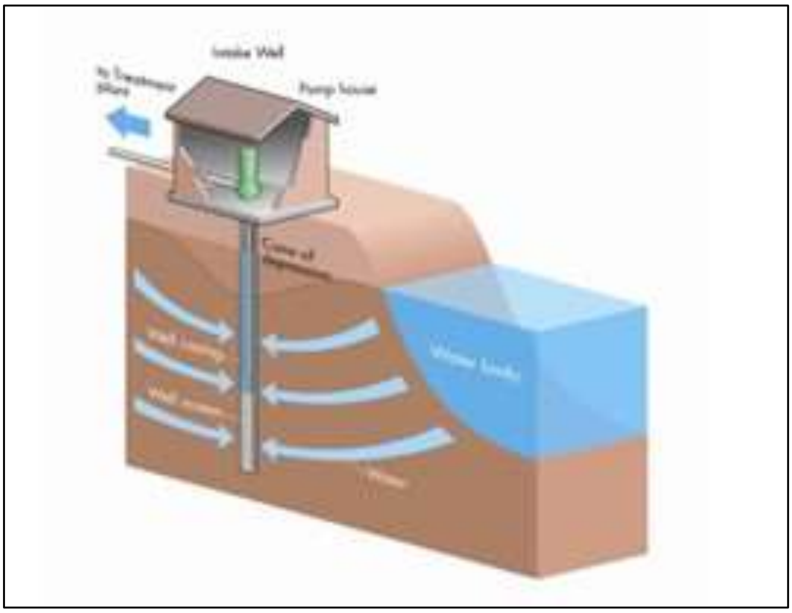

Figure 3-11 - Illustration of a vertical Bore hole accessing cold deep sea-water (ref. "Investigation of Sea Water Intake Alternatives at Shores with Low Slope_edu15.pdf")

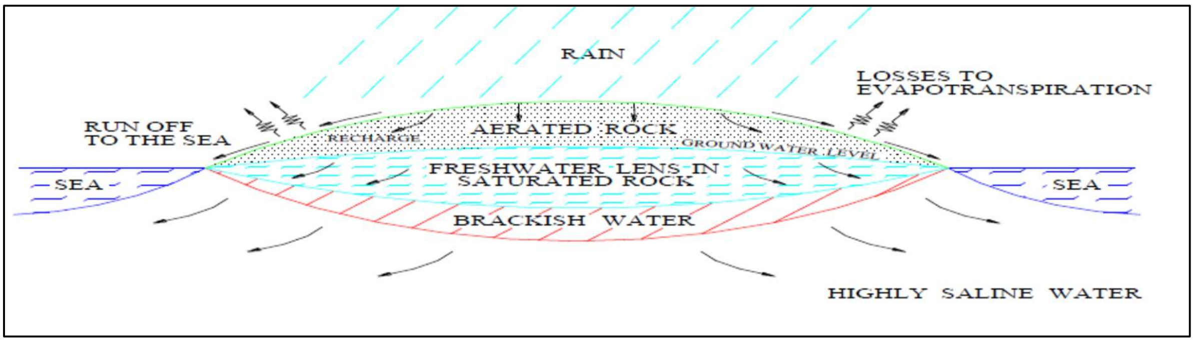

Figure 3-12 - Illustration of Highly saline Water beneath an Oceanic Island – courtesy John Bowleg

The idea to use vertical bore holes for OTEC draws on the experience gained from the district cooling system used on the **Baha Mar resort**, where 20°C water from below the resort, at a depth of approximately 300 metres (1,000 feet) is used – see Figure 3-13. It is understood that high withdrawals from large diameter boreholes are presently occurring in real-time at both the Baha Mar Resort and also at Consolidated Water Blue Hills, which is the largest regional Seawater Reverse Osmosis (SWRO) facility on the Bahamas.

