Evaluation Ocean Thermal Energy Conversion Bahamas

Inception Report

The Caribbean Community Climate Change Centre (CCCCC)

8 November 2022

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Project Leader	Raphaël van der Velde
Project Director	Peter Tienhooven

Author(s)	Rasyid Salam
Checked by	Raphaël van der Velde
Approved by	Raphaël van der Velde

Paraph 

Address

Witteveen+Bos Raadgevende ingenieurs B.V.
Leeuwenbrug 8
P.O. Box 233
7400 AE Deventer
The Netherlands
+31 570 69 79 11
www.witteveenbos.com
CoC 38020751

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

BPL	Bahamas Power & Light
CCCCC	Caribbean Community Climate Change Centre
CDB	Caribbean Development Bank
EU	European Union
GCCA	Global Climate Change Alliance
GCF	Green Climate Fund
GWP	Global Warming Potential
IGPD	Imperial Gallon Per Day
MoW	Ministry of Works
NRW	Non-Revenue Water
OPM	Office of the Prime Minister
OTEC	Ocean Thermal Energy Conversion
PDMU	Programme Development and Management Unit
RO	Reverse Osmosis
SDC	Seawater District Cooling
SWAC	Seawater Air Conditioning
SWRO	Seawater Reverse Osmosis
WSC	Water and Sewerage Corporation

1

INTRODUCTION

1.1 Purpose of this report

This Inception Report aims to provide the final implementation plan for the Project 'Evaluation Ocean Thermal Energy Conversion Bahamas' (hereinafter referred to as The OTEC Project).

This report is based on the following:
- Meetings with representatives of Office of the Prime Minister (OPM) as the Beneficiary, the Water and Sewerage Corporation (WSC), Bahamas Power & Light (BPL), and the Ministry of Works (MoW).
- Site visits to four water treatment facilities in Eleuthera, and the Seawater District Cooling (SDC) facility of Baha Mar in New Providence.

The final draft of the Inception Report was discussed on 4 November 2022 with the representatives of:
- The client, the Caribbean Community Climate Change Centre (CCCCC) - Mr. Darrel Audinette, Project Manager, Programme Development and Management Unit (PDMU).
- The beneficiary, OPM - Mr. John Bowleg, Engineer & Sr Hydrologist, OTEC Project Lead for OPM.

1.2 Introduction to the project

Background: water scarcity and the need for clean energy for the water sector in The Bahamas (Family Islands)

The project is situated in The Bahamas, a country in the north of Cuba and east of Florida. The project focuses on Family Islands, the islands that make up The Bahamas with the exception of New Providence Island, where the capital and largest city, Nassau, is located and Grand Bahama Island, where Freeport is located.

Figure 1.1 Map of The Bahamas

The public water utility in The Bahamas, the Water Sewerage Corporation (WSC), is the main water supply operator in the country; however, some other operators cover limited areas. WSC supplies New Providence and 24 Family Islands and Cays. It has historically played a major role in structuring the water sector, having both operational and regulatory responsibilities. The WSC is, however, not able to provide water services to every Bahamian citizen. It also suffers from an insecure financial situation, and provides unequal levels of service for various reasons, including differing sources of supply, availability, and age of infrastructure. There are different tariffs for residential and non-residential customers. The tariffs also differ by location, broken down into New Providence, Major Family Islands (Exuma, Eleuthera, Abaco and San Salvador) and the other Family Islands. [Hydroconseil, 2019].

The water infrastructure consists of more than 50 standalone systems, most of which include pumping stations, storage tanks, mains and pipes, and some also include pressure tanks. The two water sources used by the WSC are well fields and saline groundwater treated with Reverse Osmosis (RO) plants. So far, the RO plants have been considered as having little environmental impact. Still, in fact, this is not the case as they consume a lot of energy. Moreover, the grid power in The Bahamas comes from fuel generators using diesel and Heavy Fuel Oil as an energy source [Hydroconseil, 2019].

Due to overuse and climate change (resulting in increased seawater intrusion), well fields utilising sweet water are being replaced by RO using saline groundwater. The use of RO plants is leading to the increasing involvement of the private sector, as the RO plants are mainly (if not all) managed by private operators contracted by WSC. Veolia/SUEZ is the main operator for the WSC RO facilities.

In the figure below, the main reasons for interruptions of the water supply are presented [Hydroconseil, 2019].

Figure 1.2 Main reasons interruptions of the water supply

Origin	Most likely reason	Examples	Possible improvement
Power outage	Low quality of BPL power Absence or failure of back-up generator	North Eleuthera, North Andros	Investment
Age or inadequate quality of old pipes	Old pipes or poor procurement of old pipes	5,000 feet of low-quality grey conduit PVC along Samuel Guy Street in Spanish Wells Drainage fittings in Russell Island	Procurement requirements
Improper installation of pipes	Previous lack of works supervision	Millionaire's Road on Harbour Island Glass Window Bridge	Better works oversight (now addressed)
Pressure surges	Pumps pushing directly into distribution lines	A vast majority of WSC networks are not gravity-fed	PRV, pressure tanks or elevated tank (even small capacity)

Project framework
Witteveen+Bos has been contracted by CCCCC to perform an OTEC Feasibility study for The Bahamas (with consultancy contract number CONTRACT#69/2022/EU-GCCA/CCCCC). CCCCC has received financing from The European Union (EU) through GCCA+ programme toward the cost of the project titled 'Enhancing Climate Resilience in CARIFORUM Countries' and to apply part of the proceeds towards the OTEC feasibility study.

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

The Beneficiary under this contract is the Office of the Prime Minister (OPM), Government of The Bahamas.

Objectives
The project objective is to evaluate the feasibility of OTEC and, in combination with SDC, solar thermal and/or PV solar energy to contribute to the decarbonisation of the water supply in The Bahamas (Family Islands).

We are expected to complete four deliverables under this contract:
1. Inception Report - based on an inception meeting with local stakeholders and partners.
2. Assessment Report- A bench-level assessment of the Water Resources of The Bahamas, regarding the inverted geothermal conditions from existing Seawater Reverse Osmosis (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.

2

REPORT ON INCEPTION PHASE

The inception phase is the first phase of the project with the objective to:
1. Understand the stakeholders of the project.
2. Streamline the vision, the scope of the project, and its boundaries between CCCCC, the steering committee and the consultant.
3. Collect required data.

In this chapter, we report the undertaken activities of this phase (section 2.1) and the implication for the next phases (section 2.2).

2.1 Undertaken activities

The undertaken activities are (organisation of) meetings with stakeholders, site visits, and data collection.

During the inception phase, we visited The Bahamas with the following agenda:
- 30 October – Site visit to SWRO in the centre of Eleuthera
- 31 October – Site visit to SWRO in North Eleuthera
- 1 November – Site visit to SWROs in south of Eleuthera
- 2 November – Meeting with stakeholders
- 3 November – Site visit SDC
- 4 November – Inception meeting

2.1.1 Meeting stakeholders

The stakeholders
The critical stakeholders with contact persons for this project are:
- Dr Rochelle Newbold, Environmental & Climate Advisor for Office of the Prime Minister OPM, rochellenewbold@bahamas.gov.bs
- Dr Rhianna Neely-Murphy, Director for The Department of Environmental Planning & Protection DEPP, rhiannaneely@bahamas.gov.bs
- Mr. Harrison Lockhart | Engineer, Ministry of Works (MoW), harrisonelockhart@bahamas.gov.bs
- Mr. Leslie Hutchinson | Sr. Project Manager, Water and Sewerage Company (WSC), wcleslie@wsc.com.bs
- Mr. Burlington Strachan | Chief Operating Officer - NP Operations to Bahamian Power and Light (BPL), bfstrachan@bplco.com

The persons mentioned above together with Mr. John Bowleg and Mr. Darrel Audinette will be invited to all meetings where the draft versions of deliverables 2, 3 and 4 are to be discussed. They will receive the draft document 2 working days before each meeting.

Other stakeholders identified for this project are Veolia/Suez (operators of the SWRO facilities), University of The Bahamas (UB), The Bahamas Technical & Vocational Institute (BTVI), Cape Eleuthera and Unesco (Inter Governmental Hydrological Program).

Meetings
On 1 November, we visited the office of WSC near the drinking water plant at Naval Base and had a meeting with the manager for the Eleuthera operations, Mr. Michael Cooper. The purpose of the meeting was to collect data on the water infrastructure of WSC in Eleuthera and other Family Islands.

On 2 November, we had a meeting with the following persons:
1 Mr. Robert Deal | Acting General Manager - Water and Sewage Corporation (WSC)
2 Mr. Burlington Strachan | Chief Operating Officer, New Providence Operations – Bahamas Power & Light (BPL)
3 Mr. Harrison Lockhart | Engineer, Ministry of Works (MoW)
4 Mr. Luther Smith | Permanent Secretary for MoW
5 Mr. Leslie Hutchinson | Sr. Project Manager - WSC, for CDB & GCF Projects
6 Mr. John Bowleg | Engineer, Sr Hydrologist, OTEC Project Lead for OPM

The purpose of the meeting was to inform the stakeholders of our findings and discuss the proposed path forward. The power point in Appendix III was used during the session. We presented the approach of applying different scenarios to select the best renewable energy strategy for the three technology-upscaling locations after visiting SWRO sites in Eleuthera.

During our visit to the Bahamas, we did not meet the representatives of the following stakeholders: University of The Bahamas (UB), The Bahamas Technical & Vocational Institute (BTVI) and The Department of Environmental Planning & Protection (DEPP). However, Mr. John Bowleg was asked for their interest and proposed role in the project. We will receive this information to be incorporated into the assessment report (deliverable 2).

This project is very much in line with the corporate objectives of WSC:
- Objective 4 - Improve environmental stewardship
    - Continue energy efficiency activities and introduce RE in desalination and other activities.

On 3 November, after the visit to Baha Mar, we discussed the selection of the technology-upscaling locations and questions regarding the project approach with Mr. Leslie Hutchinson, Mr. Harrison Lockhart, and Mr. John Bowleg.

2.1.2 Site visit

The site visits required quite some effort in organizing the local transport by the Consultant team. The ferry between New Providence and Eleuthera appeared to have been cancelled for the entire period of the inception visit. As a result, nearly all flights between the two Islands were fully booked for the first few days. And last but not least, the websites of the airlines did not function properly, so we had to go to the airport to finally get the visit to Eleuthera organized. Mr. Michael Cooper (WSC) organized accommodation and car rental in Eleuthera.

We visited Eleuthera for 3 days (from 30 October to 2 November) as Mr. Darrel Audinette on behalf of CCCCC and Mr. John Bowleg on behalf of the Beneficiary convinced the consultant team that 1 day, as proposed, was not enough to visit all four water treatment plants in Eleuthera.

Eleuthera
The island of Eleuthera incorporates the smaller Harbour Island, Spanish Wells, Russell Island, Royal Island, Current Island, Windermere Island, and associated Cays. It is long and thin, being 180 km (110 miles) long and, in places little more than 1.6 km (1.0 mile) wide. The island's total area is 200 square miles (518 km^2), with the highest elevation being 200 feet (60 m). According to the 2010 Census, the population of Eleuthera is approximately 8,202. The principal settlements are Governor's Harbour (the administrative capital), Rock

Sound, Tarpum Bay, Harbour Island with its unusual pink sandy beaches and Spanish Wells [Hydroconseil, 2018].

Eleuthera SWRO

Eleuthera was selected by Witteveen+Bos to be visited in the proposal phase since, according to the Terms of Reference, the two operators owning most of the water supply facilities in the Family Islands both have locations on this island. Additionally, according to the information in the ToR, this island should have both expired SWRO locations and locations still in operation. However, from meetings with Mr. John Bowleg, we understood that expired means that the contract is expired, but the installations are still in operation. In Eleuthera, only the contract with Suez for the plant in Waterford is expired.

Also, Mr. John Bowleg, on behalf of the Beneficiary, proposed to focus on Eleuthera for the following reasons:

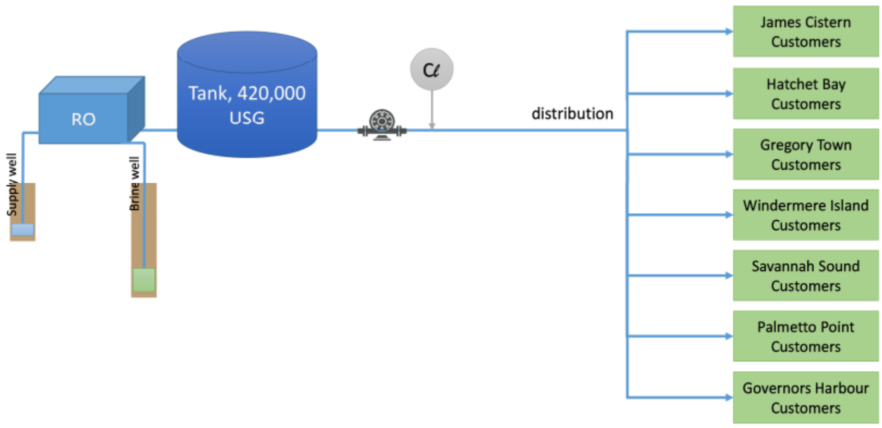
1. There are major challenges with BPL power supply, particularly at the Bogue and Naval Base plants and very active discussions are ongoing regarding possible alternative energy solutions for both locations.
2. The Island School at Cape Eleuthera (South Eleuthera) has a very strong aquaculture, fisheries and deep sea research facility on the island, and this could be an important part of building a research and commercial ecosystem around an OTEC facility.
3. Spanish Wells (in the North of Eleuthera) is perhaps the fishing capital of The Bahamas, and any discussion regarding a major fisheries component of an OTEC facility could benefit from their proximity and involvement.
4. Both the Bogue and Naval Base Plants require approximately 400 KW. A 100 to 250 KW or even larger OTEC facility at either location could assist in producing the base load power requirements.

We visited all four SWRO plants in the Eleuthera islands, which are: Naval Base (Central Eleuthera), Bogue (North Eleuthera), Tarpum Bay and Waterford (both South Eleuthera)

Naval Base

Naval Base is the second largest SWRO plant in Eleuthera, with a capacity of 450,000 IGPD. Naval Base SWRO serves 2074 customers (2017), with the majority being the residential customer (1378 customers) and the rest being commercial and government. The reported Unaccounted For Water (UFW) is 39.5 %. The plant operates at full capacity most of the time. The electricity consumption design capacity is 330 kW [Hydroconseil, 2018].

Figure 2.1 Block diagram water supply system Naval Base



The water treatment represented by 'RO' block in the schematics above (and for all visited four plants below) consists of 5-µm cartridge filters, followed by high-pressure pumps, one or more trains of RO membranes, remineralisation filters and chlorination using hypochlorite.

The pictures below were taken during the site visit showing the poor condition of the infrastructure. The tank shown could not be filled more than 50 % because of excessive leakages. Some PVC pipes are partly installed above ground, causing a shorter lifetime and increased water temperature (inducing the risk of bacteria growth in the system).

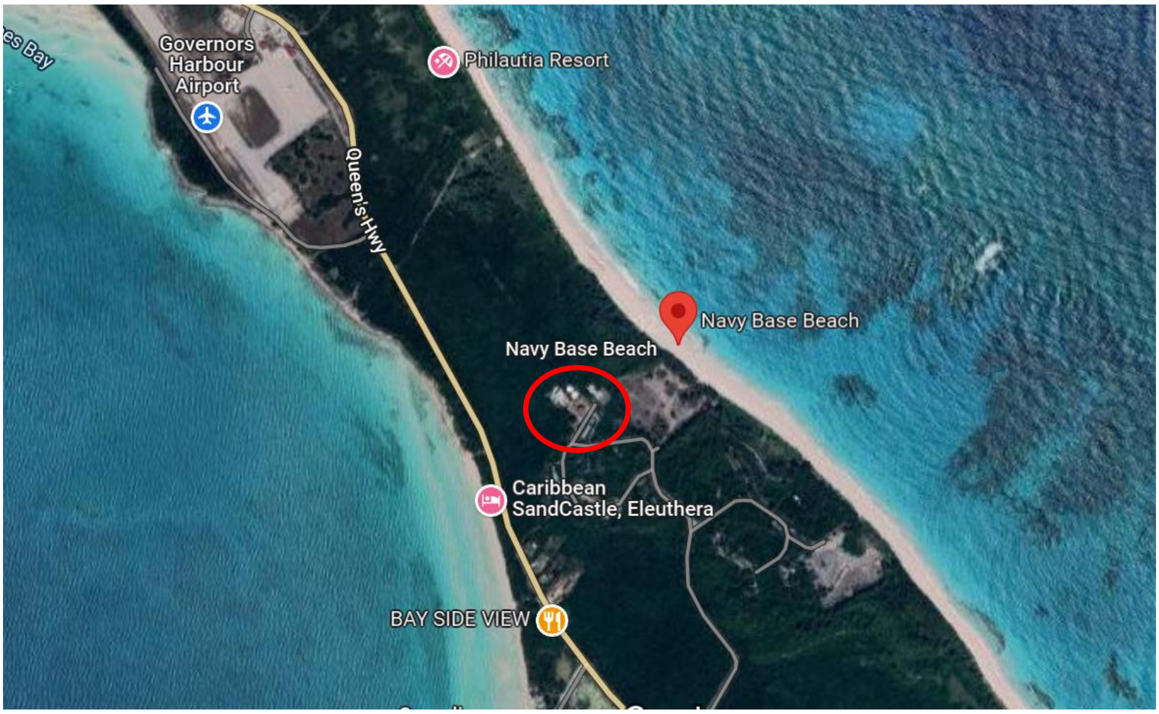
Figure 2.2 Naval base

It was recommended to make the system more robust and reduce UFW by replacing 5 % of the pipes, installing a pressurised tank, a new holding tank and additional chlorination [Hydroconseil, 2018].

In the vicinity of the water treatment plant, hardly any other buildings can be found, only the rather small airport building. In order to supply cooling to this building, long insulated pipes need to be installed, which is not considered feasible.

It also can be seen that there is insufficient space for large PV installations without removing forests in the areas directly surrounding the facility.

Figure 2.3 Naval Base water treatment plant and surrounding area



Bogue (North Eleuthera)

Bogue is the largest SWRO plant in Eleuthera and the Family Islands. The plant has a capacity of 650,000 IGPD and operates at full capacity most of the time. However, only one extraction well is in place. The plant delivers to 2692 customers. Around half of the demand comes from Harbour Island and Spanish Wells Island. The electricity consumption design capacity is 480 kW [Hydroconseil, 2018].

The water treatment represented by RO in the schematic below consists of 5 um cartridge filters, followed by high pressure pumps, two trains of RO membranes, remineralisation filters and chlorination using hypochlorite.

In Bogue the high iron content of the saline groundwater extracted, requires that Sulphuric Acid is continuously dosed in the extraction well that feeds the RO, in order to prevent clogging of the membranes. Every two weeks the cartridge filters need to be replaced. Also, the membranes do not last for more than a year (normally membranes should last for 5 years in similar applications).

Flooding of the location was also reported to have happened. With respect to climate change, this is considered a serious risk.

