Evaluation Ocean Thermal Energy Conversion Bahamas

Energy Audit Report

The Caribbean Community Climate Change Centre (CCCCC)

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ABBREVIATIONS

BPL	Bahamas Power & Light
CCCCC	Caribbean Community Climate Change Centre
CC-OTEC	Closed Cycle OTEC
EU	European Union
GCCA	Global Climate Change Alliance
IG	Imperial Gallon
IGPD	Imperial Gallon Per Day
LCOE	Levelised Cost of Energy
NPV	Net Present Value
NRW	Non-Revenue Water
OC-OTEC	Open Cycle OTEC
OTEC	Ocean Thermal Energy Conversion
PV	Photovoltaic
RO	Reverse Osmosis
SDC	Seawater District Cooling
SWAC	Seawater Air Conditioning
SWRO	Seawater Reverse Osmosis
WSC	Water and Sewerage Corporation

PREFACE

Witteveen+Bos has been commissioned by the Caribbean Community Climate Change Centre (CCCCC) to perform a feasibility study for Ocean Thermal Energy Conversion (OTEC) in the Bahamas.

The project aims to evaluate the feasibility of OTEC pairing with SWRO plants and its combination with Solar District Cooling (SDC), solar thermal and/or solar PV to contribute to the decarbonization of the water supply in The Family Islands.

There are four deliverables from this project:

1 Inception Report - based on an inception meeting with local stakeholders and partners.
2 Assessment Report - bench-level assessment of the Water Resources of the Bahamas, regarding the inverted geothermal conditions from existing SWRO wells to support OTEC.
3 Energy Audit Report - energy efficiency audit of existing SWRO facilities and implications for OTEC pairing.
4 Conceptual Design Specifications for SWRO-OTEC pairing system.

This document is the third deliverable, Energy Audit Report.

The CCCCC has received financing for this project from The European Union through the GCCA+ programme toward the cost of the project titled 'Enhancing Climate Resilience in CARIFORUM Countries' and applied part of the proceeds towards this consultancy project.

The Global Climate Change Alliance Plus (GCCA+) is a European Union flagship initiative helping the world's most vulnerable countries address climate change.

OTEC is an emerging technology that requires research and scaling-up effort. We are pleased to assist in the development of this technology in the Bahamas.

EXECUTIVE SUMMARY

Freshwater in Family Islands is mostly produced from Seawater Reverse Osmosis (SWRO) plants. The process is highly energy intensive. The energy comes from the power grid, which is still mostly generated by diesel power plants. In this report, we assess the energy consumption of SWRO plants operated the majority by Veolia on behalf of the Water and Sewerage Company (WSC) in the Family Islands. Further, we assess the cost-benefit analysis of Ocean Thermal Energy Conversion (OTEC) as an energy source for the SWRO plants. The Bahamas is utilizing cold saline groundwater for District Cooling from underground at 1000 ft depth. Though there is not yet evidence that the reverse geothermal conditions continue deeper, it is useful to evaluate the cost and benefits of OTEC to determine the attractiveness to further investigate this. In this study, we assess the cost-benefit of implementing OTEC for 3 SWRO locations in the Family Islands.

Energy efficiency

The energy consumption of the SWRO plants is in the range of 2 - 4 kWh/m^3 produced, with an average of 3,65 kWh/m^3 produced. This is within the range of typical installations with the same configurations. In Eleuthera, all SWRO plants have utilized this energy recovery technique. The energy efficiency was calculated for the volume produced, not delivered. Non-Revenue Water (NRW) has been reported to be close to 50 %, of which a large part occurs during distribution. Focusing on NRW reduction would significantly increase overall energy efficiency.

Cost-benefit analysis

The cost-benefit analysis has been performed on three SWRO locations, determined in the previous Assessment Report (Witteveen+Bos, 2022). The locations are Lower Bogue, Naval Base, and Cockburn Town. In each location, we design an OTEC system to supply 100% electricity demand of the SWRO plants. As alternative mature renewable energy options, we also assessed the implementation of solar PV, wind turbine, or their combinations at each location. The concept design has resulted in the following system for each location:

Table 1 Selected technology for each location

Location	OTEC system	Alternative
Lower Bogue	500 kW OC-OTEC	1500 kW wind turbine and 11.4 MWh Li-ion battery
Naval Base	350 kW CC-OTEC	2000 kWp, and 7.9 MWh Li-ion battery (charge)
Cockburn Town	60 kW CC-OTEC and SDC	350 kWp Solar PV and 1.4 MWh Li-ion battery

In the analysis, we have estimated the capital cost and operating costs. The benefit of OTEC installation comes from selling electricity for the SWRO plants at the cost of $0.2/kWh. For Open Cycle (OC) OTEC, fresh water is also generated and valued at $9.3/1000 imperial gallon (IG) at Lower Bogue. Seawater District Cooling (SDC) benefit comes from the energy saving for cooling.

Table 2 Cost-benefit analysis results

System	Lower Bogue	Naval Base	San Salvador
OTEC	**OC-OTEC 500 kW**	**CC-OTEC 350 kW**	**CC-OTEC 60 kW**
NPV (30 years, r = 4%)	-$15,193,000	-$23,694,000	-$10,248,000
NPV/capital cost ratio	-0.34	-0.85	-1.1
LCOE ($/kWh)	0.37	0.57	1.11
SDC			

System	Lower Bogue	Naval Base	San Salvador
NPV (30 years, r = 4%)	-	-	$579,000
NPV/capital cost ratio	-	-	0.52
Alternative	**1500 kW wind turbine and 11.4 MWh Li-ion battery**	**2000 kWp, and 7.9 MWh Li-ion battery (charge)**	**350 kWp solar PV and 1.4 MWh Li-ion battery**
NPV (30 years, r = 4%)	-$3,913,000	-$3,773,000	-$789,000
NPV/capital cost	-0.16	-0.21	-0.24
LCOE ($/kWh)	0.24	0.26	0.27

The results show that the OTEC for electricity generation alone is not yet cost-effective. But the combination with freshwater generation increases the business case significantly. The 500 kW OC-OTEC in Lower Bogue produces additional freshwater capacity equal to 40% of the current SWRO plant capacity. The LCOE is almost 40% lower than the case of without freshwater production at Naval Base.

The SDC in San Salvador gives a positive NPV with an NPV/capital cost ratio of 0.35. Combining SDC with OTEC increases the business case. In San Salvador, the LCOE of OTEC improves from 1.24 to 1.11 $/kWh. In this case, only 25% of cold water is utilized due to low demand quantity. Higher utilization of cold water would give a better business case.

The results suggest that the OTEC business case is greatly enhanced when combined with freshwater generation and providing cooling. However, this analysis is based on the assumption that cold water (< 7°C) water is available at a depth of 1 km. Therefore we suggest performing a test well to a depth where the water has a temperature difference of plus or minus 20°C compared to shallow saline groundwater and confirming this cold water availability. And since OTEC is a developing technology, it is also wise to start with a smaller scale for piloting. In the next report, we will provide design specifications for 30 kW open cycle OTEC in Lower Bogue. While in Naval Base and Cockburn Town, we will provide the design specification for wind and/or solar PV with batteries.