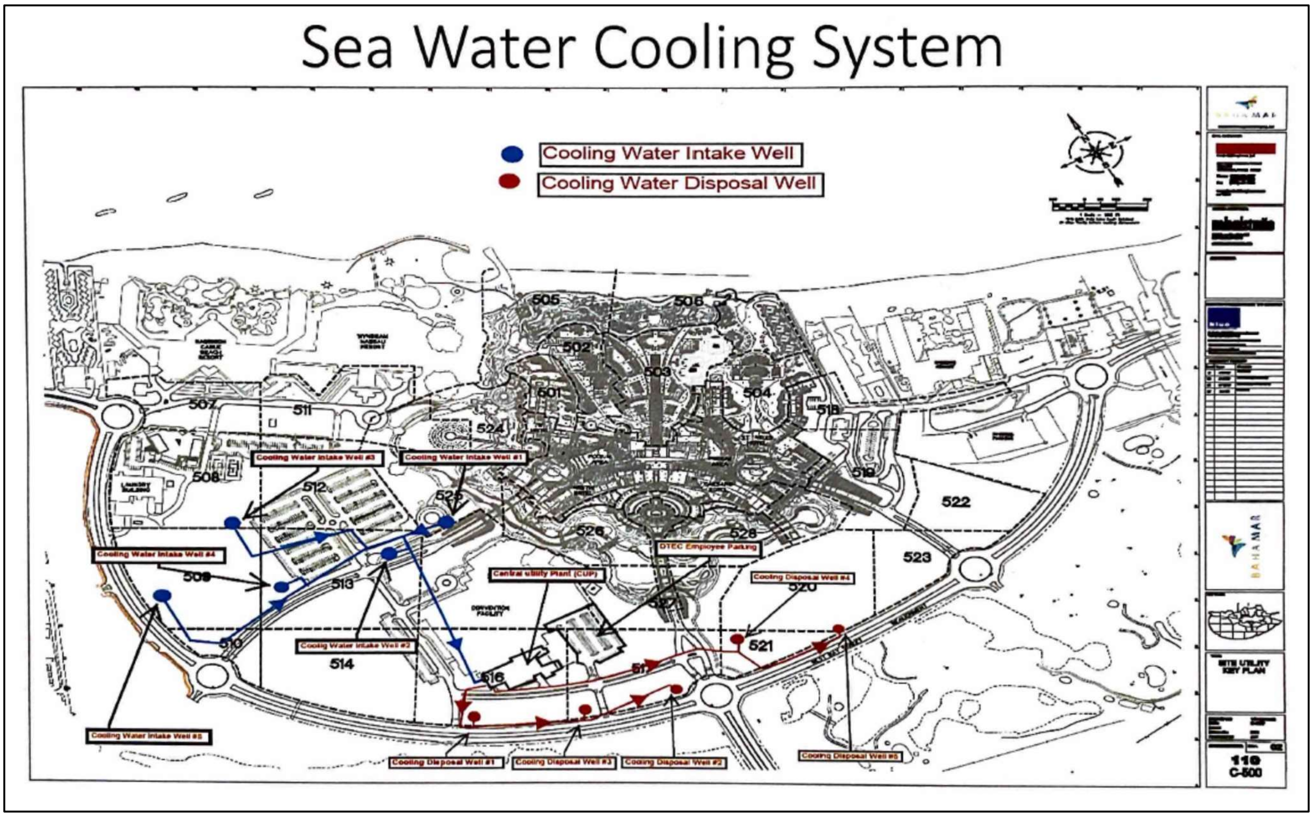

Figure 3-13 – Baha Mar Resort, Nassua, Bahamas

3.8. OTEC Suitability for the Bahamas Archipelago

The Bahamas Archipelago is well placed to benefit from OTEC due to the warm surface ocean temperatures plus proximity to deep cold water in several locations where the sea-bed drops away at a steep angle, which tends to occur around coral and volcanic islands. Longer term floating OTEC ships (see Figure *3-14*) could utilise the OTEC resource in the large Bahamian Exclusive Economic Zone (EEZ). However, in the shorter term a land based OTEC facility will be simpler and cheaper to build, install and operate, compared to floating. Hence land based OTEC is the focus of this Diagnostic Note, despite the very significant potential benefit of floating OTEC to the Bahamas in the long term.

It is worth noting that the Bahamas are not too far from the Gulf of Mexico. Hence the considerable oil and gas infrastructure in the Gulf of Mexico, including expert personnel, barges, tugs, crane vessels, directional drilling rigs, etc could be utilised in the Bahamas without too high a mobilization cost. This is a significant economic feasibility benefit.

Competitive Issue	OTEC	Nuclear	Coal, Oil & Gas	Wind & Solar	Wave	Current
Source of Fuel	Local renewable	Often Imported internationally-restricted trade	Mostly Imported in our target markets	Local renewable	Local renewable	Local renewable
Is Fuel Accessible?	Yes	Not always country-specific Internationally-restricted trade	Not always requires considerable port & storage areas in target market	Yes	Not always dependent on wave density and frequency	Not always site dependent
Predictable Energy Supply	Yes base load power	Yes base load power	Yes base load power	No unpredictable and usually much lower at night	No	Yes usually predictable
Meeting Load Profile	Constant generation	Constant generation	Constant generation	Unpredictable source	Unpredictable source	Constant generation
Land Required	Small area	Buffer zone required	Fuel handling and storage	Large amounts of real estate	Must be underwater	Must be underwater
Affected by Typical Weather	No unlikely to be affected	No unlikely to be affected	No unlikely to be affected	Yes weather changes cause power output to vary	Yes weather changes cause power output to vary	Yes weather changes cause power output to vary
Affected by Tropical Storms/Hurricaines	No buried pipelines and equipment	No protected equipment usually unaffected	Yes shipping, storage and port facilities vulnerable	Yes structures usually exposed and vulnerable	Yes structures very exposed and vulnerable	Yes structures very exposed and vulnerable
Emmissions/Waste	No Fuel	Problematic waste	High level of pollution	No Fuel	No Fuel	No Fuel

Table 4-1 – Summary of OTEC Versus Other Sources of Energy, courtesy of Ocean Thermal Corp.

A key benefit of OTEC is that it provides 365 days a year night and day **baseload power** and if configured suitably, also freshwater generation. Thus, it avoids the significant intermittency and associated energy storage problem associated with waves, wind, solar and to a lesser extent tidal currents. There is a seasonal summer to winter variation in OTEC power production and this needs to be accounted for in the design stage.

Unlike wind (land based or floating) or solar power (land based or floating) the area footprint requirements for OTEC plants are small. Hence with OTEC the sea surface will be un-cluttered and marine eco-systems will still receive their normal solar input. In the Bahamas land availability and cost are significant factors, which need to be considered for any new proposed projects. It is important that the environment is preserved and enhanced to continue to attract responsible tourism to the Bahamas.

Wave power device survivability for a hurricane prone region is a concern. In addition, wave power is intermittent and the technology is still evolving.

Compared to most oil and gas production the OTEC process is simple with relatively low operating pressures. Simplicity typically results in high equipment up times and high reliability, as has been seen by the OTEC plants operating in Hawaii and Kumejima Island (see Figure 3-7 and Figure 7-4).

4.1. Why OTEC is not yet a mainstream source of Renewable Energy

The key factors which have delayed OTEC becoming a mainstream renewable energy source are:

- High initial capital cost due the required number and size of heat exchangers, associated mechanical systems plus the sea-water intake and discharge systems
- High OTEC capital cost tends to result in an electricity US$/kWhr price higher than that generated by hydrocarbons. This is relevant for relatively small power outputs, as associated with prototype units. The electricity price lowers for larger OTEC plants where significant economies of scale can be enjoyed.
- Lack of large-scale OTEC operational experience
- Lack of knowledge about the technology, how it works and its potential. For example, there are no obvious wind turbine rotating blades.
- Only applicable to tropical regions where technical capability and financial resources historically were more limited.