Figure 2.4 Block diagram water treatment and supply system Bogue (North Eleuthera)

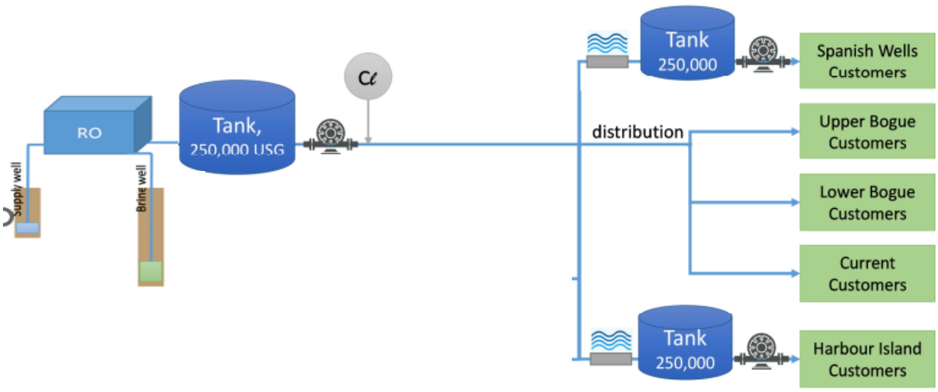
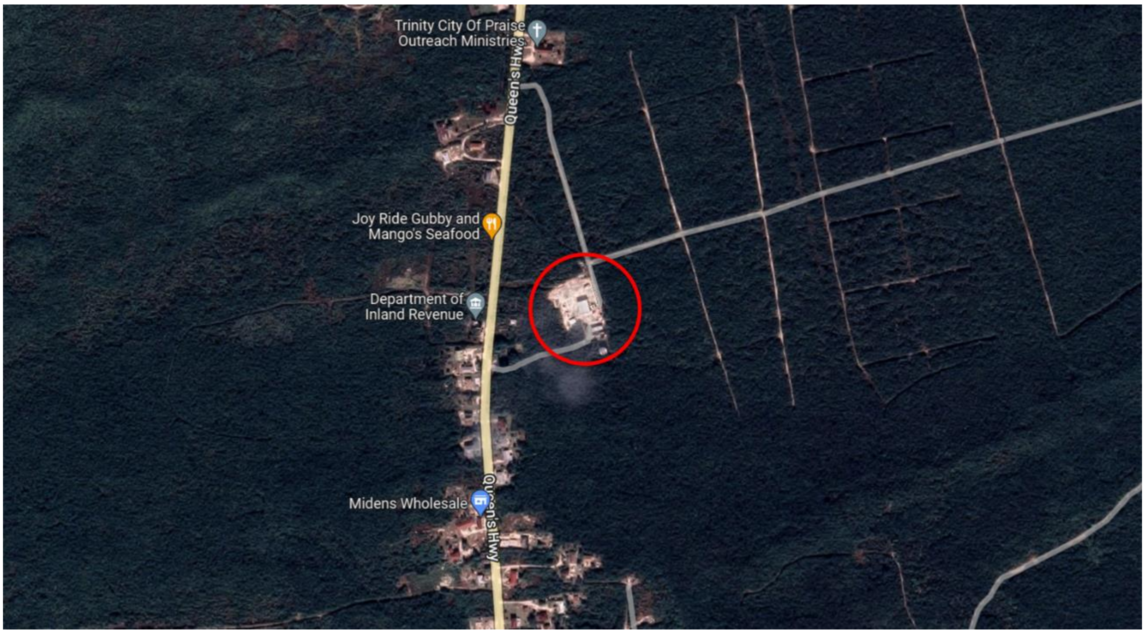


Figure 2.5 Sulphuric Acid Storage at Bogue WTP

Figure 2.6 Bogue water treatment plant and surrounding area



Tarpum Bay

Tarpum Bay SWRO plant has a production capacity of 240,000 IGPD. Energy design capacity is 180 kW [Hydroconseil, 2018]. The plant delivers freshwater for 1236 customers in the Rocksound and Tarpum Bay areas. The SWRO installation is in a container. The cartridge filters which look in poor condition are to be replaced by a new type similar to the ones in Naval Base and North Eleuthera. The chlorine dosing pump which is in a bad condition is also to be replaced by a new pump by the operator Suez.

Figure 2.7 Block diagram water treatment and supply system Tarpum Bay

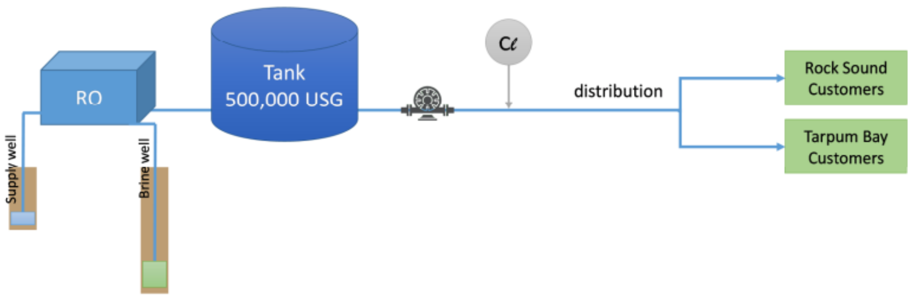
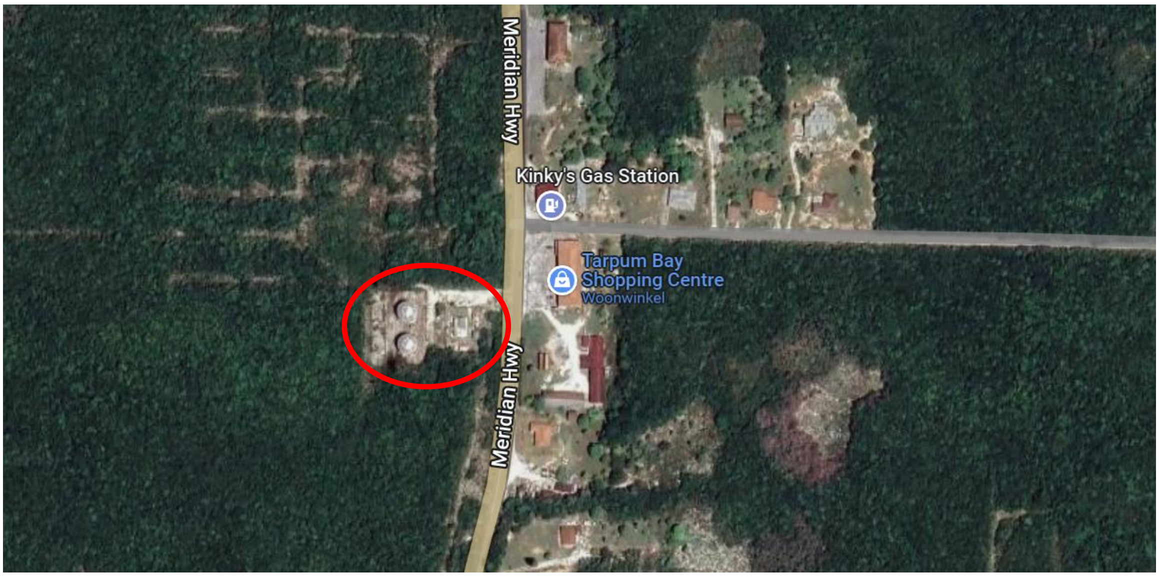


Figure 2.8 Tarpum Bay water treatment plant and surrounding area



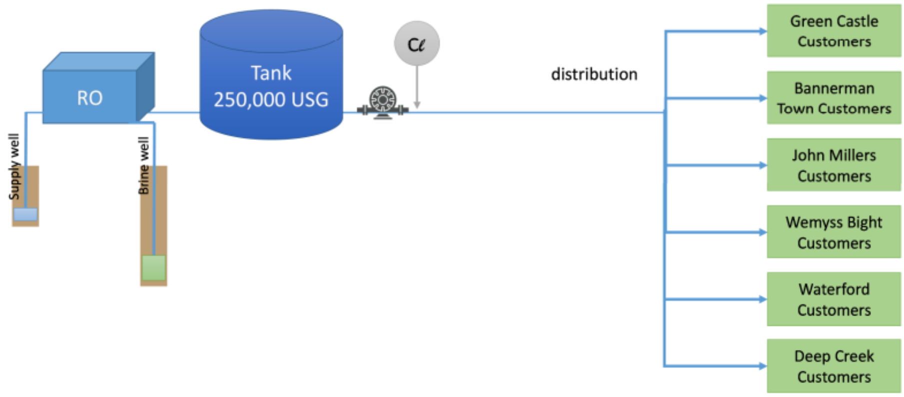
The two holding tanks in Tarpum Bay (see this report's cover picture) are in good condition (only 10 years old). In the vicinity of the water treatment plant, hardly any other buildings can be found. In order to supply cooling, long insulated pipes would need to be installed, which is not considered feasible.

It was also observed that there is insufficient space for large PV installations without having to remove forest in areas surrounding the facility.

Waterford

Waterford is the smallest RO plant in Eleuthera. The plant has a capacity of 90,000 IGPD and operates at full capacity most of the time. One extraction well is in place. The plant delivers to 744 customers. The power design capacity is 70 kW [Hydroconseil, 2018].

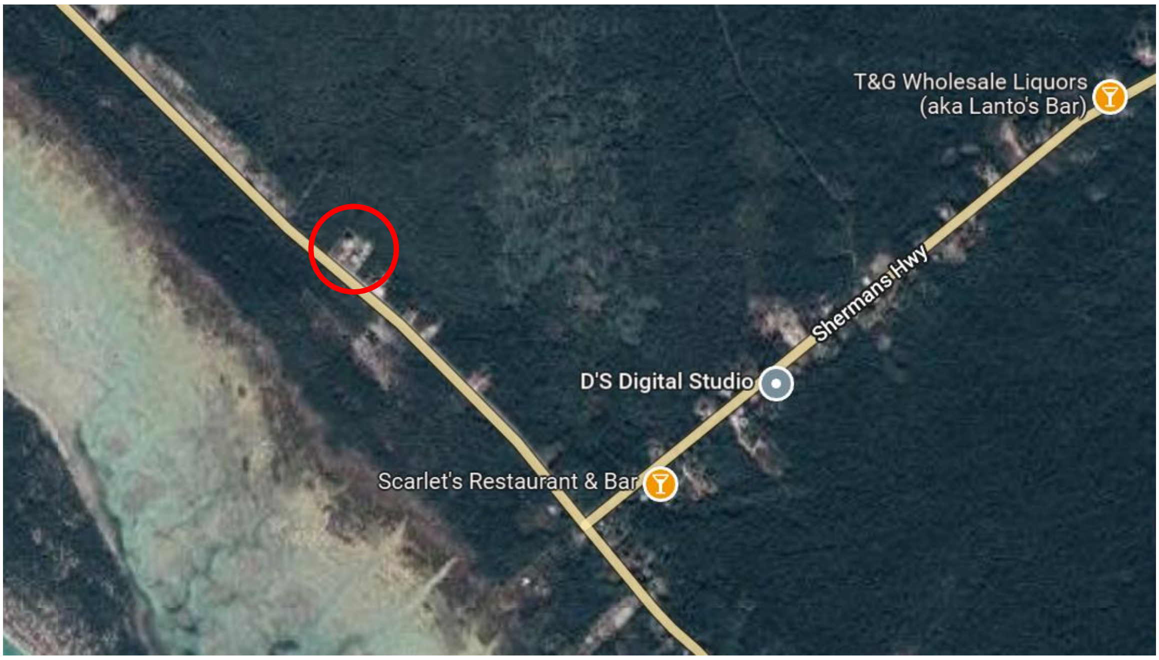
Figure 2.9 Block diagram water treatment and supply system Waterford



In the vicinity of the Waterford water treatment plant, there were hardly any other buildings. In order to supply cooling, long insulated pipes need to be installed, which is not considered feasible.

There is also insufficient space for large PV installations without having to remove forests in areas surrounding the facilities.

Figure 2.10 Waterford water treatment plant and surrounding area



Findings from the Eleuthera SWRO visits

Three of the four plants produce water 24/7 at their maximum capacity. We would have expected a lower capacity during the period when there are hardly any tourists. The population of the island is three times higher during the tourist season. Given a similar per capita consumption during the tourist season, it would have been logical to see a three times lower demand in the period August-November. As this is not the case, we recommend that the water treatment capacity be increased to meet the demand at all times during the year. However, what is complicating this analysis is the fact that many second-home owners and hotels also have their own RO and holding tanks. So this capacity also adds to the overall water supply capacity on the Island, especially during the tourist season.

As a result, we recommend not to increase the capacity of the water treatment facilities and use the current installed electrical capacity as a starting point for the design of on-site renewable energy production.

From the point of renewable energy strategy, we strongly recommend initiating a UFW reduction programme and implementing most of the recommendations of Hydroconseil. (We have a different view on the recommendations for pressurised tanks and chlorination.)

All water treatment plants in Eleuthera are far away from potential consumers of substantial amounts of cooling capacity. So it is considered not feasible to combine the SWRO and SDC in the water treatment plants in Eleuthera as this will require high investment in long insulated pipes. The length and low demand will also result in low energy efficiency.

Baha Mar District Cooling

On 3 November, we visited the Baha Mar resort on New Providence to see the highly automated district cooling system utilising cold saline groundwater. We were assisted by the team of Mr. Donald Nouguez, Facility Manager of DTEC Plant Services Ltd., who took us on a tour of their facilities.

Colder groundwater (71 – 72 °F) from 5 wells is used for the refrigerant system. The refrigerant system produces 42 °F chilled water to provide cooling for Baha Mar complex, which consists of 2300 rooms, many restaurants, swimming pools, casino, shopping malls, conference centre, etc. A room temperature of 55 °F can be achieved. The wells and installations have already been in operation for 12 years without any major problems. The extracted groundwater temperature has stayed constant throughout the year since the operation.

The wells extract groundwater from a 580 to 810 ft depth. The saline groundwater is injected back (after being used for cooling) with a temperature of 76-77ºF from 5 injection wells at a depth of 184.5 to 433 ft [Ardamann & Associates, 2013].

Figure 2.11 Baha Mar

However, it was observed that the Baha Mar chiller system uses refrigerant R-134a. The R-134a refrigerant is a potent greenhouse gas with a GWP (global warming potential) value of 1,430. In other words, the greenhouse effect of the R-134a refrigerant is 1,430 times the 100-year warming potential of the same volume of carbon dioxide. There are nowadays other refrigerants available with a much lower GWP value, which are highly recommended to apply in any future project.

2.1.3 Data collection

In general, the data collection activity went well. All documents provided were uploaded to our SharePoint. The relevant documents for our project are listed in a reference list to be included as an appendix to our Assessment report (deliverable 2 according to the contract). Mr. Michael Cooper the Island manager and Mr. Leslie Hutchinson from WSC were very supportive in providing the required data, and OTEC Project Lead for OPM facilitated the data required from other institutions.

However, we still need the data mentioned below for our next phase, Assessment report:

1. Data on deep wells e.g. from oil/gas exploration
2. Information as requested from BPL on 3-11-2022 on **electrical power production & grid system as follows:**
   1. Organization scheme of BPL
   2. Objectives of BPL for 2022 or if available 2023
   3. GIS map of the electricity infrastructure in the Family Islands (powerplants and grid)
   4. Table with capacity of the powerplants and grid in the Family Islands
   5. Investment programme for the next 5 years (or if not available only what is available)
   6. Amount of Diesel needed per year (2021) for each powerplant
   7. Electricity tariff for 2023 (or if not available 2022)

8 Plans/investment programme for extension of capacity of both powerplants and grid (next 5 years)
9 Plans/investment programme for renewal existing infrastructure (next 5 years)
10 Electricity (kWh/year) in 2021 for each family Island supplied to WSC/Suez/Veolia or any other water supply operator
11 Plans/investment programme for Renewable Energy Sources & Energy Efficiency (next 5 years)

3 The interest in the project and proposed role of all stakeholders in this stage and subsequent project stages

2.1.4 Preliminary analysis

Based on the discussions in the meetings, site visits, and documents received, we share our analysis as the basis for the proposed adjustments to the original work plan.

Renewable Energy Source in The Bahamas
We suggest not only to focus on OTEC as the renewable energy source, but also to compare OTEC with PV, PT, wind energy, sea/ocean (e.g. wave energy) or combinations of these sources to produce electricity. This comparison is to be done in the energy audit (deliverable 3). Based on the comparison, we will select the best option to be further elaborated for the 3 technology-upscaling locations

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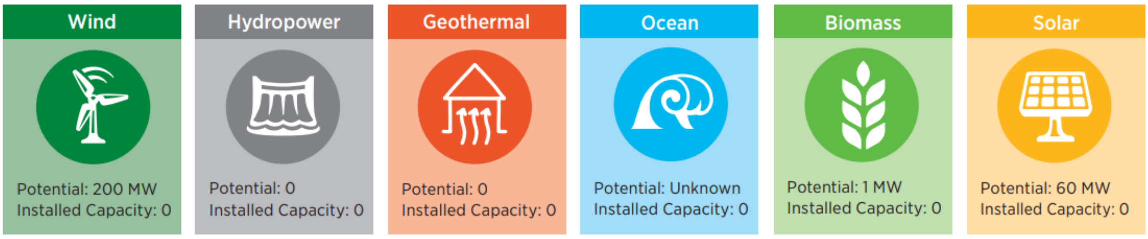
The main goal of OTEC for SWRO is to decarbonise the water sector. OTEC is not the only renewable energy option for SWRO in The Bahamas. The country has moderate potential for variable renewables - wind and solar - but limited or no potential for baseload renewables (other than OTEC) such as hydropower or geothermal.

Figure 2.12 Renewable energy potential Bahamas (Energy Transition Initiative, 2015)



Wind and solar resources offer the greatest potential for renewable energy development in The Bahamas. With average Global Horizontal irradiance (GHI) of 1951 kwh/m^2, The Bahamas has a 60 MW solar potential (Global Solar Atlas, 2022), while wind power has a potential of 200 MW with an average wind speed above 20 km/h. Figure 2.13 and Figure 2.14 map the solar and wind resource in The Bahamas.