Section 12 outlines possible ways how the Bahamas may be able to overcome these challenges and thus benefits from the considerable advantages that OTEC could provide to tropical island nations with large Exclusive Economic Zones (EEZs).

4.2. Floating Solar – Comparison Case

A marine renewable energy system which has recently received greater prominence is Floating Solar – see Figure 4-1. Floating solar has some similarities to OTEC in that it utilises the solar radiation received by the ocean. However, OTEC utilises the heat in the surface and cold in the depths, so the area required any OTEC plant is relatively small compared to masses of solar panels. From a Bahamas context a key concern for any renewable energy system is hurricane survivability. Large scale open ocean Floating Solar is inevitably at high risk of hurricane damage or even destruction – see Figure 4-2. However, the buildings required for a land based OTEC plant can all be designed to withstand hurricane conditions. The experience from Hawaii, see section 3, is that the sea-water intake systems can be designed to resist earthquake and hurricane conditions. Vertically deployed boreholes will also be well protected from hurricane conditions.

Figure 4-1 - Illustration of a Floating Solar Installation in Sheltered Water

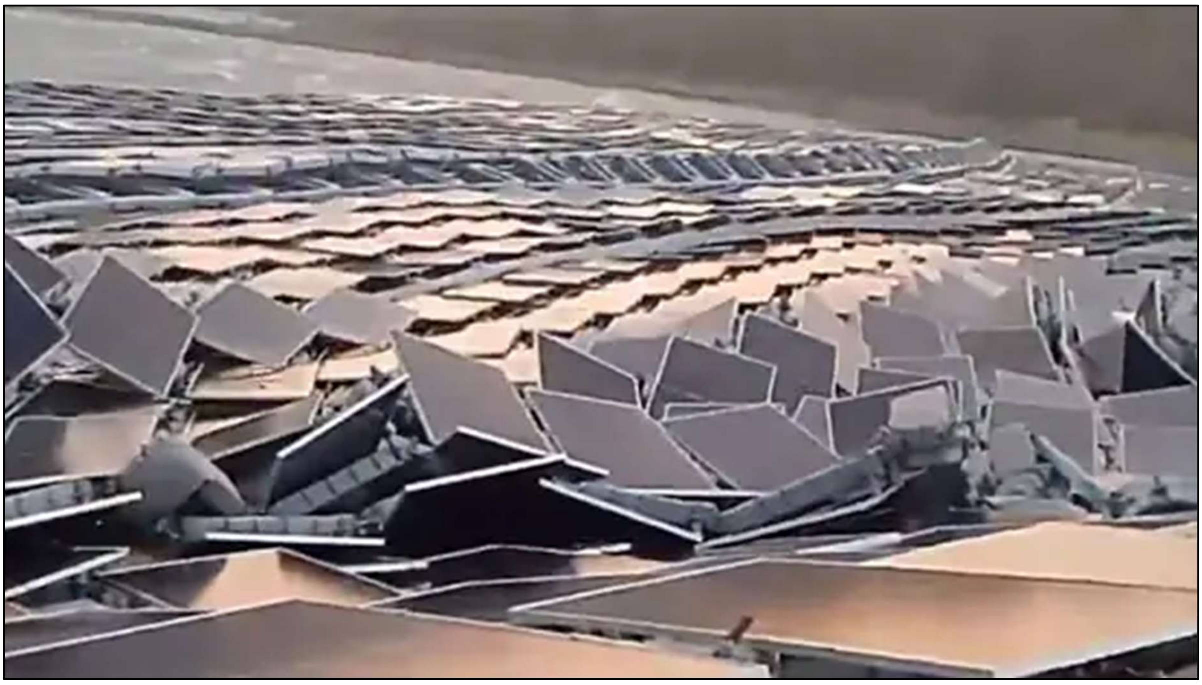

Figure 4-2 - Storm damages the world's largest floating solar plant in Madhya Pradesh, India – note this was being built on the backwaters of Omkareshwar Dam, not at sea (ref. Hindustan Times, Sun, Oct 12, 2025.

5. OTEC derived electricity and other associated products compatibility assessment with the Four Goals of the Bahamas National Energy Policy

The following are the Four Goals of the Bahamas National Energy Policy[2]–.

Goal 1: Bahamians will become well aware of the importance of energy conservation, use energy wisely and continuously pursue opportunities for improving energy efficiencies, with key economic sectors embracing eco-efficiency.

Goal 2: The Bahamas will have a modern energy infrastructure that enhances energy generation capacity and ensures that energy supplies are safely, reliably, and affordably transported to homes, communities and the productive sectors on a sustainable basis

Goal 3: The Bahamas will be a world leader in the development and implementation of sustainable energy opportunities and continuously pursues a diverse range of well-researched and regulated, environmentally sensitive and sustainable energy programmes, built upon our geographical, climatic and traditional economic strengths

Goal 4: The Bahamas will have a dynamic and appropriate governance, institutional, legal and regulatory framework advancing future developments in the energy sector underpinned by high levels of consultation, citizen participation and public-private sector partnerships.

It is apparent that OTEC meets almost all the criteria associated with the Four Goals.

Figure 5-1 summarises the 17 goals of the United Nations (UN) Sustainable Development Goals (SDGs). Again, OTEC can assist with helping to achieve most of these Goals.

Figure 5-1 United Nations Sustainable Development Goals (SDGs) – OTEC can assist with most

[2] The Bahamas Energy Policy (2013 - 2033).pdf

One potential regulatory area of some concern is that Independent power producers are not granted access to the national grid by law. This could be a barrier to the entry of new innovative companies, hence this restriction is highlighted in this document in the hope that this barrier can be removed.