Figure 2.13 Solar potential in The Bahamas (Global Solar Atlas, 2022)

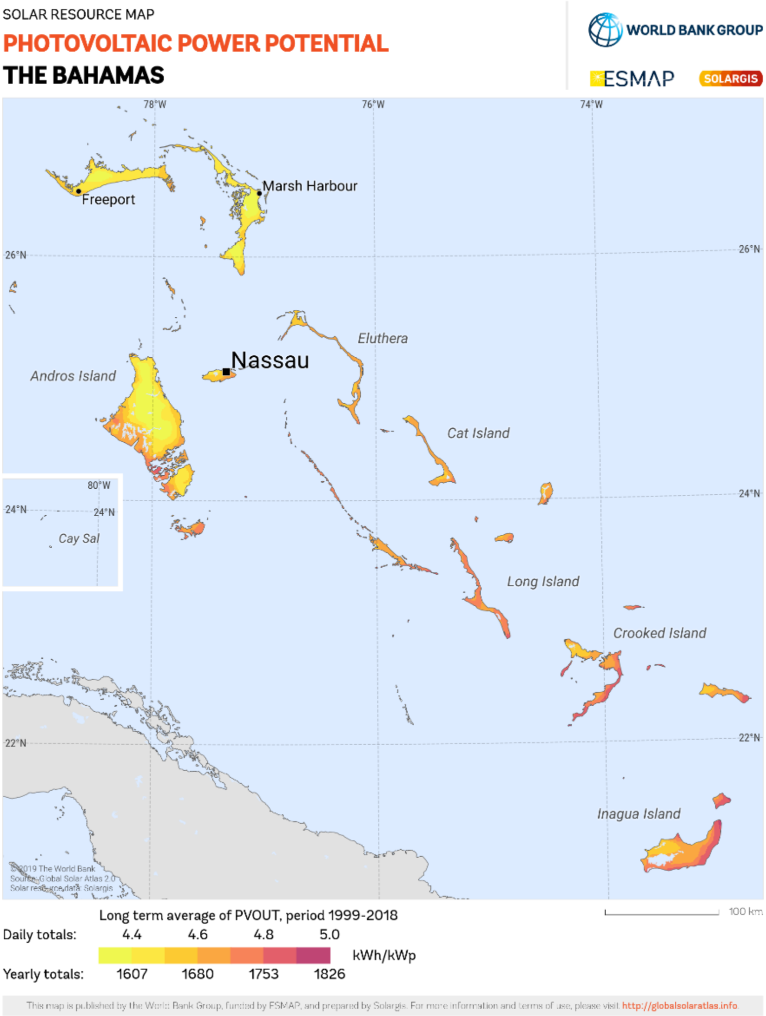


Figure 2.14 Wind potential in The Bahamas (Global Wind Atlas, 2022)

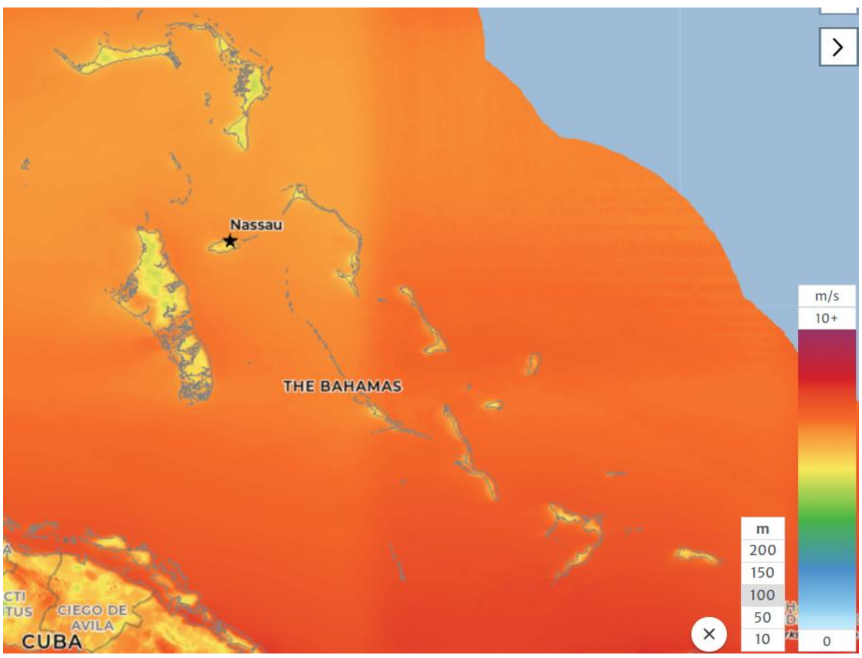
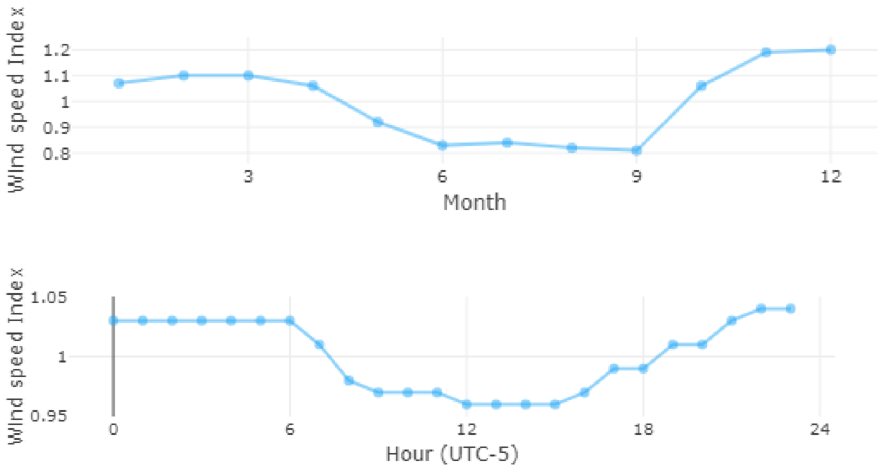


Figure 2.15 Wind speed variance by month and hour (Global Wind Atlas, 2022)



OTEC Technology types
We propose to compare the two most common options for OTEC: Closed or Open Cycle system in the Energy Audit phase (deliverable 3). We suggest to exclude the hybrid system, as it is less developed compared to the other two options. Based on the assessment, we will select one best option to be used for all three locations.

Closed cycle OTEC
A closed cycle (CC) OTEC plant employs a thermodynamic natural fluid such as ammonia or artificial refrigerant. This is contained in a completely closed system including the plant turbine. Hot surface seawater is used to evaporate the fluid and the vapour is then exploited to drive the turbine. The vapour from the turbine exhaust is condensed using the cold, deep ocean/ground water, and returned to the beginning of the cycle where it can be reheated.

Open Cycle OTEC
In an open cycle (OC) OTEC system the seawater itself is used to provide the thermodynamic fluid. Warm seawater is expanded rapidly in a partially evacuated chamber where some of it 'flashes' to steam. This steam is then used to drive a steam turbine. From the exhaust of the turbine, the vapour is condensed using cold seawater. The vapour produced by flashing warm seawater is at relatively low pressure, so it requires a very large turbine to operate effectively.

One of the major advantages of the open cycle system is that the water condensed from the turbine exhaust is fresh, not salt water, and so the plant can also serve as a source of fresh water as well as electricity.

Open cycle OTEC eliminates expensive heat exchangers at the cost of low system pressures. Partial vacuum operation has the disadvantage of making the system vulnerable to air in-leakage and promotes the evolution of non-condensable gases dissolved in seawater. Power must ultimately be expended to pressurize and remove these gases. Furthermore, as a consequence of the low steam density, volumetric rates are very high per unit of electricity generated. Large components are needed to accommodate these flows rates. In particular, only the largest conventional steam turbine stages have the potential for integration into open cycle OTEC systems of a few megawatts gross generating capacity. It is generally acknowledged that higher-capacity plants will require a major turbine development effort.

Figure 2.16 OTEC system (Kim et al, 2021)

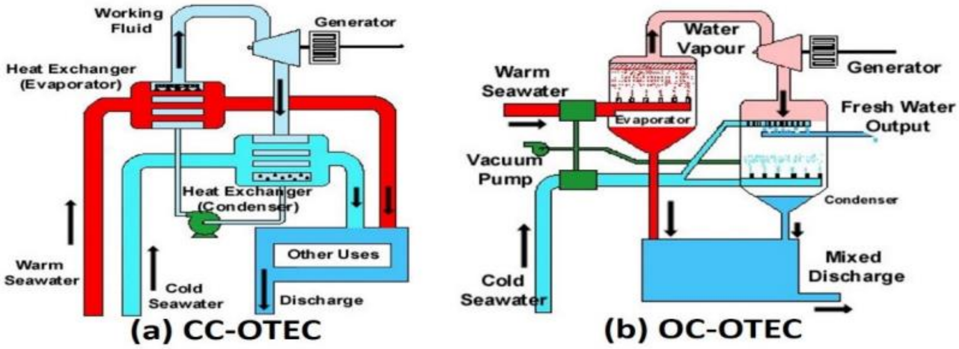


Table 2.1 Several important OTEC development projects (International Energy Agency, 2021)

No	Agency/company (Country)	Year, Location	Gross Power Rating (kW)	Net Power Rating (kW)	OTEC type
1	Claude (France)	1930, Cuba	22	-	
2	Mini OTEC (US)	1979, Hawaii	53	18	CC
3	OTEC-1 (US)	1980, Hawaii	1000	-	
4	Toshiba & TEPC (Japan)	1982, Nauru	120	31.5	CC
5	Saga University (Japan	1984, Saga	75	-	
6	NELHA (US) Open Cycle	1992, Hawaii	210	100	OC
7	Saga University (Japan)	1995, Saga	9	-	
8	NELHA (US)	1996, Hawaii	50	-	
9	NIOT (India)	2000, Tuticorin (incomplete)	1000	-	
10	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		CC
13	Makai Ocean Engineering, Hawaii USA	2015, Kona, Hawaii	100	-	CC
14	K-OTEC1000 Barge, (KRISO) South Korea	2019. Floating unit	338 to 1000		

Hybrid

Hybrid cycles combine the potable water production capabilities of open cycle OTEC with the potential for large electricity generation capacities offered by the closed cycle. **However this hybrid system is less developed compared to the other two options.**

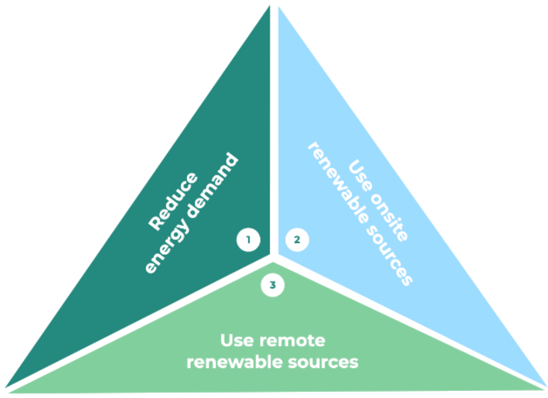
Inverted geothermal conditions

We suggest to investigate the heating of the groundwater by solar thermal as an alternative to achieve the 20 °C temperature difference required for OTEC. The investigation is to be performed in the energy audit (deliverable 3). The reason is that it is yet unknown whether deeper drilling is cost-effective and if it will result in a further temperature decrease or increase.

A pilot well was drilled down to 304.8-m (1000-ft) and logged, in the Cable Beach area of New Providence. At 304.8-m (1,000-ft) the water had a temperature of 20.3 °C (68.5 °F) [Ardaman & Associates 2013]. However, no data deeper than this well has been retrieved. It is very uncertain how the temperature develops going deeper. **So it is highly recommended to search for data on deeper wells in The Bahamas and surrounding area (Florida, Cuba) with similar geological conditions in order to get an idea of the potential of colder or warmer water when drilling deeper.**

Renewable energy as part of an integrated project
We recommend that we follow the NEW Trias Energetica rules. Therefore, this project should be integrated into an overall upgrade of the technology-upscaling locations and UFW reduction programme.

Figure 2.17 Trias Energetica [Paul Schurink, 2021]



Energy generation often comes with a negative impact on the climate and the environment. In order to deal with this negative impact, a systematic approach is recommended. A commonly used model is the Trias Energetica. This model is very effective for improving the sustainability of energy consumption. To minimize the amount of renewable energy needed and the impact on the environment (e.g. land use, or impact on groundwater), it is strongly recommended that the implementation of the project is preceded by a programme to reduce UFW and increase awareness among the management and operational staff on energy efficiency.

The capacity of Renewable Energy in the technology-upscaling projects
We recommend if OTEC is to be applied, it should not exceed the current installed capacity of SWRO in the 3 technology-upscaling locations for the energy audit (deliverable 3). In the conceptual design (deliverable 4) we propose a maximum OTEC capacity of 100 kW.

In most of the SWRO locations in the Family Islands, NRW is high (average 37 %). A NRW reduction programme is expected to result in higher reliability of supply y to the client. Now the installed water treatment and supply capacity is nearly equal to the average capacity supplied during the whole year. As the number of tourists on average is twice the number of inhabitants and as most tourists come in the period mid-December to July, a factor of 3 on a monthly basis would have been expected. On the other hand, many tourists have a second home or stay at resorts that have their own wells with RO and storage tanks. So it is expected that the current SWRO systems of WSC should be able to meet most of the demand after the implementation of the NRW project.

As the OPM is in the process of signing a memorandum of understanding with Okinawa Prefectural Government (Japan) for OTEC assistance and as they have a 100 kW installation installed, it seems logical not to exceed this capacity initially.

Selection of 3 technology-upscaling locations
We suggest to select (1) North Eleuthera - Bouge (Eleuthera island), (2) Naval base (Eleuthera island), (3) Cockburn town (San Salvador island) as the three technology-upscaling locations.

We suggest to select the following three technology-upscaling locations to be used in the analysis in deliverables 2,3 and 4:

1 North Eleuthera - Bouge (Eleuthera island)
This site has the highest production capacity and demand in the Family Islands. Decarbonisation of the site provides the highest impact. The area is the main destination for tourists coming to The Bahamas and, therefore, would give a higher opportunity to promote OTEC technology. A second and deeper well provides the opportunity for better water quality and redundancy.

2 Naval base (Eleuthera island)
The naval base is the second largest SWRO plant in Family Islands. It was a former US submarine base. It is close to the Atlantic Ocean and therefore offers opportunities for alternative energy technologies like wave or tidal energy. There is currently only one extraction well. There is a plan to add another well to provide redundancy and increase the reliability of the groundwater supply. The drilling of the new well can be designed to accommodate OTEC.

3 Cockburn town (San Salvador island):
This plant is proposed on the list because of the future plan of re-opening and expanding Club Med in the region. New capacity and drilling would be expected. The drilling can be combined to obtain cold water. The proximity of the Club Med would also provide an opportunity to supply SDC to that facility. Moreover, the contractor for the RO Plant is also Suez, therefore, this would make the organisation easier.

For the selection of the 3 technology-upscaling locations, the below criteria's have been applied:

- Within Family Islands
- Operational site
- High cost of electricity
- Issue with grid electricity
- Challenge providing water at a better cost
- Impact on the community
- Different opportunities between the 3 locations

3

FINAL WORK PLAN

During the proposal phase, we delivered our work plan. Please refer to Appendix I. With the new information we receive during the inception phase, we propose several changes to the scope and work plan as described in Section 3.1 and Section 3.2.

3.1 Changes to the scope

1. Previously OC-OTEC was proposed in the ToR. Upon reviewing and discussion with WSC and OPM, CC-OTEC is preferred for the following reasons:
   - CC-OTEC is more efficient and well developed and demonstrated compared to OC-OTEC
   - OC-OTEC produces both water and energy; in many cases, the water supply capacity is already enough. Furthermore, it can threaten the water business of current SWRO operators.

   We propose to compare both options in the Energy Audit Report (deliverable 3).
2. The OTEC system's main purpose is to provide clean energy for SWRO operations. Therefore OTEC will not be oversized to feed to the power grid. For the technology upscaling, a scaled approach is proposed, for example, starting the OTEC scale to deliver power for only a 7.5 hp (5.5 kW) distribution pump.
3. The OTEC system will be evaluated compared to other renewable energy alternatives (solar, energy from the sea - e.g., wave and tidal - and wind) to provide a better overview of the OTEC pros and cons.
4. NRW in the Bahamas is considered high. In our study, we recommend a reduction program to significantly reduce the level of NRW.
5. We will only consider SDC for 1 of the 3 locations (San Salvador).

3.2 Changes to the work plan

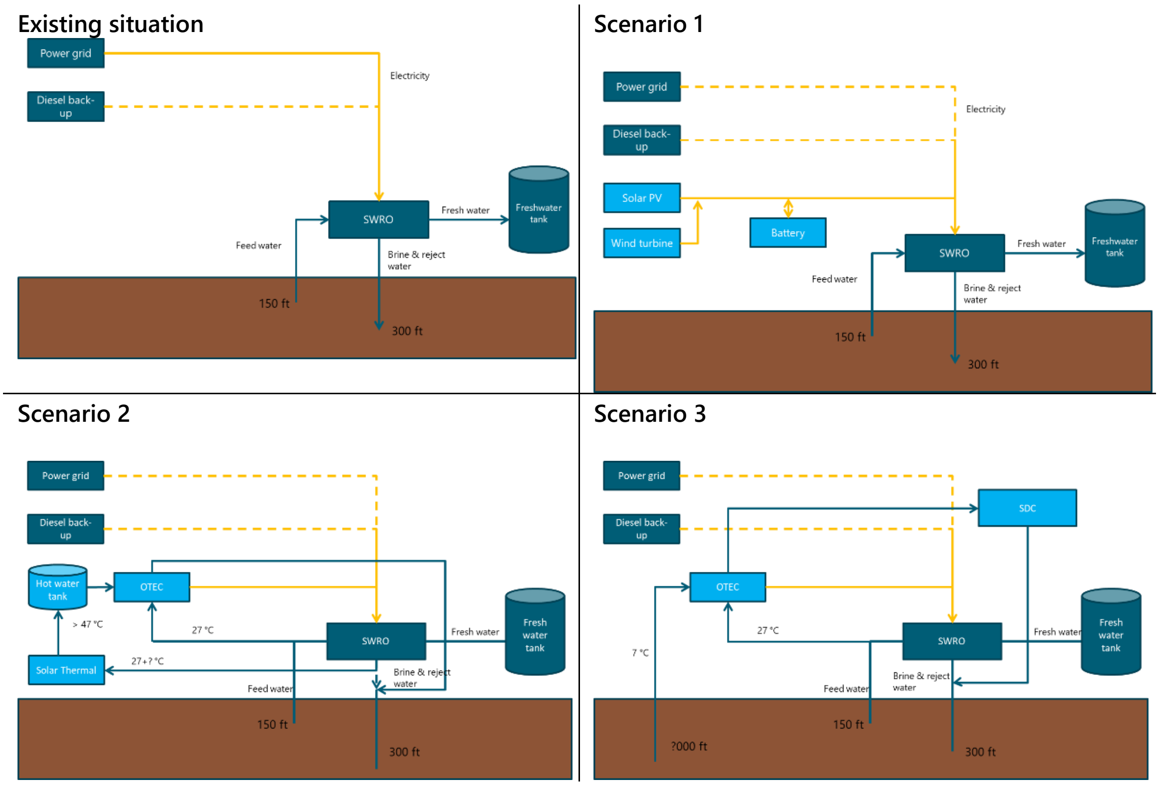
Deliverable 2 Assessment Report
In the technical proposal, one of the activities is to evaluate the financial and environmental implications of the sites with expired contracts. Upon consultation with OPM and WSC, it is advised not to evaluate the expired sites. The evaluation could damage the relationship between WSC and Suez. Moreover, there is less likelihood that WSC (The Bahamas government) would buy the expired sites.

Deliverable 3 Energy Audit report
In this work package, we propose to start by comparing OTEC with renewable energy alternatives to give a complete overview of the benefit and drawbacks of OTEC as a renewable energy source, and to understand the sweet spot for the OTEC application in The Bahamas. This system would be system scenario 1.

In scenario 2, we apply OTEC technology with the assumption of using existing SWRO wells for both cold and warm water. The water temperature from the well is around 27 °C. Therefore, the water must first be heated with solar thermal to at least 47 °C. A hot water tank can be provided as heat storage to enable continuous operation.

In scenario 3, we assume that a cold water source (around °6 C) is available at a certain depth. This would be an ideal condition for OTEC.

Figure 3.1 OTEC system scenarios



The system scenarios entail pros and cons, as shown in Table 3.1:

Table 3.1 Pros and cons of the scenarios

Scenario	Pros	Cons
1	- Relatively mature technology compared to OTEC	- requires large space - intermittent without battery - increase the cost considerably with battery
2	- Does not require additional well	- Risk of insufficient water flow from the existing well - Solar thermal is intermittent without heat storage (hot water tank) - Hot water tank needs to be well insulated and can be expensive
3	- Constant power production	- Require drilling of deep well

Deliverable 4
No changes were proposed.

3.3 Changes to the planning

According to the contract, the services shall be completed by the 28 February 2023 and the contract shall automatically terminate on 31 March 2023 (or other date if parties come to an agreement). The proposed planning below is directed towards finalisation on 21 January 2023.