5.1. Seawater Air Conditioning (SWAC)

In the tropics conventional air conditioning is expensive due to large electrical power requirements, particularly for large complexes, such as hotels, offices, hospitals, data centres, etc. If the electricity for a conventional air conditioning system is generated by fossil fuels this results in significant CO_2 emissions. However, depending on the proximity to deep cold ocean water SWAC can reduce normal electrical consumption by 80 to 90 percent, see Figure 5-2. This substantial financial saving and the associated reduction in CO_2 emissions can help justify the installation of the required sea water systems, as has been seen by several projects around the world, for example on Marlon Brando's private island in French Polynesia. SWAC can either be undertaken as a standalone project or in conjunction with an OTEC development as might be the case for a new build eco-hotel on a tropical island – see Figure 5-3, an example of which is the SWAC system at the International Intercontinental Hotel in Bora Bora, which has been operational since 2006.

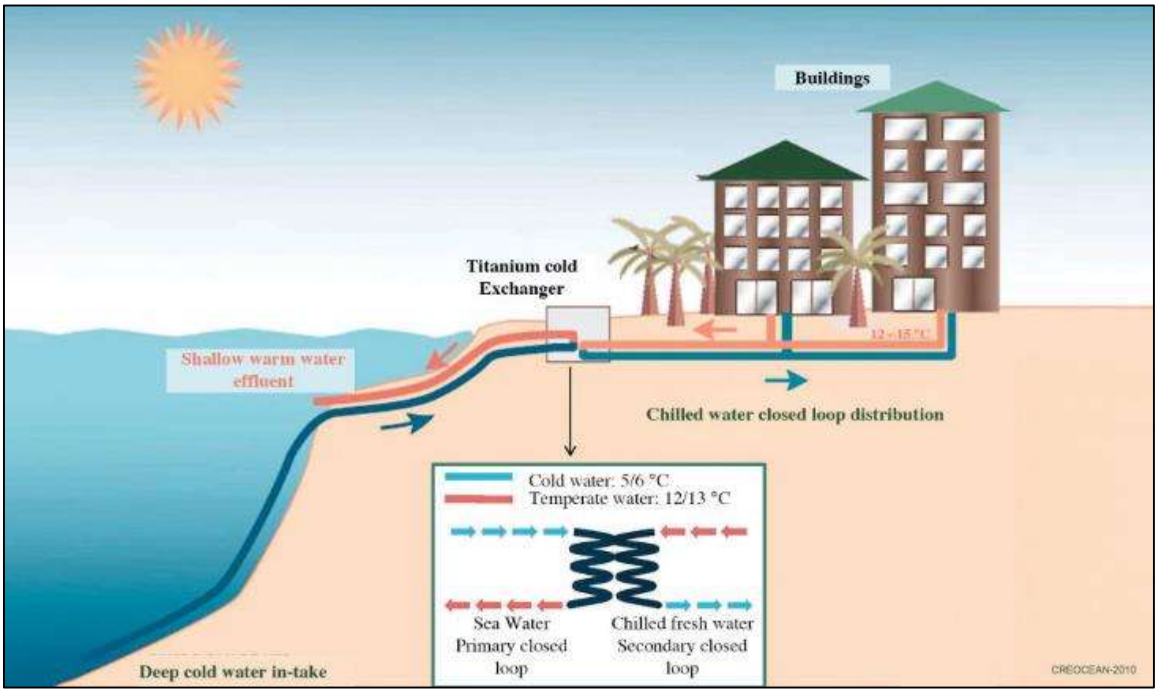

Figure 5-2 Illustration of Standalone Seawater Air Conditioning (SWAC) Courtesy of Resinex/Crocean

Figure 5-3 illustrates one way cost might be saved by incorporating a 150-foot sea water discharge system as part of the deep (3,000 feet) seawater intake systems.

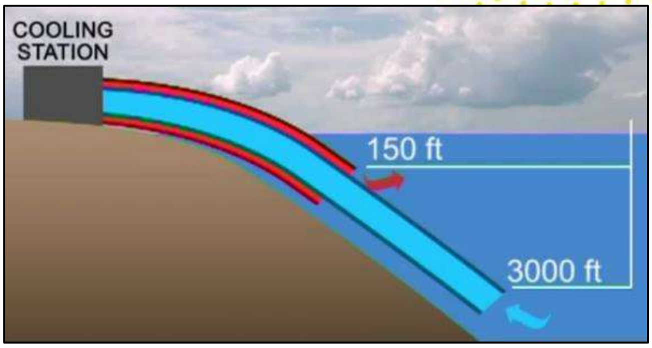

Figure 5-3- Illustration of Bora Bora sea water Intake and Innovative Annulus Discharge System (ref. "InterContinental Bora Bora Deep Sea Water Air Conditioning." YouTube, uploaded by InterContinental French Polynesia, 30/03/2013)

5.2. Fresh Water Generation as Part of the OTEC Process

Figure 3-6 illustrates how fresh water can be generated as part of the open cycle OTEC system. Figure 5-4 shows the large diameter rotor of a turbine planned for use on a desalination system for Kavaratti in the Lakshadweep Islands of the Indian ocean.

Figure 5-4 – The Kavaratti OTEC project has achieved a significant milestone with the successful dynamic balancing of its 65 kW Open-Cycle turbine's rotating components. Ref. National Institute of Ocean Technology (NIOT), Chennai, India

OTEC generated electricity and fresh water can be used by a hospital, school or for a housing district. In other words, for public use and not just for luxury hotel complexes. The 24 hour baseload nature of OTEC power, without the intermittency associated with wind or solar, is ideal for use in public sector or private developments. In addition, OTEC can help with grid stability due to the spinning reserve associated with rotating turbines. Hence OTEC can be part and parcel of new major infrastructure projects in the Bahamas.