The issue of draft and final deliverables is foreseen at the following dates:

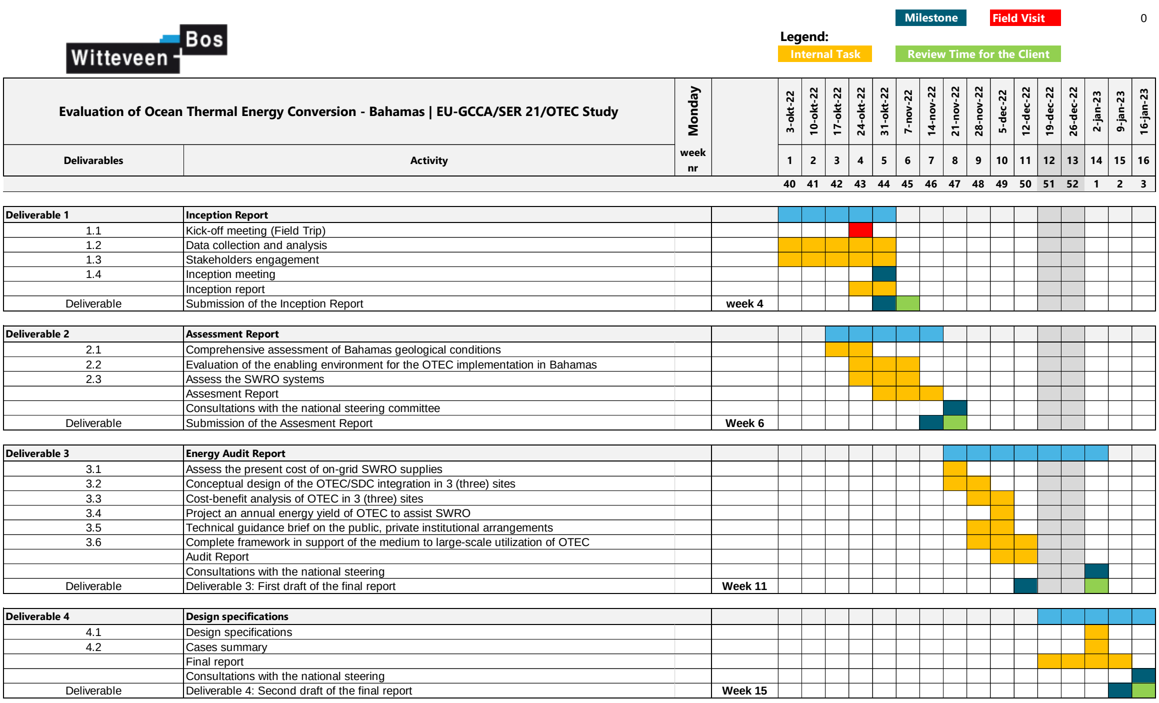
- Deliverable 1 - Draft Inception report 4 November 2022 & final Inception report 8 November 2022
- Deliverable 2 - Draft Assessment report 18 November 2022 & final Assessment report 25 November 2022
- Deliverable 3 - Draft Energy Audit report 16 December 2022 & final Energy Audit report 6 January 2023
- Deliverable 4 - Draft Conceptual Design Specification for SWRO-OTEC pairing system 14 January 2023 & final report on January 21 2023

Digital Meetings using MS Teams with CCCCC, OpM and critical stakeholders to discuss the draft documents are scheduled on:

- Deliverable 1 Inception Report : 4 November 2022 (CCCCC & representative OpM/DEPP only)
- Deliverable 2 Assessment Report : 23 November 2022 11 a.m. (Eastern America time)
- Deliverable 3 Energy Audit Report : 19 December 2022 11 a.m. (Eastern America time)
- Deliverable 4 Conceptual Design report : 18 January 2023 11 a.m. (Eastern America time)

With this schedule the Client, the Beneficiary and critical stakeholders have a total of 2 working days to read and comment on each deliverables.

Figure 3.2 Planning



Appendices

APPENDIX: SUBMITTED TECHNICAL PROPOSAL

Evaluation of Ocean Thermal Energy Conversion, Bahamas

Technical Proposal

The Caribbean Community Climate Change Centre (CCCCC)

28 July 2022

Project	Evaluation of Ocean Thermal Energy Conversion, Bahamas
Client	The Caribbean Community Climate Change Centre (CCCCC)
Document	Technical Proposal
Status	Final version
Date	28 July 2022
Reference	132728/22-011.300
Project code	132728
Project Leader	Raphaël van der Velde
Project Director	Peter Tienhooven
Author(s)	Merab Apkhazava, Rasyid Salam
Checked by	Raphaël van der Velde
Approved by	Raphaël van der Velde
Paraph	

Address	Witteveen+Bos Raadgevende ingenieurs B.V. Leeuwenbrug 8 P.O. Box 233 7400 AE Deventer The Netherlands +31 570 69 79 11 www.witteveenbos.com CoC 38020751

TABLE OF CONTENTS

1

PREFACE

Raphaël van der Velde MSc - Team Leader

We see our task as assisting our clients with our expertise throughout the entire value chain of energy generation, storage, distribution and use. In achieving the energy transition we aim to make the best possible use of the opportunities arising for health, safety and nature, and to prevent or minimise negative effects.

One of the most important challenges in the worldwide energy transition is how we can combine new, sustainable energy solutions from production to distribution and use in one integrated system. It is important to see things from the point of view of the end-users and consumers and consider the Public, Private, and Partnership arrangements.

Coupling the Ocean Thermal Energy Conversion (OTEC) technology with SWRO in Bahamas represents a unique technical task with promising potential. It is in Witteveen+Bos core business to respond to such challenges and discover the un-used potential of energy systems. We have ample examples to prove that the clients who delegated us such unique tasks never regretted.

My experience in research, renewable energy, drinking water infrastructure, CAPEX/OPEX studies, energy audits, and also a recent project with OTEC on Curaçao gives me extra confidence in our capability to provide the highest quality for the Caribbean Community Climate Change Centre (CCCCC). Moreover, the access to the corporate capacities of Witteveen+Bos, such as previously developed/paid technical & financial tools/models and available expertise (e.g. offshore infrastructure and geology) of other colleagues, gives us a distinguished advantage.

Introduction

The Caribbean Community Climate Change Centre (CCCCC) invites eligible firms to prepare a study funded by the European Union on Coupling the Ocean Thermal Energy Conversion (OTEC) technology with the Sea Water Reverse Osmosis plants on the Bahamas. Bahamas, together with its unique geology of continuous sequence of carbonate/evaporite rocks beneath 6 meters under the ground, makes the study special and requires a good technical and commercial understanding of the systems and environment in a local context. With the energy transition and circular ambitions, our clients face a major challenge with complicated combinations of options.

Witteveen+Bos is expressing our sincere interest for provision of the requested consulting services by submitting the technical and financial proposals including a detailed methodology, work schedule, and cost breakdown (separate pdf document). In the chapters of this document we introduce CCCCC to our previous experience and the team and share our approach to the task.

2

WITTEVEEN+BOS

2.1 Company Profile

Witteveen+Bos is a firm of engineering consultants, established in the Netherlands 1946, with over 1,400 professionals across the Netherlands and 15 branch offices worldwide. The many international projects that we have successfully completed over the years are evidence of our effective expertise and ability to adapt to local requirements. We are able to keep abreast with changes in society and thus with the needs and preferences of our clients. We always aim to be creative and innovative while offering cost-effective solutions.

Mission

Witteveen+Bos offers its clients valued-added consultancy and design services. We deliver reliable solutions built on knowledge, experience, intellect and social insight. At Witteveen+Bos we work on an exciting and inspiring project portfolio. Professionalism, respect and integrity are our core values.

Vision

We strive to be a top-class consultancy and engineering firm. To deliver top performance it is essential to have an international outlook towards products and markets. We wish to retain our identity and independence and to be acknowledged as an organization that delivers high quality.

An important objective for us is to perform our work in a socially responsible way. Our code of ethics lays out principles for doing business fairly and defines our standards and values.

Global presence

As one of the leading consulting engineering firms in the Netherlands, our knowledge and expertise is also frequently called upon from abroad. More than 20 % of our annual turnover is achieved through international projects.

Witteveen+Bos has a number of international offices and registrations in Indonesia, Singapore, Vietnam, Kazakhstan (3x), Dubai (UAE), United Kingdom (UK), Belgium (3x), Latvia, Ghana, and Panama.

Memberships, Registrations and Quality System

Witteveen+Bos is member of the Netherlands association of consulting engineers (NL engineers) and the Fédération Internationale des Ingénieurs Conseils (FIDIC). The firm is registered with all major international financing institutions, such as the African Development Bank, World Bank, and the **European Union**. All services and products provided by Witteveen+Bos are based on the procedures and regulations set down in the Witteveen+Bos Quality Assurance Management System, conforming to ISO-NEN-9001.

2.2 Added value

Witteveen+Bos supports its clients in issues relating to the energy transition and reduction of energy consumption. We go from analysis to proposing solutions to guiding and implementing measures in practice.

At Witteveen+Bos, we investigate all possible forms of geothermal energy from an independent, conscientious and integrated perspective. We contribute along the entire chain: from exploration to decommissioning. Our extensive technical knowledge of geology, geophysics, geohydrology, seismicity, energy, and water treatment – and our experience in preparing **business cases**, risk analyses and engineering – enable us to effectively examine the **technical and financial feasibility of projects**. Our expertise in above-ground heat/cold transfer, distribution infrastructure, and end-user applications (for example, in district heating/cooling systems) is also a big advantage.

At Witteveen+Bos, we always design according to our sustainable design principles, derived from the United Nations Sustainable Development Goals (UN SDGs). This means, for example, that we make use of the natural processes already occurring in the ground, and that we commit to using the geothermal energy source as efficiently as possible in combination with, for example, heat pumps. In this way, we are contributing to a sustainable future.

Witteveen+Bos has a long lasting history of operations on the **Caribbean islands** (and similar climatic conditions), especially in the water sector. For some time we also had a local office on Sint Maarten, which was with time substituted with an office in Panama. In section 2.3 we demonstrate some of our previous experience, but the list is not exhaustive.

Witteveen+Bos is also working a lot on IFI funded projects, including those funded by EU-commission. Our project manager Raphaël van de Velde is familiar with the standards and procedures and can provide the highest quality assurance and project management.

2.3 Experience

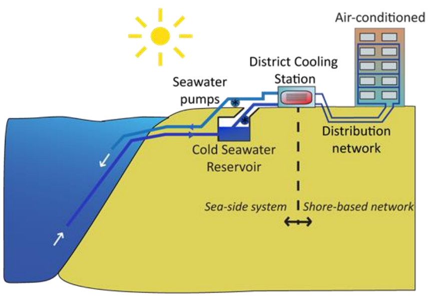
In the tables 2.1 and 2.2 below we present project demonstrate our more relevant and recent experience that meet the criteria.

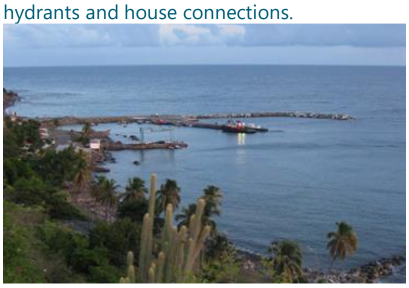
Table 2.1 Reference Evaluation Grid

#	Reference Name	Cost Benefit Analysis/audit of RE systems	Designing RE systems	Water Infrastructure in Caribbean / similar climatic conditions	SWRO
1.	Review OTEC, Curaçao.	+	+	+	
2,	Water supply and network St. Eustatius.			+	+
3.	Water supply improvement Mahé, Seychelles.			+	+
4.	Blue Energy Plant Feasibility Study Delfland.	+	+		+
5.	Engineering Reverse Osmosis Treatment plants, The Netherlands.				+
6.	Feasibility study renewable energy production at sewage treatment plant. Al Saja'a, UAE.	+	+		+

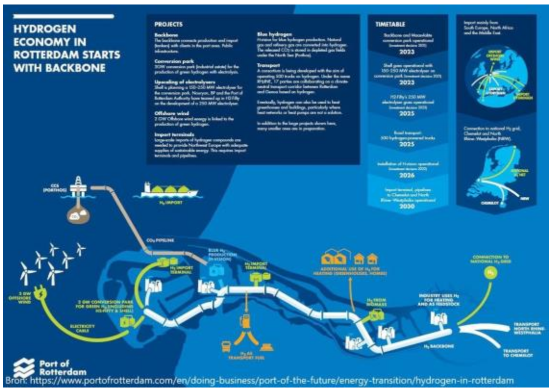
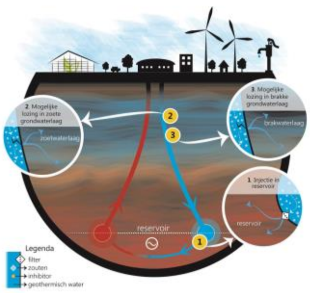
#	Reference Name	Cost Benefit Analysis/audit of RE systems	Designing RE systems	Water Infrastructure in Caribbean / similar climatic conditions	SWRO
7.	Feasibility Study Hydropower Sierra Leone.	+	+		
8.	Waste and Sludge to Energy W2E Plant Manila.	+	+	+	
9.	Hydrogen cooling and compression study for a 2GW electrolyzer park in Rotterdam.	+	+		
10.	Groundwater monitoring near geothermal systems.	+	+		
11.	CO2 emission feasibility and synergy study wastewater plant Terwolde.	+	+		+

Table 2.2 Reference Description

#	Reference Name	Description	Status	Budget
1.	Review **OTEC**, Curaçao	CA SDC and Bluerise have developed a plan to make electricity from the difference in temperature between the deep sea (1000 meter; 4ºC) and the surface (25 ºC) in the sea bordering the airport on Curaçao. This concept is called **Ocean Thermal Energy Conversion (OTEC)**. Additionally the cold from the deep sea is to be used to cool the airport buildings and a Data centre at Curaçao Airport. This concept is called Seawater Cooling System (SCS) For the transport of the cold a transport and distribution network design was made by Bluerise.  Witteveen+Bos has reviewed the design and business case of three different options for the design of this system.	Completed Duration: 2018	EUR 50,000.--
2.	Water supply and network, St. Eustatius	The project was divided into 2 phases: Phase 1: preparation of project masterplan for seawater desalination and drinking water production, preparation of **Caribbean** Island Regulations on Drinking Water, preparation of design, DC tender documents, assistance in tendering and tender evaluation.	Completed Duration: 2000 - 2013	EUR 452,000.--

#	Reference Name	Description	Status	Budget
		Phase 2: masterplan, design, modelling and preparation of tender documents according to European format of the drinking water network of St. Eustatius, consisting of PE pipes, diameters varying from 50 - 160 mm, two pumping stations, pressure zoning, reducing valves, water meters, fire hydrants and house connections. 		
3.	Water supply improvement Mahé, Seychelles	The combination of increasing water demand (tourism and population growth), water resources constraints and a high proportion of Non Revenue Water (NRW) on island of Mahé, pose severe constraints on water supply service. An assessment by feasibility study was prepared, and improvement options have been proposed. Several improvement options have been elaborated in preliminary designs and tender documents in **EuropeAid** format: - Water meter replacement programme. - Water meter workshop. - NRW reduction by means of leakage detection. - Distribution system improvement by means of pipe replacement. - Remote monitoring and SCADA water control programme. Witteveen+Bos performed: Feasibility study, NRW analysis, Preliminary design distribution system improvement, Preliminary design SCADA system improvement, Preparation of tender documents in **EU format.**	Completed Duration: 2007 - 2010	EUR 120,000.--
4.	Blue Energy Plant Feasibility Study Delfland	Witteveen+Bos conducted a feasibility study and preliminary design for a so-called Blue Energy Plant to produce renewable energy from the salt gradient between fresh WWTP effluent and salt seawater. In 2017, the board of the Delfland Water Board (HvD) adopted the motion 'Delfland energy neutral 2025'. This expresses the aspiration to be energy neutral as a water board by 2025. Witteveen+Bos was responsible for: - Project management. - Workshops Sustainable Design Principles. - Integrated design sessions. - Drafting Technological and Technical Design. - Preparing sustainability analysis / CO2 design. - Life cycle costing. - Drawing up a value case. - Multi-criteria analysis weighing method. - Stake/Shareholder analysis.	Completed Duration: 2018	EUR 39.000,--
5.	Engineering Reverse Osmosis Treatment plants, The Netherlands	For client water company Oasen, Witteveen+Bos has performed engineering and project management services for the parallel engineering of new **Reverse Osmosis** (RO) water treatment plant De Put and RO water treatment plant De Hooge Boom. For the engineering of both projects, Witteveen+Bos carried out services for preliminary design, final design, procurement and permitting. The following disciples were involved: civil, mechanical, electrical and	Completed Duration: 2019 - 2021	EUR 700,000.--

#	Reference Name	Description	Status	Budget
		process automation. The design of each project consists of a site layout, a building for the treatment plant, a treatment train consisting of Reverse Osmosis, Ion Exchange and Remineralization.		
6.	Feasibility study renewable energy production at sewage treatment plant, UAE	At the Al Saja'a sewage treatment plant (STP) in United Arab Emirates, approximately 25,000 m3 of municipal wastewater is treated per day. To improve the sustainability of the STP, the production and use of renewable energy can have a big impact. Witteveen+Bos has performed a feasibility study to the technical and economic potential of renewable energy resources to the power supply of the STP.	Completed Duration: 2019	EUR 40,000.--
7.	Feasibility Study Hydropower Sierra Leone	Riverblade is aiming to develop medium hydropower stations in Sierra Leone with a total capacity of 50-75 MW. In this first stage Riverblade aims to develop 4-5 hydropower stations, totalling 20 MW and in a second stage several location reaching 30-50 MW. During pre-feasibility study, potential locations are determined using a GIS model of hydropower potential in Sierra Leone (a tool developed by Witteveen+Bos). A first selection of sites has been made by filtering on the vicinity of towns or other large consumers. During pre-feasibility phase, again a selection has been made based on site characteristics.	Completed Duration: 2016 - 2017	EUR 400,000.--
8.	Waste and Sludge to Energy W2E Plant Manila Philippines	One of the activities of Manila Water is the treatment of wastewater and septage. During wastewater treatment sewage sludge is produced. Both sewage sludge and septage contain organic material, which can be digested anaerobically to produce biogas to be used as a sustainable energy source. Organic urban waste, food waste may be added to the digestion mixture to increase biogas production. This memorandum explores the possibility to apply anaerobic digestion (AD) to produce biogas from sewage sludge, septage and food waste and estimates the achievable biogas production for Manila Water based on the supplied data. Witteveen+Bos performed: - Feasibility study. - Biogas production calculations & design. - Pilot Plan. - Proposal Piloting and Engineering Services. - Project Management.	Completed Duration: 2015-2017	EUR 15,000.--
9.	Hydrogen cooling and compression study for a 2GW electrolyzer park in Rotterdam The Netherlands	The Port of Rotterdam Authority (HbR) sees an active role for the port in the development of hydrogen production. She is looking for opportunities to establish OSBL systems (OutSide Battery Limit) on electrolyzer parks at locations in the port. The aim of this study is to determine to what extent it is technically and economically interesting to centralize cooling water systems and hydrogen compression at the relevant Electrolyzer park. Costs (**CAPEX, OPEX**), space requirements and, for cooling, future options for heat decoupling (external utilization) were examined.	Completed Duration: 2020	EUR 55,000.--

#	Reference Name	Description	Status	Budget
		 Witteveen+Bos performed: - Simulations performed for hydrogen compression and cooling. - **Assessments performed** to determine the best applicable compression systems including the number of stages and machines required taking into account maximum temperatures (API618). - Air cooling calculations performed to determine size and dimension of (inter)cooling. - Conducted **market consultations** for selection and pricing of compressors and refrigeration systems. - Layouts determined of the compressor stations and refrigeration facilities. - Estimates made of maintenance, energy and other OPEX. - Options determined for the electrical infrastructure of the various options. - CAPEX comparisons made for the various options in order to determine the **most economically attractive** option.		
10.	Groundwater monitoring near **geothermal** systems The Netherlands	A monitoring approach has been developed for the detection of **brine leakage from geothermal wells** to protect (potentially) high-quality groundwater. The aim here is a generic groundwater monitoring approach that is applicable to the range of Dutch geohydrological conditions, so that it is practical, simple and unambiguous. Witteveen+Bos performed: - Design groundwater monitoring for 3 practical locations. - Tests of practical implementation. - **Cost-benefit analysis** (SSK estimate). 	Completed Duration: 2018 - 2020	EUR 40,000.--
11.	CO2 emission feasibility and synergy study wastewater plant Terwolde	A **synergy study** into sustainability (CO2 emissions and Environmental cost indicator) and **costs** (Realization costs, **CAPEX, OPEX**) has been carried out for a waste water treatment plant (WWTP). This concerns the water and sludge	Completed Duration: 2018	EUR 15,000.--

#	Reference Name	Description	Status	Budget
		lines of both WWTP, with the sludge processing and the discharge on the river IJssel. Important themes in addition to the performance of the statutory tasks are climate adaptation, **circular economy** and energy transition. These three themes play an important role as criteria in the variant study of the various possible synergy solutions for the WWTP Terwolde and Deventer. Witteveen+Bos performed: - Preliminary design. - CO_2 design. - **Cost Benefit Analysis.** - Circular Design Principle analysis. - MKI calculations.		