5.3. Data and High Performance AI Computer Centres - Cooling with Deep Sea Water

High-performance data and Artificial Intelligence (AI) computing centres use very significant quantities of electricity and generate significant heat. A high-performance computing centre such as the CSCS (Swiss National Supercomputing Centre) uses as much electricity every day as a small town. About a third of this electricity is used for cooling. If supercomputers are not constantly cooled, they overheat and, in the worst-case scenario, may be damaged.

CSCS wanted to run its new computer centre in Lugano as energy-efficiently and cost-effectively as possible. Hence, they installed a Lake water cooling system using the coldness of Lake Lugano – see Figure 5-5.

Figure 5-5 - Suction strainers for the lake water pipe before they were lowered 45 metres into Lake Lugano (picture: CSCS).

At present there is a worldwide boom in data centres and super computers due to developments in Artificial Intelligence (AI). Data centres and super computers both require significant electrical power and cooling. OTEC can provide pollution free electrical power as well as deep sea-water for cooling.

Figure 5-6 and Figure 6-3 illustrates the Submarine Cable Network around the Bahamas. It is apparent that the Bahamas Archipelago is, relatively speaking, close to the South Florida data market. Also given the number of locations around the Bahamas archipelago that are near deep cold sea-water it is apparent that this water could be used for cooling future Bahamian data and computing centres. It is suggested that this business potential should be investigated further – see recommendations in section 34.

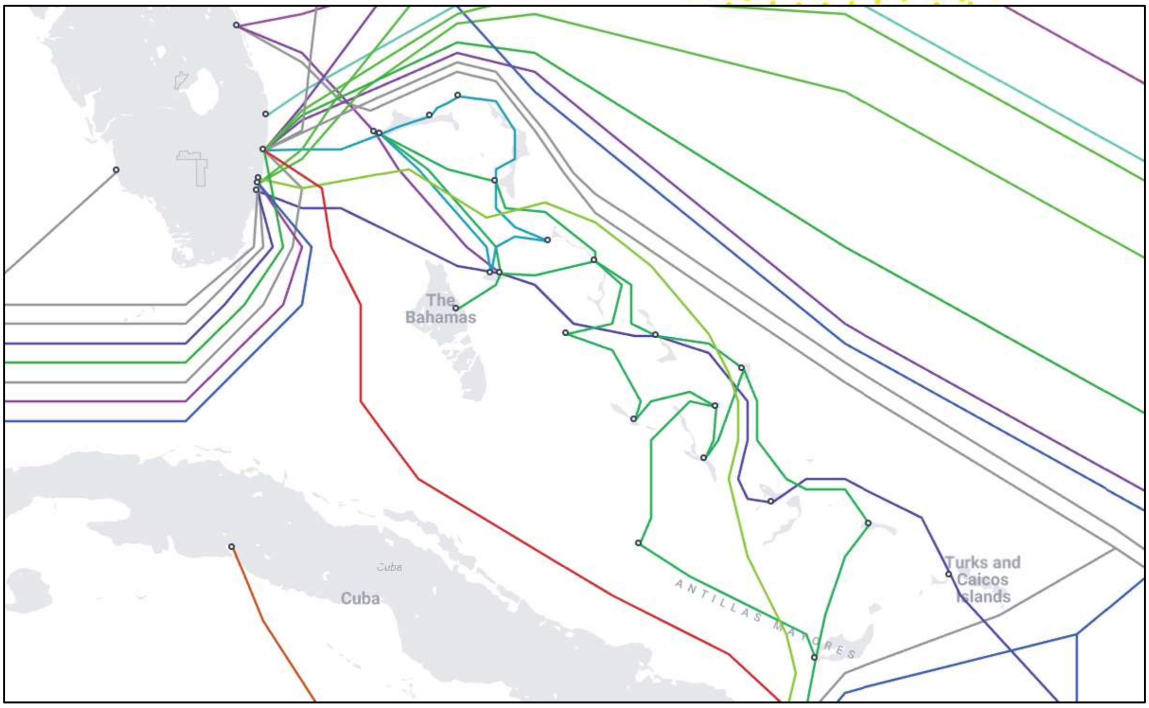

Figure 5-6 - Submarine Cable Network around the Bahamas, note proximity to the South Florida data market (ref. https://www.submarinecablemap.com/)

6. Summary of previously investigated OTEC Sites

6.1. Potential Sites – Bahamas Archipelago

Past "Caribbean Community Climate Change Centre" (CCCCC) work has looked at the potential of OTEC for specific sites in the Bahamas Archipelago see Figure 6-1, Figure 6-4, Figure 6-2 and Figure 6-5. Table 6-1 summarises the size and type of the proposed OTEC sites – see also reference 10. The studies for these sites all assumed that circa 1,000m deep vertical wells will be able to access adequate quantities of cold (circa 4°C) sea-water. It is understood that no wells have been drilled to this depth in the Bahamas or the surrounding islands. Hence, whether this is correct is a matter of conjecture.

Location	OTEC System
Lower Bogue	500kW OC-OTEC
Old Naval Base	350 kW CC-OTEC
Cockburn Town	60kW CC-OTEC & Sea Water District Cooling (SDC)

Table 6-1 - Previous OTEC Studies in the Bahamas

Table 2.1 Site locations

Site	1	2	3
City/Town	Lower Bogue	Naval Base	Cockburn Town
Island	Eleuthera	Eleuthera	San Salvador
Country	Bahamas	Bahamas	Bahamas
Latitude	25.463901°	25.271333°	24.063465°
Longitude	-76.70415°	-76.314554°	-74.533702°
Altitude	10 m a.m.s.l.	18 m a.m.s.l	5 m a.m.s.l
Timezone	UTC -5	UTC -5	UTC -5