3

CURRICULUM VITAE

In this chapter we provide a detailed CV of our Team Leader Raphaël van de Velde as well as elaborate on his responsibilities as a project manager. We find it necessary to indicate the back-stoppers in risk of illness of the key expert. Witteveen+Bos has over 300 highly skilled professionals working in the energy & water sectors, who will be able to provide any necessary support and inputs for this project.

3.1 CV

Witteveen+Bos

CURRICULUM VITAE

R.T. Van der Velde (Raphaël) MSc

Business Unit Manager Energy Systems

Profile

Raphael van der Velde has been **working in the field of Energy Engineering, Water Supply** and **Water Reclamation** since he graduated in 1991 as an **Environmental Engineer** (**MSc**) at the University of Wageningen in The Netherlands. Due to his education and his professional career he is familiar with energy saving and r**enewable energy** production technology available nowadays. He has been involved in energy efficiency projects in Industry, biogas, hydrogen, energy storage, geothermal, hydropower, district heating and cooling infrastructure projects, Due diligence projects for EBRD in Kazakhstan and other clients concerning district heating, water supply, wastewater treatment and sewerage systems. He has been involved in feasibility studies for Seawater Reverse Osmosis (**SWRO**) and design of boiler feed water systems from very salt produced water where RO is an integral part of the water treatment. He is currently involved as a project manager for energy efficiency studies, industrial waste heat utilisation, large scale energy storage, hydrogen and water quality based geothermal design for both industries and government institutions in The Netherlands. In 2018 he was the project manager of a feasibility study for **OTEC** and Seawater District Cooling (**SDC**) connected to the airport of Curacao in **The Caribbean**. Raphael is senior Team Leader and Project Manager with extensive experience working for IFI funded projects and familiar with their standards and guidelines.

Personal

Year of birth	1966
Nationality	Dutch
Gender	Male

Career

2020 - date	Witteveen+Bos, Business Unit Manager Energy Systems
1998 - 2020	Witteveen+Bos, Senior Consultant / group leader
1993 - 1998	Water Supply Company Groningen, Project Manager
1993 - 1993	Mul BV, Project assistant
1991 - 1993	AquaSense/RIZA, Project Assistant
1990 - 1990	AidEnvironment, Research assistant

Experience

2022 - 2022	Project Director - Technical Due Dilligence Study of District Heating System Rotterdam, Netherlands
2021 - 2022	Team Leader - Compendium of Energy Solutions for the Water Sector, EBRD A tool has been designed for water companies to assess the **energy efficiency** and opportunities for renewable energy (**renewable energy audit**) of their drinking water and wastewater processes and technologies installed. With the tool it is possible the determine options for improvement and the related energy efficiency gains and

	investment connected to the measures to be taken. All water technologies worldwide applied are part of the tool (**SWRO** is one of them).
2022 -2022	Team Leader - Market assessment of direct us of **geothermal heat**, IRENA Project included literature **research** on the existing geothermal technologies, SWAT, and **Cost/Benefit** analysis.
2021 - 2021	Project Director - Risk assessment of abandoned salt caverns on the shallow subsurface and surface, The Netherlands **Research** into processing mechanism in relation to salt cavern abandonment in relation to the local (shallow) subsurface, geohydrology and construction for Nobian.
2021 - 2021	Project Director - Regulatory Geothermal Framework Chile Review of international soil energy and **geothermal regulations** to advise on amendments to soil energy and geothermal legislation in Chile.
2021 - 2021	Project Director - Energy System Meinerswijk, The Netherlands Preliminary design and **business case analysis** for a carbon neutral energy system (**renewable energy audit**) for a new residential area. The system consists of a ATES, heat pumps and low temperature district heating for multi-story buildings, **aqua thermal energy** to balance the system and electrical energy from a small hydro power to heat individual dwellings with heat pumps
2021 - 2021	Project Director - National water system viewer, The Netherlands A GIS viewer has been developed for Public Works (Rijkswaterstaat) to make the energy (**aquathermal**) potential visible to project developers that is available in the National Water Systems. A model using Python was developed to convert data from different sources into one database and to assess the **aquathermal potential**
2020 - 2022	Team Leader - Development Hydrogen Roadmap 2020-2030, The Netherlands **Research** among major Industrial natural gas consumers in the Clean Tech Region in order to assess the need for hydrogen in their **energy transition**.
2020 - 2021	Team Leader - Quick Scan Permits and Safety Megawat Hydrogen Bromide flow battery, The Netherlands QRA and permitting assessment for the installation of a 1 MW/5MWh hydrogen bromide flow battery (pilot phase) and 25 MW/250MWh (full scale) flow battery
2020 - 2020	Senior Expert **Renewable Energy Feasibility** (**renewable energy audit**) modification heating process to hydrogen and energy efficiency For Steel Industry we have been **research**ing the energy-saving options and the possibility of using green hydrogen and oxygen produced in-house from renewable electricity sources to heat steel to 1,200 degrees.
2020 - 2020	Project Manager Feasibility study sustainable district heating Brand brewery and Wylre, The Netherlands Feasibility **research** into heat transport and **heat exchange technology** and preliminary **design** into a sustainable district heating system for both Brand brewery and the surrounding village Wylre (**renewable energy audit**). Brewers Mash and local biomass is to be used as a **renewable source** for the heating. Based on the design a budget estimate and business case analysis is prepared for the municipality Gulpen Wittem. This municipality used this for Grant application.
2019 - 2019	Team Leader - Aquathermy from River IJssel Basic Design and cost estimate of river intake and outlet system and heat storage (ATES) and **heat exchange technology** for heating of 500 apartments
2019 - 2019	Project Manager Hydrogen workshop Clean Tech Region Organisation of workshop for Industry in the Clean Tech Region to inform them on Hydrogen **Technology and Economics**
2019 - 2019	Project Manager Design of groundwater monitoring system for geothermal wells **Research**, Conceptual Design and capital cost analysis of system to monitor groundwater near geothermal wells
2019 - 2019	Team Leader - Electrical **energy from Surface Water**

	Research into **renewable energy technologies** and their potential capacity to produce or store electrical energy in all surface waters of The Netherlands, including the North Sea
2018 - 2021	Team Leader - Green Refinery and Hydrogen Hub Deventer, The Netherlands Development of green hydrogen and oxygen and heat production using electrolysis and **renewable electricity**. A consortium of interested companies was brought together and financing of the project was arranged. The best overall system is defined in a scenario study. The best scenario is developed in conceptual and basic design
2018 - 2019	Team Leader - EED audit Nouryon, The Netherlands Energy efficiency and **renewable energy Audit. Research** into the energy management system and installations consuming energy and drafting of energy improvement programme according to the guidelines of the Energy Efficiency Directive.
2018 - 2019	Team Leader - Engineering Services Waste Heat Project Rotterdam, The Netherlands For the purpose of waste heat utilisation for a district heating network in The Province of Zuid Holland in The Netherlands basic design and business cases are drafted for 20 Industrial and geothermal facilities in the Port of Rotterdam
2018 - 2019	Team Leader - Energy Transition Pump supplier, The Netherlands **Research into heat exchange technology and renewable energy audit** utilising waste heat from a large pumps testing facility for heating of buildings. The pumps are large pumps for fire fighting, sewerage systems, drinking water transport and emergency situations like flooding from rivers.
2018 - 2018	Team Leader - Review **OTEC and SDC** Curaçao Airport (**Caribbean**) CA SDC and Bluerise have developed a plan to make electricity from the difference in temperature between the deep sea (1000 meter; 4oC) and the surface (25 oC) in the sea bordering the airport on Curaçao. This concept is called Ocean Thermal Energy Conversion (**OTEC**). Additional the cold from the deep sea is to be used to cool the airport buildings and a Data centre at Curaçao Airport. This concept is called Seawater District Cooling (**SDC**). Witteveen+Bos has reviewed the design and business case of three different options for the design of this system.
2018 - 2018	Team Leader - Analysis of (environmental) impact of inhibitors in geothermal facilities **Research** into a monitoring approach the detection of **brine leakage from geothermal wells** to protect (potentially) high-quality groundwater.
2017 - 2018	Specialist Renewable Energy sustainability pipelines and the energy transition in the Netherlands a market survey **Research** into the role of the current pipeline network for the transport of gases and liquids would be in the energy transition Together with AT Osborne and Panteia, representatives of all major industrial clusters, regional network operators and Gasunie, interest groups for pipeline owners and expertise centres were interviewed..
2017 - 2017	Team Leader - **Geothermal Water Quality** characterization using OLI and corrosivity impact analysis The project included **Cost/Benefit** analysis and Environment impact assessment.
2016 - 2017	Project Manager Sustainable heat from Rotterdam for Heineken largest Brewery Feasibility analysis, Basic Design, contracting of Detailed design, Build and Maintenance of connection to new **heat transport pipeline** of 87 km and upgrade hot water of 90 oC to 135 oC saturated steam.
2016 - 2017	Team Leader - Energy Efficiency studies Waste Processing Industries Energy Efficiency Scans and **renewable energy audits** of buildings and industrial processes
2016 - 2016	Team Leader - Energy efficiency scan Paint processing Industry Energy Efficiency Scans and **renewable energy audits** of buildings and industrial processes.
2016 - 2016	Team Leader - Feasibility Study **Geothermal Energy** Deventer

Feasibility (technical, **financial** and institutional) **research into heat exchange technology** including the Geothermal potential in the municipality of Deventer. Geothermal heat to be supplied to district heating system.

2015 - 2017 Specialist AEB Risk analysis biogas and natural gas storage and production
Risk analysis of H_2S and CH_4 concentration and capacity of storage and transport facilities in biogas from Wastewater Treatment Plant Amsterdam West and biogas from Municipal waste facility AEB.

2015 - 2017 Renewable Energy Specialist PLUS office
Development of Masterplan and preliminary design of **renewable energy production** facilities and energy storage for the existing office of Witteveen+Bos. The office is to become a zero fossil energy and water consuming building with a healthy climate.

2015 - 2017 Team Leader - FleXtore
Pilot test of Hydrogen Bromide Flow Battery connected to PV panels and to energy consuming processes in the office of Witteveen+Bos.

2015 - 2016 Team Leader / Senior specialist district heating /cooling Energy neutral Residential Area IJburg Central Island
Research into heat exchange technology and the heating and cooling demand in different scenarios of realization of housing and amenities. In addition for a number of solutions including CHS, district heating, geothermal energy and air / water heat pumps, detailed technical and cost estimates **CAPEX and OPEX** were prepared

2015 - 2015 Project Manager Warmtestad CBA, The Netherlands
Cost/Benefit analysis of development of new district heating system compared to autonomous development of heating infrastructure of buildings in case not connected to the district heating.

2015 - 2015 Lead Process Engineer Catro, Domestic Water Plant
Feed design of a drinking water plant.

2015 - 2015 Team Leader - Hydropower and Water Supply for Balikpapan from Hutan Arsari Lestari
Feasibility **research** into a sustainable electricity and drinking water supply (including **SWRO**) in a reforested area.

2014 Team Leader - feasibility Power to Gas at at wastewater treatment plant Cuijck
Research into the correct process configuration and technical and **financial feasibility** of producing methane from hydrogen and carbon dioxide at a sewage treatment plant. The hydrogen gas is extracted from the wastewater via electrolysis. The oxygen released in electrolysis is used to aerate the wastewater.

2013 - 2013 Senior Process Engineer Water Management Study Tengiz
Selection of alternatives for the water supply and reuse of produced water and wastewater to the oil field of Tengiz (Kazakhstan) including energy consumption. Search for sustainable alternatives for energy supply (wind, solar). **SWRO** was one of the technologies studied.

2013 - 2013 Energy Specialist Due Dilligence City Heating Systems Essent Warmte
Technical analysis of existing city heating systems throughout the Netherlands that are owned by Essent (RWE).

2013 - 2013 Team Leader - Phase 2 design Potable Water Treatment Rotational Village
Selection of preferred alternative for the potable water treatment of village for workers in oil field.

2013 - 2013 Team Leader - Renewable energy and City Heating Kirchberg (Luxembourg)
Renewable energy audit, including development of scenario's for the future integration of renewable energy into city heating system based on natural gas.

2011 - 2017 Lead Process Engineer SGP Water Systems Upgrade
FEED design for the upgrade of several Water Treatment Facilities within the Tengiz Oil Field for boiler feed water production and injection of wastewater streams into the aquifer. The source water is very saline.The processes designed include Dissolved Air Flotation, Mixed Bed Ion exchange, Sour Water Stripping and modification of Coagulation/Flocculation/Sedimentation, Multi Media Filtration and **Reverse Osmosis**. Design of Air Coolers and Cross **heat exchangers** are also part of the project.

2010 - 2017 Team Leader - Natural Gas Infrastructure design and construction
In order to reduce CO2-emissions the aim of the project is to construct a central gas transport network and a facility to improve biogas (65 % methane) to a quality of natural gas (88 % methane). Manure digesters and other type of digesters and gasproducing installations should be connected.

2009 - 2009 Team Leader - Due Dilligence **Water Infrastructure** Rehabilitation Aktau
Feasibility study of priority investment program for rehabilitation of drinking and technical water supply, city heating and wastewater treatment and collection of Aktau Vodokanal (water company), Kazakhstan.

2008 - 2009 Team Leader - Due Dilligence **Water Infrastructure** Rehabilitation Shymkent
Feasibility study of priority investment program for rehabilitation of drinking water supply, and wastewater treatment and collection of 'Vodnye Resursy-Marketing' private water utility company in Shymkent, Kazakhstan.

2008 - 2009 Team Leader - Feasibility Study Reuse of Produced Water
Feasibility study and pilot **research to analyse** the best option for treatment of **saline** produced water in the KarazhanBasMunai oilfield, Kazakhstan. The goal is to produce boiler feed water for steam production. Zero Liquid Discharge is the goal to be reached. **Reverse Osmosis** (RO), Ion Exchange (IEX) and chemical precipitation were part of the processes studied.

1998-2013 Various other projects

Project Manager of a study into the emission of glycol to surface water as a result of de-icing aircraft, commissioned by Schiphol Airport; project leader of a feasibility study and design of a water supply system for Leeuwarden Air Base. The aim is to choose the best design (technical, security of supply and financial) for an adequate water supply from a number of alternatives. The client is the Buildings and Sites Department of the Ministry of Defence;

Future survey of industrial water use in Limburg commissioned by the Chamber of Commerce. The aim is to provide insight into developments that affect industrial water use, including European regulations (Water Framework Directive);

Project Manager for the calculation of benefits of the Ministry's policy to combat acidification and eutrophication for drinking **water infrastructure** in the Netherlands and Europe. This project is commissioned by VROM in cooperation with Kiwa and is a follow-up to an earlier global study;

Feasibility Study into the local retention of precipitation and grey water in Heerlen. Various measures at building and neighbourhood level have been identified to realise water reuse. The municipality of Heerlen was the client;

Project Manager, drawing up a worksheet for the Association of Dutch Installers 'Working safely and hygienically with sewers';

Project Manager, supplying equipment for sampling and analysing water to State Laboratories of the Environmental Inspectorate in Donetsk Oblast in the Ukraine. Ring tests and training were also provided in this context. In addition, process-integrated measures and recommendations were made for wastewater treatment of a galvanic industry;

Project Manager, setting up a practical handbook/website for Riza on water aspects on sustainable business sites. Project leader, feasibility study into the central supply of irrigation water and the treatment of wastewater from the greenhouse horticultural area Luttelgeest II to be constructed in the NO polder;

Project Manager, **research into** the causes of the failure of activated carbon filtration to function as expected in groundwater remediation for the Meijerij in Schijndel (Brabant); drawing up Ideeënboek Duurzame Glastuinbouw (Idea Book for Sustainable Glasshouse Horticulture) commissioned by Novem. This described the reuse of drainage water, reduction of the use of pesticides and the collection of rainwater at both company and cluster level;

Process supervision of Romanian Standardisation Body (ASRO) to develop a more market-oriented method of working;

Coordinator and reporter of project evaluations for the Water sector at Witteveen+Bos.

Education

1991	Wageningen University, **Environmental and Chemical engineering MSc**,

Courses

2017	Zwijndrecht, PBNA, Safety for Operational Supervisors SSC
1997	Rotterdam, Lloyd's, Register Quality Assurance
1997	Rotterdam, Lloyd's, Auditor training course Environmental Management Systems
1996	Zwolle, Open University, Environment and Technology,
1995	Delft University, Post graduate course Resource Recovery
1995	Groningen, PVK Group, Project management
1994	Utrecht Institution for Water education, Implementation of environmental management systems,

Languages

Dutch	Excellent
English	Excellent
French	Fair
Indonesian	Fair
German	Fair

Publications

1999 Lecture PAO-course More than Effluent; The WWTP as a source of water. 1999 TU Delft, R.T. van der Velde

Memberships

Member of the Management Board of Local Sustainable/ Clean Energy Company of Zwolle
Member of the Association for the issue of drinking water in the Netherlands (KVWN)
Member of Dutch Membranes Society
Member of the association of environmental engineers

Additional functions

Treasurer Wijbedrijf Dieze, Zwolle, The Netherlands

3.2 Project management

Our Project Team Leader Raphaël van der Velde performs three major tasks with respect to project management:

- Provide an accountable and reporting structure linking the project activities with the requirements of CCCCC. Progress according the planned schedules is monitored on a weekly basis.
- Resource management: ensure that the consultants' resources are made available timely and used effectively to achieve project objectives. If required additional (senior) experts will be involved and backstopping is organized when necessary.
- Ensure stakeholder involvement, to improve the quality and acceptance of the project outcomes. He will be the contact for CCCCC and other stakeholders in this project on behalf of Witteveen+Bos and will be assisted by a project facilitator to organize meetings and other communication.

3.3 Quality Control

Raphaël van der Velde (Project Team Leader)is responsible for focus and delivery of the contract. He will ensure on time delivery and within budget of the project. He will organize technical support from non-key specialists on specific research topics if needed (e.g. PPP, CBA, geology and offshore infrastructure).

The Project Team Leader is responsible for guiding and directing the non-key technical staff to ensure effective utilization and achievement of the activities. He will consistently communicate, resolve, and anticipate on issues that may arise during the project process.

He will also receive copies of all contract correspondence and will review offsite and management meetings, progress reports and site correspondence.

The main project responsibilities and duties that will be carried out by the Project Team Leader are:

- Provide overall planning, execution and monitoring and feedback of all the activities.
- Managing and maintaining overall design, task and subconsultant budgets; reporting on budget and schedule; ensuring timely and accurate invoicing; ensuring high quality timely work products; providing timely notice and documentation of changes.
- Overall direction and management of project staff and as required the needed technical, contractual and socio-economical guidance to the Team.
- Perform a Quality Assurance review of all the work.
- Review contract progress achievement and reporting procedures.
- Co-coordinating the combined resources to provide technical support.
- Overseeing any contract variations and provisional acceptance applications.

3.4 Non-Key Experts

To assure the highest quality on each relevant field of expertise, proper Quality control of deliverables and mitigate the risks of illness of the Team Leader and avoid the project from halting, we propose to include Non-Key experts in the team. In this manner, we will secure smooth project execution and be prepared to cover the un-availability risks.

Table 3.1 Non-Key Experts

Name	Expertise	Position
Robert Kools MSc	Senior Water and Energy System Expert	Back-stopper project management
Peter de Jong	Public Private Partnership	Senior Specialist
Liesbeth Jorissen	Geology	Senior Specialist
Hilko Timmer	Offshore Infrastructure	Senior Specialist
Ingrid Mouwen	Cost Benefit Analysis	Senior Specialist
Rasyid Salam MSc	Renewable Energy Expert	Project Facilitator

R.J.E. Kools (Robert) MSc

Mr Kools graduated as a mechanical engineer (MSc) at the Eindhoven University of Technology in 1990. He has worked on various positions for Witteveen+Bos until he joined PWN Technologies to become Director of Engineering and Projects. In 2017 he returned to Witteveen+Bos as a senior project manager. He currently also holds the position of head of Industrial Heat and Energy group and he is one of the senior project managers for water and energy projects. He has extensive experience in both waste water and drinking water projects and energy projects, from feasibility studies to design, tendering and construction management. Mr Kools has worked on various projects in Worldwide, like an industrial waste water treatment plants in Africa, the drinking water sector project in Niger, a feasibility study for sea water desalination in Mauritania and, recently, extension of the potable water production and distribution system in Niamey, Niger. Mr Kools is fluent in French, English, German and Dutch.

P. de Jong (Peter) MSc

Mr de Jong has graduated in environmental engineering at the Agricultural University of Wageningen. In 1984 he was employed by Witteveen+Bos as process engineer wastewater, followed by the positions of business development manager and head of the wastewater department at Witteveen+Bos in 2001 and director of the Water sector of Witteveen+Bos in 2007. Since 2014 he has served as senior advisor in Energy, Water and Environment, specialized in process engineering, contracting and project management. Mr de Jong has been responsible for the design and contract management as well as Private, Public Partnership scope of many large-scale water treatment plants in the Netherlands and Netherlands Antilles in the Caribbean.

E.L. Jorissen (Liesbeth) PhD

Liesbeth has a broad academic background in geology, sedimentology and stratigraphy, which she acquired during her PhD at Utrecht University. Since 2020 she has been working at Witteveen+Bos as a consultant within the group geotechnics and hydraulic engineering in Utrecht. Within projects, she works at the interface between geology and geotechnics on, among other things, the interpretation of soil research and the construction of geological ground models based on offshore seismic lines, offshore cores, borings, CPT's and laboratory analyses. She also carries out geotechnical design work, so that she has a good idea of the geological relevance for geotechnical applications, such as stability or settlement calculations.

H. Timmer (Hilko) BBE, BEc

Hilko Timmer (1974) graduated in land, water and environmental management with specialization land and water engineering in 1998. He started his professional career as works foreman for the construction division within Oranjewoud Consulting Engineers (ANTEA). In 2001 Hilko started a study business economics with specialization marketing and graduated in 2005. Meanwhile he entered Witteveen+Bos Consulting Engineers in 2001 to work abroad in Kazakhstan. Till 2008 he worked as supervisor for marine projects (e.g. dredging, reclamations, (off-shore) geotechnical survey, construction of quay walls, jetties, dikes, etc.) alternately in Kazakhstan and the Netherlands for the division ports and hydraulic engineering. In 2009 he moved for two and half years to Witteveen+Bos' branch office in Jakarta. Here the focus was more on project management/ engineering for marine projects rather than supervision. In 2011 he returned to Witteveen+Bos' head office in the Netherlands. Hilko continued his role as a supervisor and project manager/ engineer for the dredging group within the division ports and waterways. Since 2014 he is predominantly working as site engineer for dike enlargement projects. Hilko is a charismatic person who is devoted to his job and stringent when necessary though sending his positive energy with a smile. His passion for travelling gave him a broad sight on the world. Countries independent travelled comprise Argentina, Australia, Belize, Botswana, Cambodia, Costa Rica, Chili, China, Egypt, Germany, Guatemala, Hong Kong, Iceland, Italy, Malaysia, Mexico, Namibia, Nepal, Norway, South Africa, Tanzania, Thailand, United States of America and Zanzibar. Countries of work experience comprise Abu Dhabi, Bahrain, Bangladesh, Canada, Indonesia (resident engineer), Kazakhstan, Latvia, Serbia.

I.A.A.C. Mouwen (Ingrid) MSc

Mrs I.A.A.C. Mouwen (Ingrid) works as a senior consultant and head of the group Project Control at Witteveen+Bos. The main activities of Mrs Mouwen are in the field of project control for property and civil developments: project control, business cases, feasibility studies, lifetime costs, cost management, risk analysis and risk management and planning. Mrs Mouwen knows how to clearly present and explain complex financial analyses in a convincing manner. Mrs Mouwen has a wide experience as consultant, where she has worked for a variety of clients. Keywords are: involved, knowledgeable, fast switching, high level of abstraction, out of the box minded, good communicator.

M.R. Salam (Muhammad Rasyid) MSc

Rasyid Salam is a motivated engineer with a background in sustainable energy and chemical engineering. During his master's study in sustainable energy, he has accumulated knowledge on all-around low carbon technologies. He has been involved in projects on heat recovery from wastewater and emerging sustainable energy technology such as hydrogen and carbon capture storage. He has prior experience working as a process engineer in the oleochemical industry. During his time as a process engineer, he has worked on projects concerning energy savings, water conservation, debottlenecking, production losses, product innovation, and safety improvement.

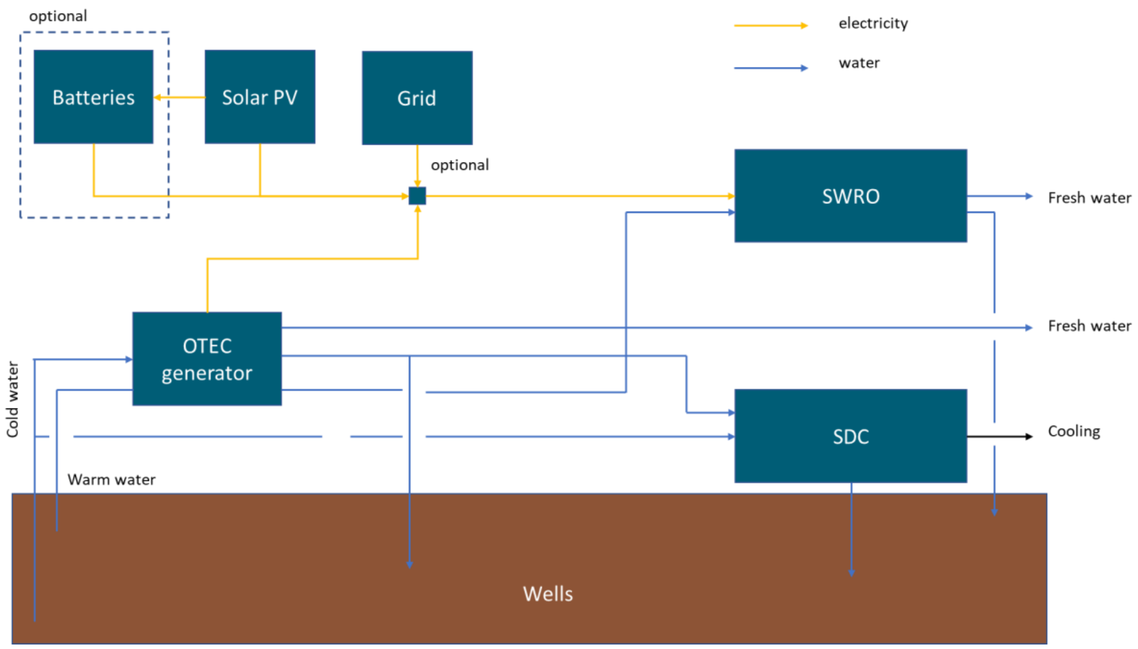
4

DETAILED WORK PLAN

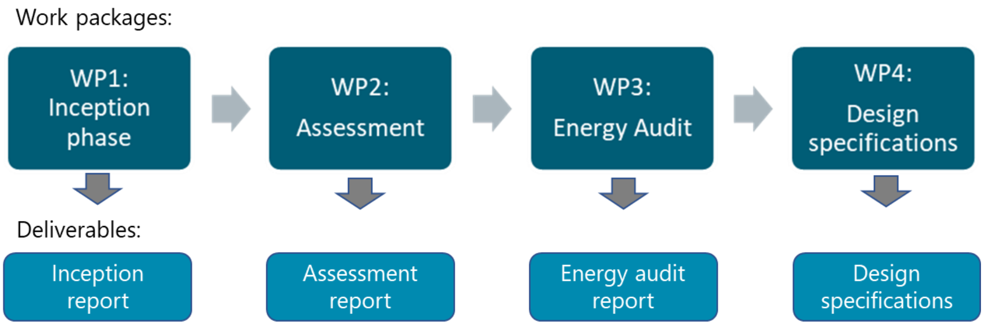
The goal of the project is to perform a feasibility study for the integration of OTEC into existing SWRO plants in the Bahamas, and outline the business case, taking into account the options for public-private partnership. The scope is limited to a small-scale 'Open Cycle' OTEC generator with a maximum capacity of 30 kW.

Open cycle OTEC generates electricity and desalinated water. The electricity powers the SWRO, while desalinated water increases the freshwater supply. To further increase sustainability and to enable off-grid operation, OTEC pairing with solar and energy storage (e.g., salt water battery) will be investigated. Additionally, the cold water return from OTEC (or directly from the well) can be utilized for SDC (Seawater District Cooling) to improve the business case. This integration is illustrated in Figure 4.2.

Figure 4.1 Diagram of an open cycle OTEC and its integration with SWRO, Solar PV, and SDC



In this chapter, we provide a detailed work plan and schedule for our services. The work plan is divided into 4 (four) work packages (WP), as shown below.



4.1 Work Package 1: Inception phase

We start the project with an inception phase to ensure that project is off to a great start. This WP aims to:
1 Get to know each other by the main team members both from CCCCC, Steering Committee and consultant.
2 To have a mutual understanding of the project scope between CCCCC, the steering committee and the consultant.
3 Get on-site information, including confidential (digital) data of the project locations and contact with the responsible stakeholders.

In order to ensure a good basis and direction to start the study. We expect that the representative from CCCCC will be able to meet with our Project Manager in the Bahamas for the kick-off meeting.

The WP 1 consists of these main activities:

1. 1 Kick-off meeting
The kick-off meeting, which is preferably in the Bahamas with CCCCC and the complete Steering Committee, will follow a standard project management practice. We discuss our plan and align our understanding and your project expectations. We also exchange the knowledge and resources that are relevant for the study.

1.2 Data collection and analysis
In this step, we visit representative project sites (we suggest to visit Eleuthera sites only), gather data that are relevant to the study, which includes:
- Data on SWRO sites:
  - Location.
  - Technical specification of the installed process equipment.
  - Electricity grid connection specification (including the reliability of supply and backup systems).
  - Operator organization and contact details.
  - Operational costs.
  - Status of equipment (visual inspection and meeting with operator).
  - History of usage.
- Data related to inverted geothermal conditions and suitability for OTEC, which includes:
  - Geophysical well's logs.
  - Borehole data.
  - Temperature data.
  - Geophysical well logs.
  - Pump test.
  - Core material (if available).
  - Seismic data.
- Data on the seawater conditions:
  - Temperatures on target depth for OTEC intake and outlet.
  - Currents.
  - Sea bottom conditions (incline, type of sediment, coral et cetera).

  - Protected zones for ecology, fisheries and other functions.
- Data on potential OTEC/SDC and solar Installation locations:
  - Available space.
  - Potential for electricity grid connection.
  - Climate and soil conditions.

We compile the relevant information, provide an overview of available data and indicate missing relevant data to be looked for. Further, we analyse the data and improve our plan to make it more specific based on the data and previous studies.

With respect to the representative location, we expect to visit the sites on Eleuthera only as the two operators owning most of the locations both have locations on this island and as this island has SWRO locations which are expired and still in operation.

1.3 Stakeholders engagement
The OTEC integration to SWRO involves multiple parties (private and public). We find it useful to meet and get in contact with the stakeholders, for data collection and interviews. We expect CCCCC to introduce our team to the relevant stakeholders. We hope to meet most of them in real life. If that is not possible, we will expect digital meetings through MS Teams. Relevant stakeholders for this project are:
- Operators of existing SWRO sites.
- Operator of electricity grid.
- Electricity suppliers.
- Potential investors / operators of future OTEC/SDC facilities.
- Organisations (Government) responsible for policy/permitting with respect to developing old SWRO sites.

1. 4 Inception meeting

We organize an inception meeting to present and discuss our refined plan for the following work packages based on activities 1.1, 1.2, and 1.3. We also discuss which criteria are relevant to select three sites for WP 3 and 4 (e.g., cost, technical conditions, environmental conditions)

The outcome is an inception report that presents project risks and opportunities and a resulting refined and fit for purpose project plan. To achieve this key objective and establish the contacts with the stakeholders, we propose a 1 (one) working week field visit by our Team leader and a Non-Key Expert - Project Facilitator to Eleuthera and Nassau. In addition to establishing personal contacts with key stakeholders, the site visit will allow us to confirm the inverted geothermal conditions of groundwater in Bahamas, since it is the main enabler for OTEC/SDC implementation, as well as pre-examine the technical conditions of the existing SWRO facilities. We believe it will facilitate the study tremendously by providing valuable inputs for WP 2 & 3 and by giving a possibility for organizing the life kick-off meeting with stakeholders.

In support for organizing the field visit, we provide its preliminary schedule with key activities and objectives in the table 4.1 and elaborate on the benefit for such event.

Table 4.1 Field Trip Activities & Objectives

Day #	Activity	Objectives
Day 0	Arrival at the project site	
Day 1	- Kick off meeting at Nassau with CCCCC and the Steering committee. - Meeting with key stakeholders from the Government (policy on drinking water, environmental protection and energy transition).	- Kick-off meeting will facilitate the project in streamlining with the stakeholders the projects objectives, analysing the bottlenecks, and agreeing on the following steps. - Kick-off meeting will include presentation of the project. - Exchange contact details, collect the insights on the project objectives. - Gather input on the legal and political framework for development of OTEC and Solar PV connected to water supply.
Day 2	- Site visits to Eleuthera of if possible all sites of the 2 biggest SWRO operators in the Bahamas: · Staniel Cay Yacht Club. - Aqua Design Bahamas.	- Data collection & examining the sites and SWRO facility conditions. - Gather the technical inputs and PPP analysis input for the Work Package 2 and 3.
Day 3	- Meeting (partly digital) with key stakeholders: · Electricity Grid. · SWRO operators other Islands. · Interested investors/developers/operators of OTEC/SDC. - Review collected data. - Start writing of Inception report. - Meeting with Representative CCCCC to align and discuss nay additional information and stakeholder meetings to be organised.	- Gather the technical inputs and PPP analysis input for the Work Package 2 and 3. - Prepare an overview of project risks and opportunities and missing data.
Day 4	- Writing the first draft inception report and preparing presentation to CCCCC and steering committee.	- Stakeholders will be asked for evaluation of the meeting as well as opportunity to comment on the Summary.
Day 5	- Inception meeting with CCCCC and Steering committee. - Optional meeting with the client to consolidate the workflow. - Departure.	- Stakeholders will be shared the key take-home points and the summary of the inception meeting. Contact details and follow up actions will be exchanged. - The first Draft Inception report aims to be prepared during the field trip for review and comments of CCCCC and the steering committee. Final draft will be based on these comments.

4.2 Work package 2: Assessment

This work package aims to confirm the suitability of Bahamas geological conditions for OTEC, identify the enabling environment of OTEC implementation and identify the opportunity to implement it on SWRO plants. The output is an Assessment Report.

The WP consists of below main activities:

2. 1. Comprehensive assessment of Bahamas geological conditions
OTEC implementation in the Bahamas relies on the availability of a cold water source of around 6 °C. In this activity, we analyse the available data and reports with the aim to:
- Confirm the availability of such cold temperature at a feasible depth.
- Assess the permeability and/or transmissivity of the target formation(s).

- Ensure long-term availability of the cold water, by examination of possible non- or less permeable layers separating the warm and cold wells.

We gather all information available for both onshore and offshore wells as deep as possible with a focus on temperature and transmissivity. This information as mentioned in activity 1.2 includes: geophysical well logs, pump tests, core material (if available), seismic data. These data are important to provide information on the lithology, petrophysical properties, and temperature.

We evaluate the available data critically and make conclusions and recommendations and identify possible risks and uncertainties. Furthermore, we indicate which extra information is needed for the next data acquisition.

2. 2. Evaluation of the enabling environment for the OTEC implementation in Bahamas

Enabling environment plays a significant role for a successful implementation of OTEC. We evaluate these enabling environment at the regional and national level, which includes:

- Economic driver: such as electricity tariff and price of other energy sources and drinking water.
- Environmental goals.
- Policy instrument to incentivise clean energy production.
- Institutional organisation and financing of the water and energy sector.
- Regulations, such as permits to extract water from wells and discharge water to the sea and construct infrastructure in coastal zones.

We organise the evaluation using a SWOT (strength, weakness, opportunity, and threats) analysis framework with input from desk research and interviews of different stakeholders (including not limited to local water company and authority, energy company and authorities).

2. 3 Assess the SWRO systems

The OTEC generators are to be integrated into the existing SWRO systems. We therefore need to assess the existing SWRO facilities to:

- Understand and identify the opportunity to integrate.
- The benefit of OTEC for SWRO (electricity and extra desalinated water).
- The requirement from SWRO (electricity supply reliability, fresh water integration, space availability.
- Technical conditions of SWRO with regards to the lifetime.
- How is the organisation of the operator and the regulations for operators to be involved in electricity generations?

We perform the assessment in consultation with the water utility company. We collect data from the utility company (or the client if available) to obtain information, such as:

- Electricity grid capacity (used and additional capacity available).
- Electricity purchase cost and contract.
- Operational cost.
- Water demand and requirement.
- Energy efficiency.
- Water efficiency.
- Membrane lifetime.
- CIP (Clean In Place) conditions.

- Available space for OTEC / SDC equipment.

Furthermore, we evaluate the financial and environmental implications of the expired SWRO sites. The aim of the evaluation will be to determine the extent to which expired SWRO facilities & equipment can and will be re-used and fitted for OTEC integration. The assessments will be based on the below listed (but not limited to) parameters. Some of these parameters will be derived from the field visit and/or data collected during the inception phase.
- History of usage/reason for expiring.
- Future need for drinking water.
- Brine water discharge and OTEC flows eco-toxicological effect.

4.3 Work package 3: Energy Assessment

The goal of this WP is to evaluate the business case of OTEC/SDC connected to the SWRO and compare it to the current on-grid operation. The output is an Energy Audit Report.

The WP consists of below main activities:

3.1 Assess the present cost of on-grid SWRO supplies

We collect the present cost of on-grid SWRO supplies from the utility coordinator (or SWRO contractor/operator if unavailable). The electricity from OTEC replaces/substitutes the electricity from the grid or a diesel power generator. And the desalinated water from OTEC adds up to the fresh water supply. Therefore two important costs to be evaluated here are electricity price and the final cost of desalinated water from SWRO. As the business case of OTEC is sensitive to these two parameters, we also take into account the historical price and projections (what factors influence these costs, such as gasoline price). In some cases Seawater District Cooling might be possible, which provides an additional cost benefit. We will evaluate in which locations SDC is an opportunity.

3.2 Conceptual design of the OTEC/SDC integration in 3 (three) sites

Based on assessment in WP2, and activity 3.1 and criteria defined in inception phase, we narrow down which sites are of interest for the implementation of OTEC/SDC and which might get their energy form Solar Energy or a combination of both. In consultation with the CCCCC, we select three sites to perform conceptual design. In this design, we integrate OTEC, solar PV, energy storage for off-grid solutions, and SDC, as shown in figure 1. We provide the process flow diagram, list the equipments and important components.