Figure 2.1 Locations of the three sites

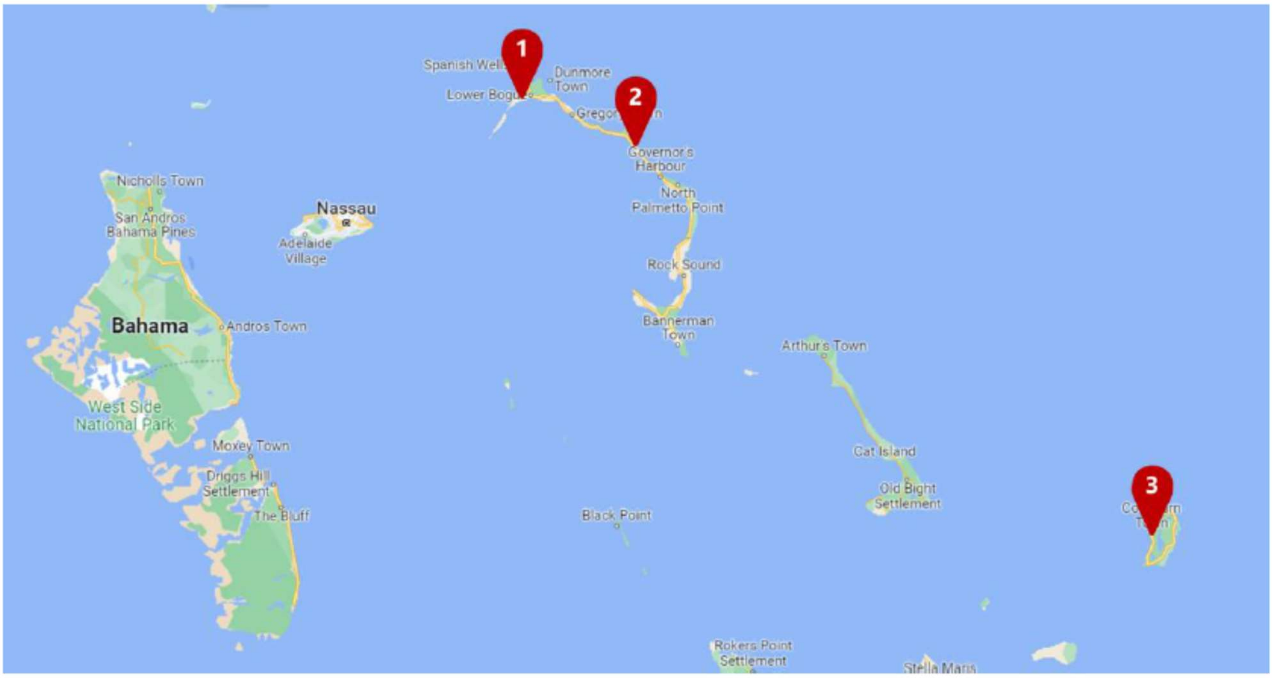

Figure 6-1 – Proposed Locations of Three Previously Investigated Potential OTEC Sites in the Bahamas

Figure 6-2 - Proposed OTEC Site –Old US Naval Base, Central Eleuthera

Figure 6-3 - Note Bahamas Domestic Submarine Network (BDSNi) makes Landing on Eleuthera at Governor's Harbour about 12km from the Old US Naval Base -see Figure 6-2

It is worth noting that Governor's Harbour International Airport on Eleuthera is the prior airstrip for the Naval Base. The Airport and the Naval Base are only about 2km apart.

Figure 6-4 - Proposed OTEC Site – Lower Brogue, North Eleuthera

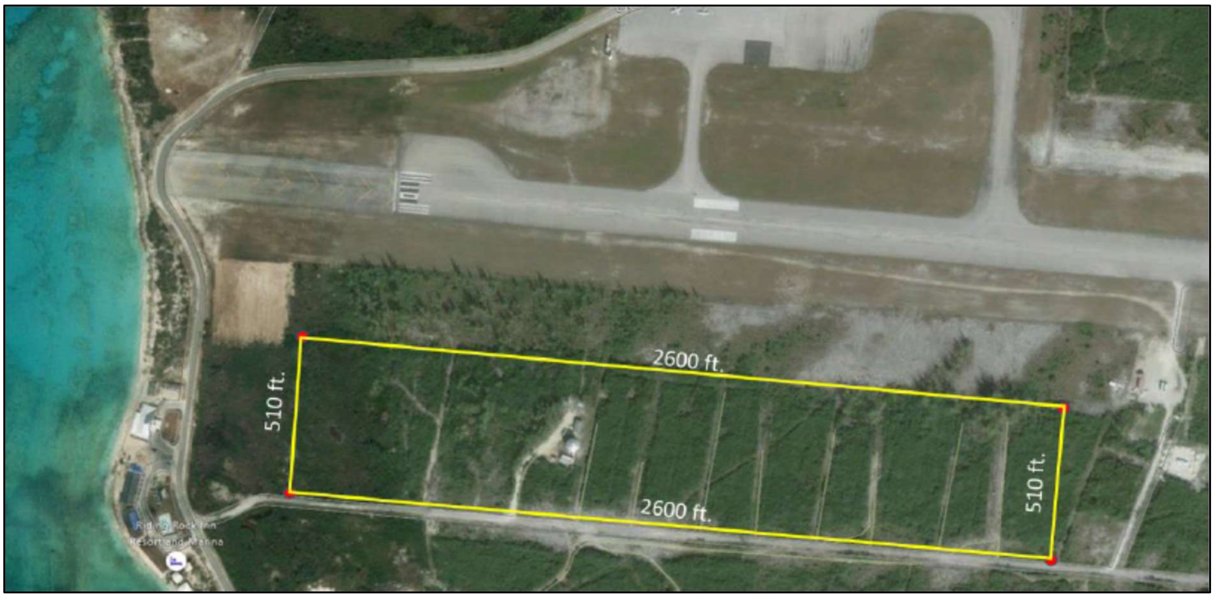

Figure 6-5 - Proposed OTEC Site – Cockburn Town, San Salvador

The estimated return on investment for these three sites was found to be disappointing from a purely commercial investment appraisal point of view. In addition, there are remaining uncertainties about whether vertical boreholes will be able to access adequate supplies of approximately 4 °C sea-water at approximately 1,000m depth. This is because no borehole has been drilled to this depth and then have water pumped at volume for an extended period of time.