3.3 Cost-benefit analysis of OTEC in 3 (three) sites

Based on the conceptual design in Step 3.2, we perform the cost-benefit analysis to compare the business case of SWRO with OTEC to an existing on-grid SWRO. The analysis takes into account:

1 Investment cost and operational cost.
  This cost is derived from the conceptual design from activity 3.2. Based on the design, we make an investment and operational cost estimate with +-50 % confidence.
2 Environmental cost and benefits.
  We will qualitatively consider the following environmental costs and benefits:
  · Impact on marine ecology near shore.
  · Green house gas emission impact.
3 Cost saving and additional revenue.
  We will provide an overview of cost saving achieved by substituting grid electricity with OTEC and solar PV, and extra revenues obtained from sales of cooling capacity and sales of generated fresh water supply from OTEC.

3.4: Project an annual energy yield of OTEC to assist SWRO

We estimate the annual energy yield of the OTEC per site, including yield from solar PV and cooling capacity from SDC.

3.5: Technical guidance brief on the public, private institutional arrangements
Based on the meetings with the operators of the SWRO facilities and meetings with the energy suppliers and review of energy and drinking water legislation and policy, we lay out the technical facts as input for future public-private partnership to support the implementation of OTEC in Bahamas. Items covered are:
- Can SWRO and OTEC SDC be operated by one and the same operator?
- How to organize independency and reliability of supply of both drinking water and electricity supply if it is not one operator for both systems?

3.6 Complete framework in support of the medium to large-scale utilization of OTEC
We provide a framework on how to organise the implementation of OTEC in these sites. For example, what steps are to be taken by which parties (companies and organisations) and who would build and operate the OTEC/SDC facility. What technical aspects should be covered in contracts between operator of the water supply and the operator of the OTEC and SWRO.

4.4 Work package 4: Design specifications and project summary

The main objective of this work package is to set up the required data for the next implementation phase of the OTEC. The output is design specifications and cases summary for the 3 sites.

4. 1: Design specifications
In WP3, we make a conceptual design of the OTEC plant. In this steps, we provide design specifications to be used as requirement for the contractor to realise the plants. The design specifications include:
- Site locations (aerial photo).
- Maximum installation footprint.
- Target power, energy yield, and peak capacity projections.
- Target reliability.
- Water quality requirements.
- Water yield.
- Number of solar panels.
- SDC racking system and number of modules.
- Solar panel area, direction, tilt angle, weight.

4. 2: Cases summary
Finally we provide the summary for the 3 cases, which includes:
- Project cost.
- Benefit.
- Simplified payback.
- Assumptions and projections of the design and energy yields.
- Summary of the gathered data and observations for identified site Risks and opportunities per location.

4.5 Work Schedule

Legend:
Internal Task | Review Time for the Client | Milestone | Field Visit

Evaluation of Ocean Thermal Energy Conversion - Bahamas | EU-GCCA/SER 21/OTEC Study

Delivarables	Activity	Key Dates
Deliverable 1	**Inception Report**	
1.1	Kick-off meeting (Field Trip)	
1.2	Data collection and analysis	
1.3	Stakeholders engagement	
1.4	Inception meeting	
	Inception report	
Deliverable	Submission of the Inception Report	**Week 2**
Deliverable 2	**Assessment Report**	
2.1	Comprehensive assessment of Bahamas geological conditions	
2.2	Evaluation of the enabling environment for the OTEC implementation in Bahamas	
2.3	Assess the SWRO systems	
	Assesment Report	
	Consultations with the national steering	
Deliverable	Submission of the Assesment Report	**Week 7**
Deliverable 3	**Energy Audit Report**	
3.1	Assess the present cost of on-grid SWRO supplies	
3.2	Conceptual design of the OTEC/SDC integration in 3 (three) sites	
3.3	Cost-benefit analysis of OTEC in 3 (three) sites	
3.4	Project an annual energy yield of OTEC to assist SWRO	
3.5	Technical guidance brief on the public, private institutional arrangements	
3.6	Complete framework in support of the medium to large-scale utilization of OTEC	
	Audit Report	
	Consultations with the national steering	
Deliverable	Deliverable 3: First draft of the final report	**Week 16**
Deliverable 4	**Design specifications**	
4.1	Design specifications	
4.2	Cases summary	
	Final report	
	Consultations with the national steering	
Deliverable	Deliverable 4: Second draft of the final report	**Week 23**

4.6 Project organisation

Our Project Team Leader will liaise with all relevant stakeholders but will ultimately report to the Head of the Programme Development and Management Unit of CCCCC or his designated representative.

CCCCC will be advised by the members of the national steering committee which includes the National Project Coordinator- Bahamas, a designated representative from the University of Bahamas, and a designated representative from Bahamas Technical Vocational Institute. The designated representative of CCCCC will organize meetings with the national steering committee to discuss project results and plans for the next project phase. Our Project Team Leader will prepare the draft agenda for these meetings and organize the project information to be available one week before each meeting.

After the field trip (inception phase) all meetings will be organised by Witteveen+Bos through MS Teams.

Appendices

APPENDIX: CHAMBER OF COMMERCE (KVK)

KVK

Business Register extract
Netherlands Chamber of Commerce

CCI number 38020751

Legal entity

RSIN	800288920
Legal form	Besloten Vennootschap (comparable with Private Limited Liability Company)
Name given in the articles	Witteveen+Bos Raadgevende ingenieurs B.V.
Corporate seat	Deventer
First entry in Business Register	13-12-1991
Date of deed of incorporation	09-12-1991
Date of deed of last amendment to the Articles of Association	03-04-2013
Issued capital	EUR 5.760.000,00
Paid-up capital	EUR 5.760.000,00
Filing of the annual accounts	The annual accounts for the financial year 2021 were filed on 11-04-2022.

Company

Trade names	Witteveen+Bos Witteveen+Bos Consulting Engineers W+B Witteveen+Bos Vietnam
Company start date	09-12-1991
Activities	SBI-code: 7112 - Engineers and other technical design and consultancy SBI-code: 78202 - Job pools (no employment projects)
Employees	947

Principal establishment

Establishment number	000038619679
Trade names	Witteveen+Bos Witteveen+Bos Consulting Engineers W+B Witteveen+Bos Vietnam
Visiting address	Leeuwenbrug 8, 7411TJ Deventer
Postal address	Postbus 233, 7400AE Deventer
Telephone number	+31570697911
Internet address	www.witteveenbos.com
Email address	info@witteveenbos.com
Date of incorporation	01-01-2017 (registration date: 20-12-2017)
Activities	SBI-code: 7112 - Engineers and other technical design and consultancy

	SBI-code: 78202 - Job pools (no employment projects) For further information on activities, see Dutch extract.
Employees	947

Sole shareholder

Name	Witteveen+Bos N.V.
Visiting address	Leeuwenbrug 8, 7411TJ Deventer
Registered under CCI number	55094503
Sole shareholder since	31-12-2012 (registration date: 04-01-2013)

Board members

Name	van der Biezen, Stephan Cornelis
Date of birth	09-06-1970
Date of entry into office	06-04-2017 (registration date: 10-04-2017)
Title	Director
Powers	Solely/independently authorised
Name	Bijman, Wouter Bernardus Gerardus
Date of birth	02-09-1976
Date of entry into office	28-10-2020 (registration date: 30-10-2020)
Title	Managing Director
Powers	Solely/independently authorised
Name	Buter, Eveline
Date of birth	15-09-1975
Date of entry into office	28-10-2020 (registration date: 30-10-2020)
Title	Director
Powers	Solely/independently authorised

Authorised representative

Name	Sluis - de Leeuw, Catharina Maria
Date of birth	22-01-1965
Date of entry into office	04-11-2021 (registration date: 15-12-2021)
Contents of power of attorney	Full power of attorney

KVK

Business Register extract
Netherlands Chamber of Commerce

	In some instances, officers' authorisation may be limited to their establishment(s); in that case, notification is provided on the extract of the relevant establishment(s).

Establishment(s)

Establishment number	000007345542
Trade name	Witteveen+Bos
Visiting address	Koningin Julianaplein 10, 12e etage, 2595AA 's-Gravenhage
Establishment number	000007345526
Trade name	Witteveen+Bos
Visiting address	Stationsweg 5 A, 4811AX Breda
Establishment number	000007345518
Trade name	Witteveen+Bos
Visiting address	Hoogoorddreef 15, 1101BA Amsterdam
Establishment number	000007345488
Trade name	Witteveen+Bos
Visiting address	Blaak 16, 3e etage, 3011TA Rotterdam
Establishment number	000007345461
Trade name	Witteveen+Bos
Visiting address	K R Poststraat 100 3, 8441ER Heerenveen
Establishment number	000040330133
Trade name	Witteveen+Bos
Visiting address	Bronland 10, 6708WH Wageningen
Establishment number	000042567432
Trade name	Witteveen+Bos
Visiting address	Daalsesingel 51 C, 3511SW Utrecht
Establishment number	000051273462
Trade name	Witteveen+Bos
Visiting address	Zernikelaan 17, 9747AA Groningen

KVK

Business Register extract
Netherlands Chamber of Commerce

CCI number 38020751

Extract was made on 21-04-2022 at 14.17 hours.
For extract

C.M.H.L. Lourens, Grouplead Zorgeloze Ondernemer

II

APPENDIX: TENDER DECLARATION

Date: 27 July 2022

Contract Tittle: An evaluation of Ocean Thermal Energy Conversion - Bahamas

Contract Number: Contract#69/2022/EU-GCCA/CCCCC

To: The Executive Director, Caribbean Community Climate Change Centre, 3rd Floor, David McKoy Business Centre, Bliss Parade, Belmopan, Belize.

TENDERER DECLARATION

I the undersigned, declare that:

1. **No Reservations**: I have examined and accept in full the content of the Bidding Documents including Addenda for Tender Reference EU-GCCA/SER 21/OTEC Study Contract#69/2022/EU-GCCA/CCCCC.

2. **Bid Validity Period**: This proposal is valid for a period of 45 days from the final date for submission of tenders.

3. **Eligibility:** I, including any subcontractors or suppliers for any part of the Contract if applicable, have nationalities from eligible countries in accordance with the eligibility requirement.

4. **Prohibited Practices and Conflict of Interest, EU Restrictive List**: I hereby agree that in competing for (and, if the award is made to us, in executing) the Contract, we comply with the Centres' Policy on Prohibited Practices as contained in CCCCC Procurement Manual – Caribbean Community Climate Change Centre (CCCCC) (caribbeanclimate.bz). We have no conflict of interests or any equivalent relation which may distort competition with other candidates or other parties in the tender procedure at the time of the submission of this application. We have no interest of any nature whatsoever in any other tender in this procedure. I am not subject to EU restrictive measures. The lists of persons, groups, entities subject to the EU restrictive measures are maintained by the DG FISMA and published on the following website: www.sanctionsmap.eu

5. **Exclusion Criteria**: In the event that my tender is successful, I undertake, if required, to provide the proofs usual under the law of the country in which I am effectively established, that I do not fall into any of the exclusion situations as identified by the Centre Procurement Manual 2021 (as contained in CCCCC Procurement Manual – Caribbean Community Climate Change Centre (CCCCC) (caribbeanclimate.bz)). The date on the evidence or documents provided will be no earlier than one year before the date of submission of tender and, in addition, I will provide a statement that my situation has not altered in the period which has elapsed since the evidence in question was drawn up. I also understand that if I fail to provide this proof within 15 calendar days after receiving the notification of award, or if the information provided is proved false, the award may be considered null and void. I will inform the Centre immediately if there is any change in the

above circumstances at any stage during the implementation of the contract. I also fully recognise and accept that any inaccurate or incomplete information deliberately provided in my bid may result in my exclusion from this and other contracts funded by the Centre.

6. **Contract Securities**: If applicable and if awarded the contract, we commit to obtain a Performance Security and/or Advance Security in accordance with the Bidding Documents.

7. **One bid per Bidder**: I confirm that I am not submitting any other bids(s) as an individual bidder or as a Joint Venture Member.

8. **Not Bound to Accept:** I note that the Centre is not bound to proceed with this tender and that it reserves the right to award only part of the contract or to cancel the procedure. It will incur no liability towards any bidder should it do so.

Authorized Signature:	Digitally signed by Diederik Johannes Frans Bel Date: 2022.07.27 14:10:30 +02'00'
Name and Title of Signatory:	Mr D.J.F. Bel MSc, Authorized representative (In absentia of Mr S.C. van der Biezen)
Address:	Leeuwenbrug 8 | P.O. Box 233 | 7400 AE Deventer | The Netherlands

III

APPENDIX: LEGAL ENTITY FORM

PLEASE COMPLETE AND SIGN THIS FORM AND ATTACH COPIES OF OFFICIAL SUPPORTING DOCUMENTS (REGISTER(S) OF COMPANIES, OFFICIAL GAZETTE, VAT REGISTRATION, ETC.)

LEGAL ENTITY

PRIVACY STATEMENT http://ec.europa.eu/budget/contracts_grants/info_contracts/legal_entities/legal_entities_en.cfm#en

Please use CAPITAL LETTERS and LATIN CHARACTERS when filling in the form.

PRIVATE/PUBLIC LAW BODY WITH LEGAL FORM

OFFICIAL NAME ①: Witteveen+Bos Raadgevende ingenieurs B.V.

BUSINESS NAME (if different):

ABBREVIATION: W+B

LEGAL FORM: Besloten Vennootschap (comparable with Private Limited Liability Company)

ORGANISATION TYPE
- **FOR PROFIT** ☒
- **NON FOR PROFIT** ☐ — **NGO** ② **YES** ☐ **NO** ☒

MAIN REGISTRATION NUMBER ③: 38020751

SECONDARY REGISTRATION NUMBER (if applicable):

PLACE OF MAIN REGISTRATION
- **CITY**: Deventer
- **COUNTRY**: The Netherlands

DATE OF MAIN REGISTRATION: 13 (DD) 12 (MM) 1991 (YYYY)

VAT NUMBER: 8002.889.20.B01

ADDRESS OF HEAD OFFICE: Leeuwenbrug 8

POSTCODE: 7400 AE **P.O. BOX**: 233 **CITY**: Deventer

COUNTRY: The Netherlands **PHONE**: +31 570 69 79 11

E-MAIL: international@witteveenbos.com

DATE 27/07/2022

STAMP

SIGNATURE OF AUTHORISED REPRESENTATIVE

Witteveen + Bos

Digitally signed by Diederik Johannes Frans Bel
Date: 2022.07.27 14:09:38 +02'00'

---

① National denomination and its translation in EN or FR if existing.

② NGO = Non Governmental Organisation, to be completed if NFPO is indicated.

③ Registration number in the national register of companies. See table with corresponding field denomination by country.

TABLE WITH CORRESPONDING FIELD DENOMINATION BY COUNTRY

ISO CODE	MAIN REGISTRATION NUMBER
AT	Firmenbuchnummer (FN) ZentraleVereinregister (ZVR-Zahl) Ordnungsnummer
BE	Numéro d'entreprise Ondernemingsnummer Unternehmensnummer
BG	Булстат (Bulstat Code) Единен идентфикационен код (ЕИК/ПИК) Unified Identification Code (UIC)
CY	Αριθμός Εγγραφής Αριθμός Μητρωου
CZ	Identifikační číslo (IČO)
DE	Handelsregister Genossenschaftsregister (Nummer de Firma) Vereinsregister (Nummer des Vereins) Nummer der Partnerschaft (Partnerschaftsregister)
DK	Det centrale virksomhedsregister (CVR-nummer)
EE	Registrikood
ES	HOJA number
FI	Yritys-ja yhteisotunnus (Y-tunnus) Företags- och organisationsnummer (FO-nummer) Business Identity code (Business ID)
FR	Immatriculation au Registre de Commerce et de Sociétés (RCS) Système Informatique du Répertoire des Entreprises (SIRENE)
GB	Company number
GR	ΑΡΙΘΜΟΣ Γ.Ε.ΜΗ (Γενικού Εμπορικού Μητρώου) Δικηγορικός Σύλλογος Αθηνών (Δ.Σ.Α)
HR	Matični broj subjekta(MBS) Pod registarskim Brojem Matični broj obrta (MBO) Registarski Broj kakladnog
HU	Cégjegyzékszám
IE	Company number Grouping registration number in Ireland
IT	Repertorio Economico Amministrativo (REA)
LT	Kodas
LU	Registre de commerce et des sociétés RCS Numéro d'immatriculation Handelsregisternummer
LV	Vienotais Reģistrācijas Numurs

MT	Registration number Register of Voluntary Organisation (Identification number)
NL	Kamer van Koophandel (KvK-nummer) Dossiernummer
PL	REGON
PT	Numero de identificaçao de pessoa colectiva (NIPC)
RO	Numar de ordine in registrul comertului Numarul inscrierii in registrul special
SE	Organisationsnummer
SI	Matična številka
SK	Identifikačné číslo (ICO)

IV

APPENDIX: BANK FORM FOR INTERNATIONAL TRANSFER CCCCC

Caribbean Community
Climate Change Centre

Bank Form for International Transfer

INTERMEDIARY BANK (if applicable):

Complete Legal Name of the Bank

Complete Address of the Bank

(Street No. and Name, City, Country)

Account number, Swift Code and ABA # at Intermediary Bank

BENEFICIARY BANK (Payee's bank):

Complete Legal Name of the Bank

Coöperatieve Rabobank U.A.

Complete Address of the Bank

(Street No. and Name, City, Country)

Croeselaan 18 ,3521 CB Utrecht, The Netherlands

Name and Address of the Beneficiary (Payee)

(Street No. and Name, City, Country)

Account Number, Swift Code and ABA# of the Beneficiary Bank

IBAN: NL69 RABO 0150449208,
Account number: 0150449208,
Swift: RABONL2U (XXX)
ABA#: not applicable.

By completing this form, you have acknowledged that the information provided is free from error and in accordance with wire instructions provided by your beneficiary bank. Any fine/fee charged by any financial institution as a result of failure to provide accurate banking information will NOT be paid by the Caribbean Community Climate Change Centre.

Note:

Beneficiary's bank account name must correspond with the purchase order/contract/invoice.

By completing this form, you have acknowledged that the information provided is free from error and in accordance with wire instructions provided by your beneficiary bank. Any fine/fee charged by any financial institution as a result of failure to provide accurate banking information will NOT be paid by the Caribbean Community Climate Change Centre.