7. Establishment of a Pre-Commercial Demonstration Site (Multi Products including Data Centre with Sea Water Air Conditioning)

At present there are two main OTEC demonstration sites in the world, both in the Pacific Ocean with over 6,000 km between the sites. The oldest site is the Natural Energy Laboratory of Hawaii which was established in 1974 -see Figure *7-2* and Figure *3-7*. The second site is the Okinawa Prefectural Deep Sea Water Research Institute on the island of Kumejima, which in turn is off the Japanese island of Okinawa – see Figure *7-3* and Figure *7-4*. This facility was established in 2013. Both the Hawaii and Kumejima sites have brought significant economic prosperity to their respective communities. OTEC has great potential for the Caribbean and therefore there is a logic that the Bahamas with its significant financial and technical resources could be the site of a "*Caribbean Marine Renewable Energy Centre*" or **CAMREC**. Such a site would not be exclusive just to OTEC, but could also cover other marine renewable energy sources, as is the case at the European Marine Energy Centre (EMEC) on the Orkney Islands off northern Scotland in the U.K. - see https://www.emec.org.uk/.

Figure 7-1 - Locations of the Two OTEC Test Centres in the World both in the Pacific Ocean – One on Kumejima Island (Japan) and One on the Big Island of Hawaii

Figure 7-2 Areial View of the Natural Energy Laboratory of Hawaii which was established in 1974 (Courtesy NELHA)

Figure 7-3 - Areial View of the Okinawa Prefectural Deep Sea Water Research Institute on the island of Kumejima which was established in 2013

Figure 7-4 – Kumejima OTEC Facility, courtesy Benjamin Martin, Okinawa Prefecture Industrial Policy Division

A potential example of such a complex is the proposed Puerto Rico Ocean Technology Complex (PROTech), which has been proposed and encouraged by the Puerto Rico government – see Figure 10 2 and Figure 10 1. It is understood that this project is presently stalled due to lack of US government support. Hence there is an opportunity for the Bahamas to become a regional leader in the Caribbean for this technology.

pipe materials such as High Density Polyethylene (HDPE), Fibre Reinforced Plastics (FRP), flexible canvas (fabric materials) have been investigated with respect to structural strength and ease of installation. Despite this work, some challenges remain in the installation of very large diameter pipes and their integrity throughout the design life of the OTEC system. For a land based system, with smaller diameter sea-water intakes this is less of a concern, as is demonstrated by the performance of the 40 inch or 1m Diameter CWP – see Figure 3-9 including surviving earthquake loading.

It is apparent that marine pipelines following a steeply shelving sea-bed have been successfully demonstrated. There are questions about whether vertically drilled boreholes to supply the required quantity of cold sea-water will prove to be fit for purpose and are also economically feasible. A test borehole to a depth of approximately 1,000 m depth needs to be drilled – see section 34.

To date the main obstacle for land based OTEC plants has been poor return on investment due to the high cost of the sea-water systems, heat exchangers and the relatively low power output for prototype units. Possible ways around this roadblock are discussed in section 12.

11. Initial Assessment of Key Stakeholders and Potential Partners – private and public sector

The following is an indicative list of public sector stakeholder who should be consulted for any proposed new developments.

Public sector

- The Ministry of Works and Urban Development
- The Ministry of Finance
- Ministry of the Environment and Housing
- Bahamas Electricity Corporation (BEC)
- Bahamas Environment Science & Technology (BEST) Commission
- Water and Sewerage Corporation
- Bahamas Chamber of Commerce

Private or specialist technical knowledge:

The following list excludes potential financial investors and venture capitalists.

- SAS Airaro, Tahiti, French Polynesia
- E^3Tec Service, LLC, Chicago, USA.
- DCO Energy, LLC, Mays Landing, NJ 08330
- Genesis, Aberdeen, U.K.
- PCCI Inc. Alexandria, Virginia, USA
- Makai Ocean Engineering, Hawaii

- Global OTEC Ltd, London, U.K.
- Xenesys Inc. Japan.
- Naval Group, previously known as DCNS, France.
- Veolia (fresh water provider in the Bahamas via sea-water reverse osmosis)
- Bahamas Power and Light (BPL).
- WSC Water and Sewerage Corporation, Bahamas
- National Institute of Ocean Technology (NIOT), Chennai, India

12. Outline Way Forward – Basis for Pre-Feasibility Study

12.1. Recommendations

This Diagnostic Note has been developed to provide guidance to the principal stakeholders in the Bahamas as to the possible pathways to exploit the marine potential of the Bahamian Exclusive Economic Zone. The intention is to obtain in the stakeholder workshop session a broad consensus as to the best Roadmap forward to be further developed in the proposed Pre-Feasibility study, which is intended to be put out to tender.

This Note suggest that at present the most promising approach given the cost and maturity of OTEC and associated technology is to establish a "***Caribbean Marine Renewable Energy Centre***" (possibly called CAMREC) to promote and publicise the technology – see section 7. This could include a drilling a test borehole to 1,000m depth to check on water temperature at this depth and if the low temperature is maintained if pumping at a significant rate. A large diameter HDPE marine pipeline (see Figure 3-9) at the same site would allow a sea water temperature comparison to be made. The marine pipeline would be of a larger diameter than the borehole, thus allowing higher flow rates and probably lower frictional losses, even though the marine pipeline would be longer than a vertical borehole to get to the same depth. It is also worth noting that it is possible there are locations around the Bahamas where nominally 4°C sea-water can be found at shallower depths than 1,000m. If this is the case this would reduce the capital cost of all cold sea-water supply systems.

Potentially the construction of the expensive sea-water systems might be funded by government to facilitate the establishment of private sector businesses around the OTEC facility. This is like the business model in place at the Natural Energy Laboratory of Hawaii and the Kumejima OTEC facility in Japan.

12.2. Finding an Optimum Site

The three previously proposed OTEC locations in section 6 are quite remote from any sizeable centre of population, although the Naval base is next door to the Airport. Thus, without a major building programme (e.g. hotel or hospital complex) probably would not enjoy the financial benefits associated with sea-water district cooling. In addition, Data Centres/High performance AI computing require good surrounding infrastructure for efficient construction and cost- effective operation, including easy access to on land and subsea data highways – see Figure 5-6. Therefore, it appears important to review all possible sites on the islands within the Commonwealth of the Bahamas to address suitability for siting a "Caribbean Marine Renewable Energy Centre". Important factors would include the option to include sea-water district cooling and high-performance computing/ an AI Data Centre, as well as freshwater needs. The return on investment on such a venture is likely to attract private sector funding. Including as part of such a project a "*Caribbean Marine Renewable Energy Centre"* would add to the green credentials of any such development and simplify planning approval. Clearly it is important that Identifying optimum sites for OTEC should revolve around the geophysical and socioeconomic realities of The Bahamas.

The long-term benefits of OTEC derived baseload power and freshwater production for the Bahamas could be substantial. With the existing financial and people resources in the Bahamas the Commonwealth is well placed to become a regional leader in the technology. The technology would also assist with helping to make progress with government decarbonisation targets.

One site that might be worth investigating is the US Navy Atlantic Undersea Test and Evaluation Center, AUTEC, on Andros Island. NAVFAC (Naval Facilities Engineering Systems Command) is familiar with OTEC and might support such a proposition to reduce base emissions and running costs.

13. References

1. Rauchenstein, L.T., (2012) "Global Distribution of Ocean Thermal Energy Conversion (OTEC) Resources and Applicability in U.S. Waters near Florida" M.S. Thesis, Florida Atlantic University
2. "Sustainable cooling: A deep dive into seawater air-conditioning solutions for the Caribbean," JONATHAN COONY, ROCHELLE SIMONE JOHNSON, July 24, 2024, https://blogs.worldbank.org/en/latinamerica/sustainable-cooling--a-deep-dive-into-seawater-air-conditioning-
3. IEA-OES, "White Paper on Ocean Thermal Energy Conversion (OTEC)," 2021, Martin Brown main author,see https://www.ocean-energy-systems.org/publications/oes-position-papers/document/white-paper-on-otec/
4. March 2020 Ocean Energy in Barbados A Review of Clean Technology Options, Available Resource and Locational Guidance for Potential Areas of Interest for Commercial Development, TECHNICAL NOTE Nº IDB-TN-01881, Sweyn Johnston, John McGlynn, Veronica R. Prado.
5. Marti_2007_OTEC_Environmental_versus_other_sources_energy.pdf
6. Investigation of Sea Water Intake Alternatives at Shores with Low Slope, Zeinab Toorang, Hamed Rahman Shokrgozar, Nazanin Nayebvali, The 15th Marine Industries Conference (MIC2013), 29-31 October 2013 – Kish Island
7. "The Bahamas Energy Policy (2013 - 2033).pdf"
8. 20150630_Lake_water_cool_supercomputers_EN.pdf
9. Evaluation Ocean Thermal Energy Conversion Bahamas, Energy Audit Report Bahamas, 3 February 2023 "OTEC Project - Executive Summary (Witteveen+Bos Consultants, Feb-2023).pdf"

10. Evaluation Ocean Thermal Energy Conversion Bahamas, Design Specifications report, 10th February 2023, “Design Specification Conceptual Report - Bahamas OTEC (2023).pdf“
11. Evaluation Ocean Thermal Energy Conversion Bahamas, Energy Audit Report, 3rd February 2023, “Energy Audit Report - Bahamas OTEC (2023).pdf”
12. Evaluation Ocean Thermal Energy Conversion Bahamas, Inception Report, 8th November 2022, “132728-22-015.996-repf-Inception Report_final.pdf “
13. Draft Environmental Assessment, OTI 1MWe OTEC Research, Development and Demonstration Facility Keahole, North Kona, Hawaii, July 2012, 195 pages
14. Ocean Thermal Energy Conversion (OTEC) Programmatic Environmental Analysis Vol. 1, U.S. Department of Energy, LBL-10511 (Vol. 1) (DE81030222), January 1980, 217 pages
15. University of Bahamas OTEC Symposium, Thursday 7th August 2025, in person and online.
16. “Caribbean Marine Renewable Energy Study tour and training programme - Study tour and training programme” Final Report 10th October 2025, N° NOVA : 25-RE-0037
17. “Marine Energy/OTEC Pre-Feasibility Assessment for the Bahamas,” Workshop presentation- Tues. 14th October 2025, Martin G. Brown, Ocean Energy Systems Limited (OESL), Aberdeen, U.K.

14. Annex A

Vertical Borehole Technical Matters

There are a few matters that need to be considered when assessing the suitability of vertical boreholes for OTEC including:

1. Height of the OTEC process plan above sea-level. The OTEC power cycle is low efficiency due to the low temperature difference. The energy required to lift water above sea-level is significant. Hence it is important that the OTEC plant should be built on an elevation as close to sea-level as possible.

2. Friction is greater for several smaller diameter boreholes compared to a single large diameter marine pipeline. Of course, a pipeline following a steeply shelving sea-bed will be longer than vertical boreholes. Frictonal losses need to bne included in the process simulation assessment.

3. The cost of drilling several boreholes to 700 to 1,000m depth. This needs to be included in the economic feasibility assessment.

4. Depending on OTEC site location the potential requirement to drill several shallower boreholes for sea-water discharge. Local rules and permits need to be fully understood.