II

APPENDIX: LIST SWRO PLANTS IN FAMILY ISLANDS

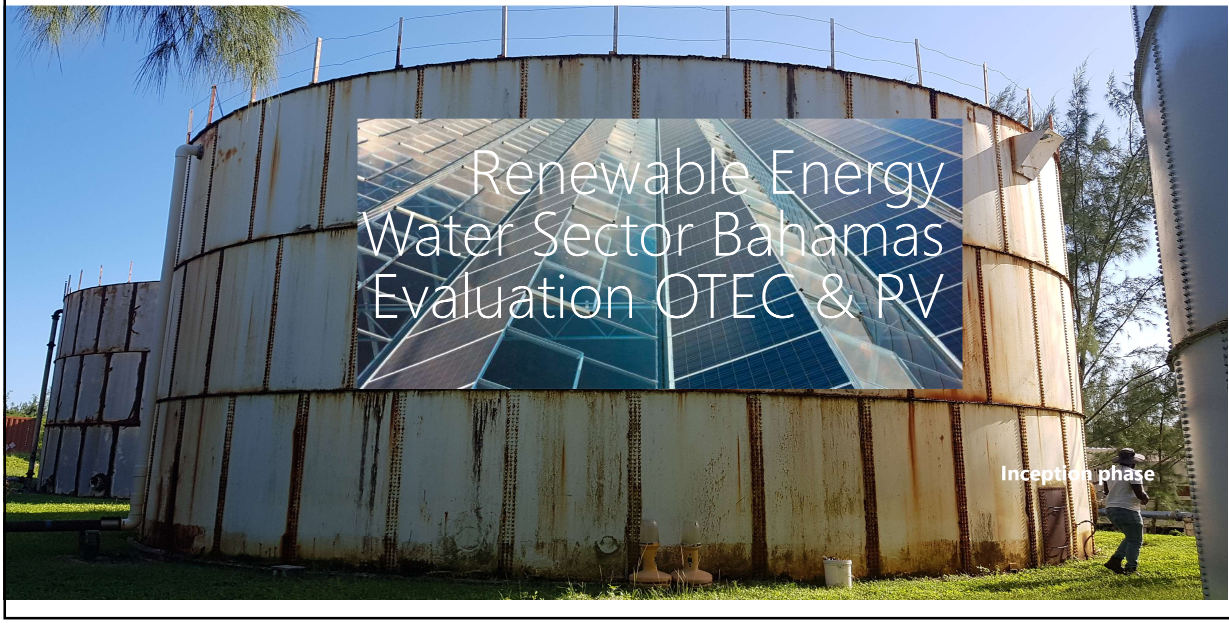
Appendix 4. Family Islands SWRO plants directory

	Code	Plant location	Contractor	Contract status
1	ABCS	Abaco – Cherokee Sound	Abaco Club	No expiry
2	ABGC	Abaco – Grand Cay	SCYC	Expires July 2020
3	ABMI	Abaco – Moore's Island	GE/SUEZ	Expires July 2019 (Notice Given)
4	AKSP	Acklins – Salina Point	SCYC	Expired April 2017
5	AKSC	Acklins – Snug Corner	SCYC	Expired April 2017
6	BIBB	Bimini – North Bimini	RAV/Influence	New/pending
7	ELNE	Eleuthera – North Eleuthera (Bogue)	GE/SUEZ	Under construction
8	ELCI	Eleuthera – Current Island	SCYC	Expired August 2018
9	ELNB	Eleuthera – Naval Base	GE/SUEZ	Expires 2025
10	ELRS	Eleuthera – Rock Sound/Tarpum Bay	GE/SUEZ	Expires 2025
11	ELWF	Eleuthera – Waterford	GE/SUEZ	Expires 2020
12	EXBP	Exuma – Black Point	SCYC	Expired April 2014
13	EXFC	Exuma – Farmers Cay	SCYC	Expired 2014
14	EXGT	Exuma – Georgetown	GE/SUEZ	Expires Nov 2019
15	EXEB	Exuma – Emerald Bay (Mainland)	Clearview/Sandals	No expiry*
16	EXSC	Exuma – Staniel Cay	SCYC	Expired April 2014
17	EXWT	Exuma – Williams Town	SCYC	Expires December 2022
18	GBSC	Grand Bahama – Sweeting's Cay	WSC (was TSG)	Owned by WSC
19	INMT	Inagua – Matthew Town	GE/SUEZ	6 months extension expires April 2019
20	LCLC	Long Cay	SCYC	Expired March 2017
21	LIDC	Long Island – Deadman's Cay	Matrix	Expires February 2019
22	LISM	Long Island – Simms	SCYC	Expires February 2025
23	MGAB	Mayaguana – Abrahams Bay	SCYC	Expires February 2025
24	MGPW	Mayaguana – Pirates Well	SCYC	Expires February 2025
25	RIDT	Ragged Island – Duncan Town	WSC (was SCYC)	Owned by WSC
26	SSCT	San Salvador – Cockburn Town	GE/SUEZ	Expires October 2019

III

APPENDIX: PRESENTATION 2-11-2022 INCEPTION PHASE OTEC REVIEW

Witteveen + Bos



1

Witteveen + Bos

Goal

- Review options for OTEC and Seawater District Cooling (SDC) in combination with water supply system in Family Islands
- Identify 3 pilot locations – conceptual design OTEC-SWRO pairing

2

2

Witteveen + Bos

Findings (1 of 2)

- WSC responsible for piped water supply on all Family Islands except Grand Bahama
- Suez contractor SWRO with 15 year agreements for all WSC locations
- After 15 years SWRO still owned by SUEZ
- Tariff insufficient, payment to SUEZ >> 50% higher (water & energy!)
- Very high (>30%) Unaccounted for water (UFW) (leakages in tanks, pumps and pipes)
- Contract with Suez is giving much freedom to Suez (e.g. downtime 8 weeks)
- Fee for Suez doesn't seem too much given CAPEX/OPEX of SWRO

3

3

Witteveen + Bos

Findings 2 of 2

- Not densely populated areas near SWRO
- Many customers have own SWRO, not well controlled by WSC and MoCW
- Not big temperature difference first 900 ft groundwater
- Groundwater system vulnerable (limited amount sweet water and brackish water)
- Groundwater temperature SWRO 78ºF, brine temperature unknown
- SWRO capacity in sufficient (as design capacity equals average capacity)
- No max temperature criteria for injection of brine/OTEC/SDC water
- Lot of sun – hardly any PV to be found in Bahamas

4

4

Witteveen + Bos

Analysis

- OTEC/PV combined with upgrade tanks, pumps and pipes – cost & energy efficient
- 3 pilots Eleuthera (North, Naval Base & Waterford) – 100% capacity
- Pairing SWRO-District Cooling very likely not feasible- very high CAPEX
- SUEZ most likely contractor to realize the OTEC/PV
- No real cold water available (OTEC requires temperature difference (~20°C/ ~45°F)
- OTEC – need to cool or heat water! = energy

5

5

Witteveen + Bos

Proposed approach (technical)

- Renewable energy Scenario- analysis 3 locations criteria on:
  1. energy efficiency (energy balance)
  2. Use of land (acres)
  3. Total Cost of Ownership 30 years (CAPEX & OPEX)
  4. Reliability (maximum uptime)
- Starting point is maximum reduction UFW **!**
- **Conceptual design of most favourable scenario**

6

6

Witteveen + Bos

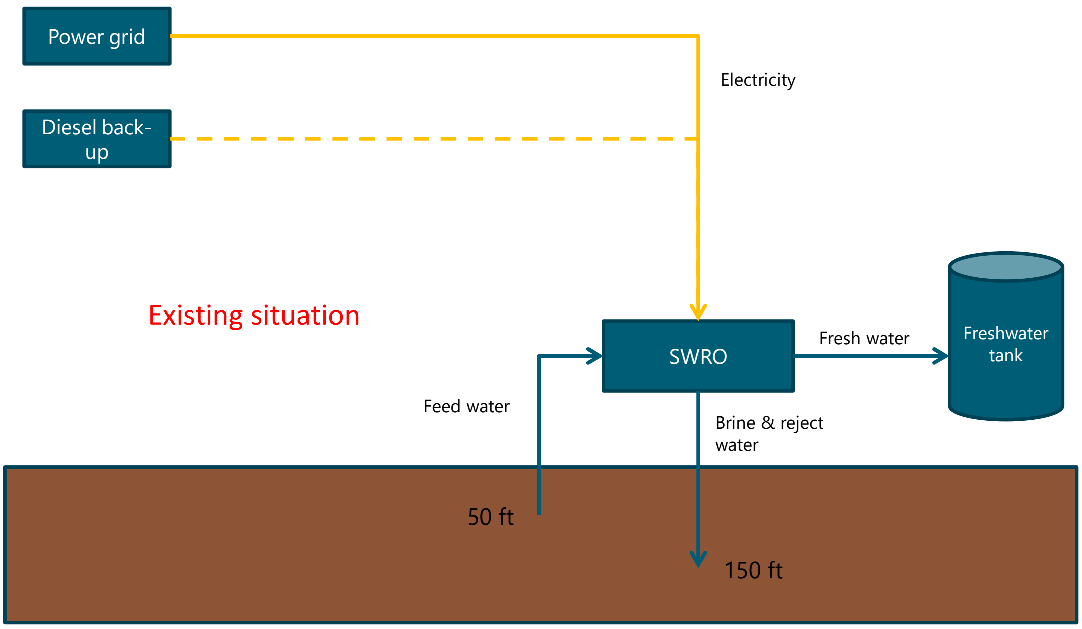
Proposed scenario's

1. SWRO + solar PV (electricity only) – backup from grid/ battery
2. SWRO + solar thermal (PT) to heat brine or partial feed flow + OTEC on feed and heated brine/partial feed flow – backup from grid/battery

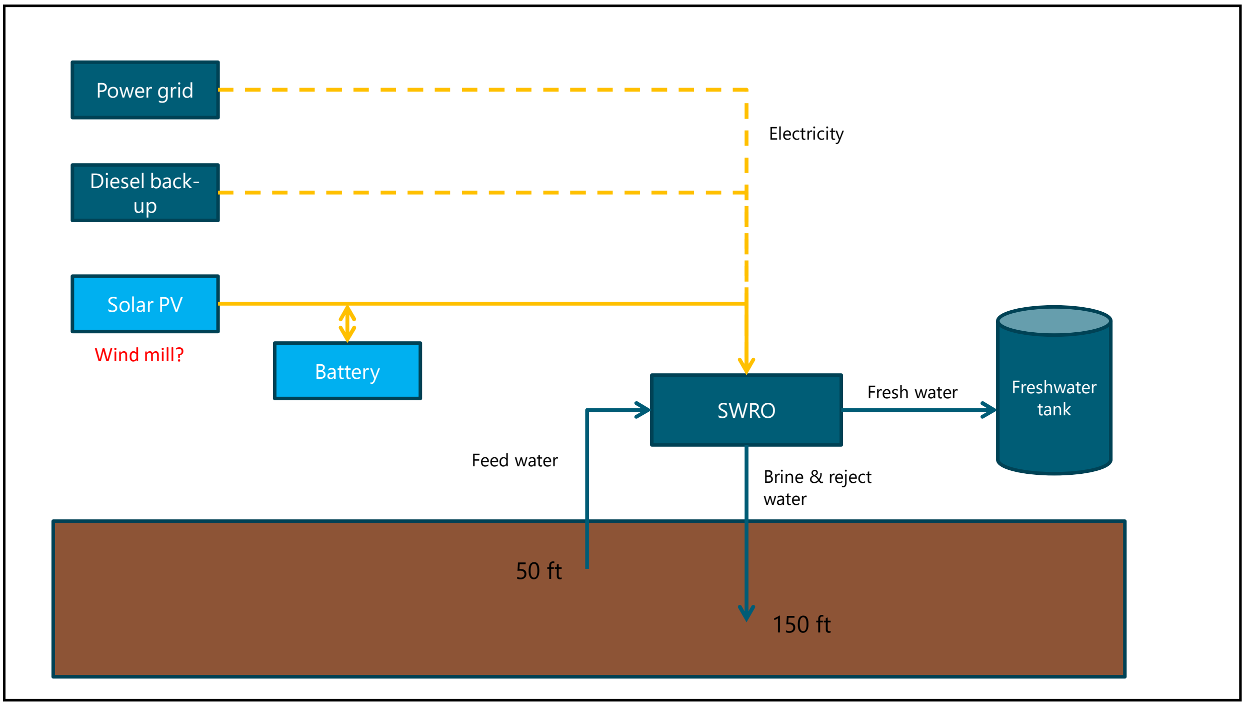
- Capacity OTEC/PV/PT based on water demand after reduction NRW
- Cooperation with Suez seems very logical- however prevent monopoly

7

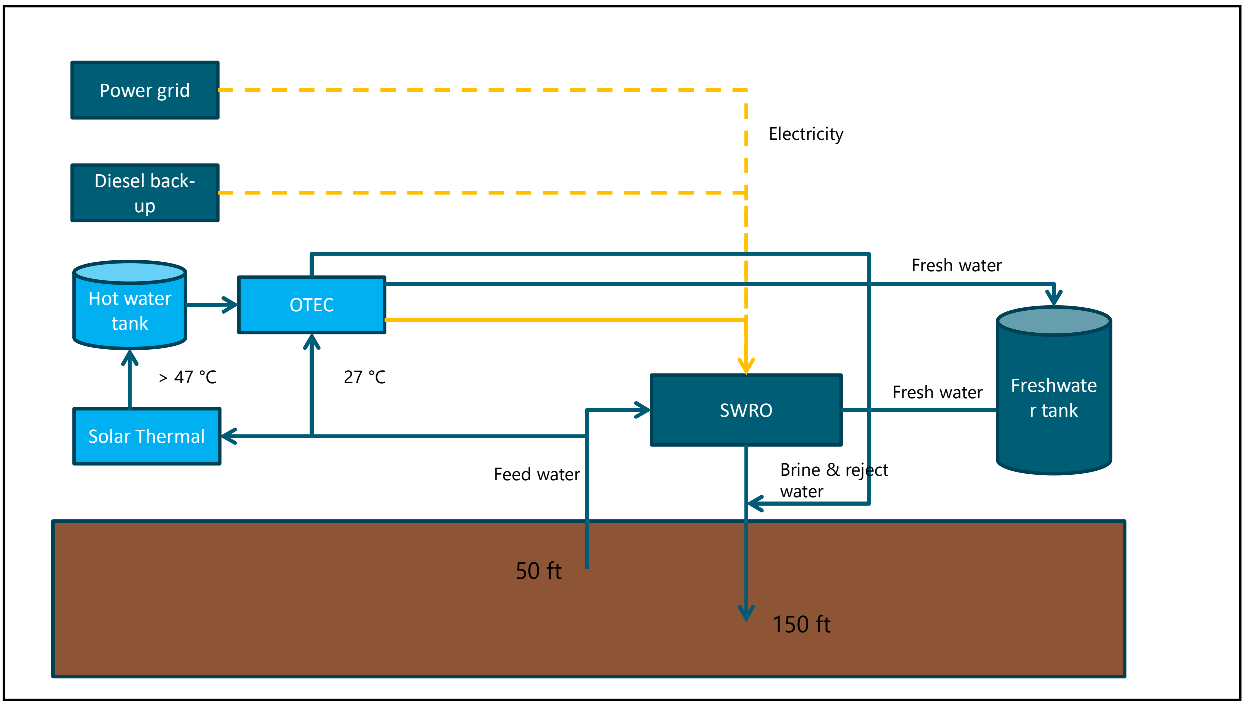
7



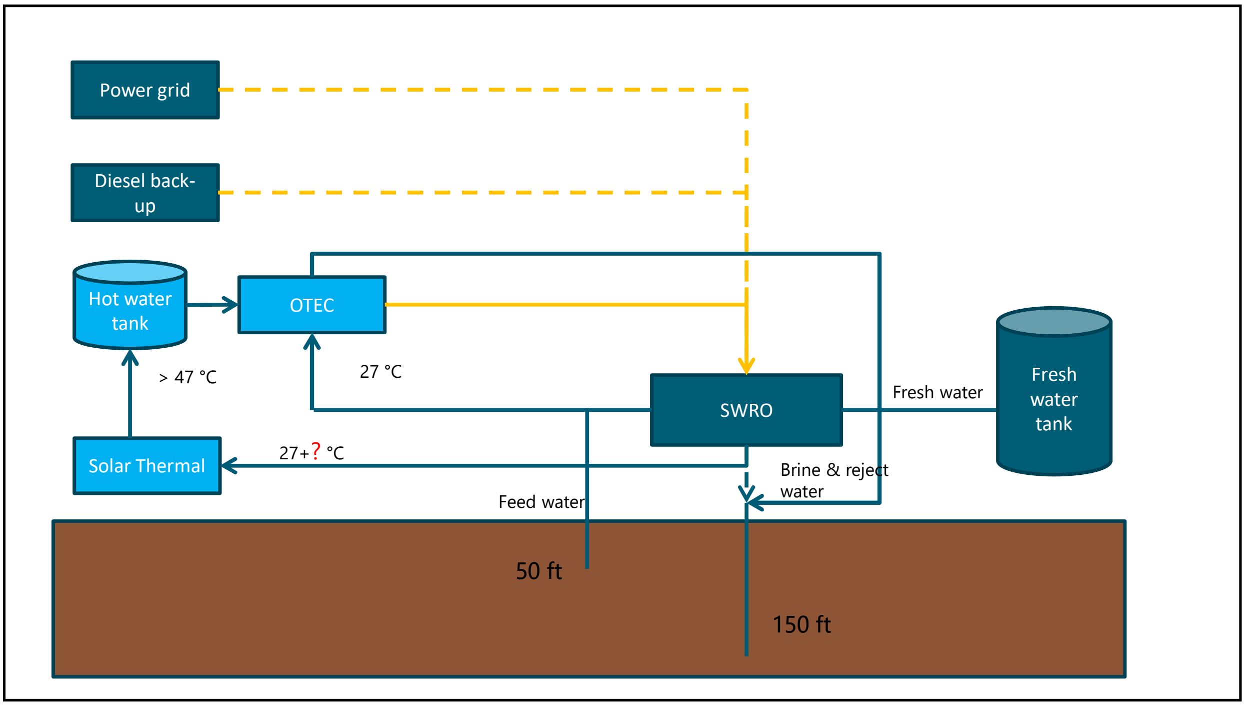
8


Power grid
Electricity
Diesel back-up
Solar PV
Wind mill?
Battery
SWRO
Fresh water
Freshwater tank
Feed water
Brine & reject water
50 ft
150 ft

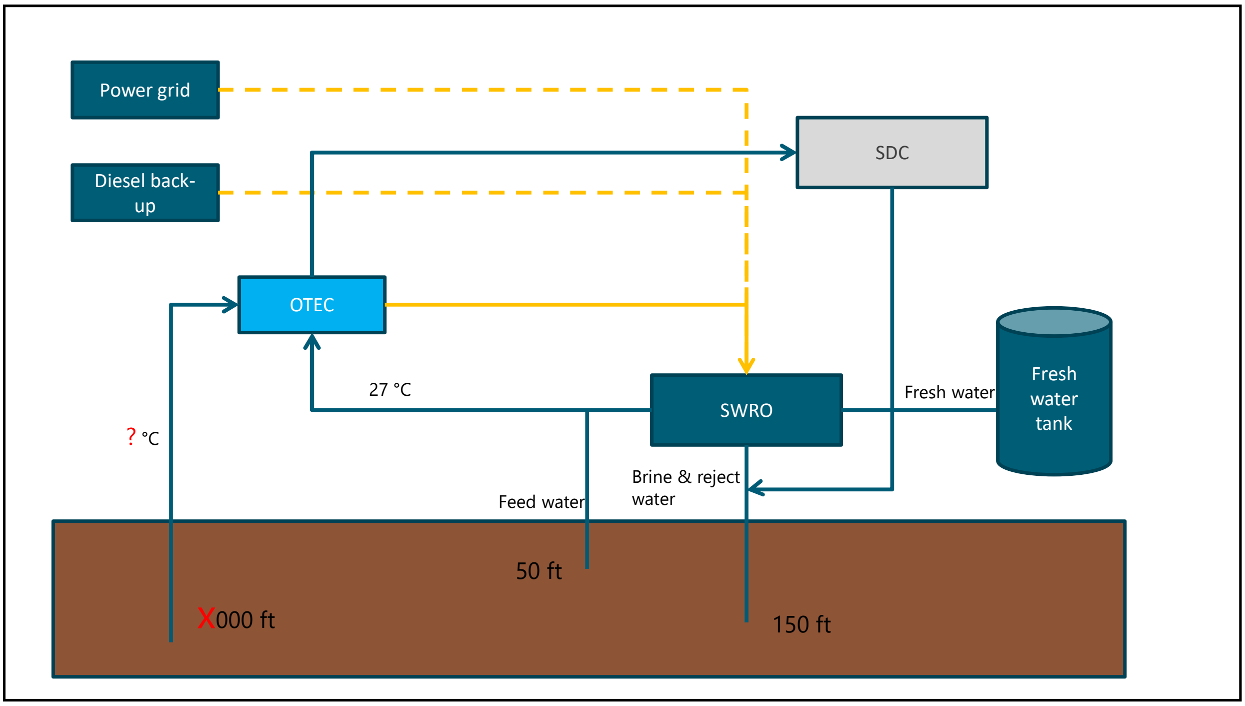
9


Power grid
Electricity
Diesel back-up
Fresh water
Hot water tank
OTEC
> 47 °C
27 °C
SWRO
Fresh water
Freshwater tank
Solar Thermal
Feed water
Brine & reject water
50 ft
150 ft

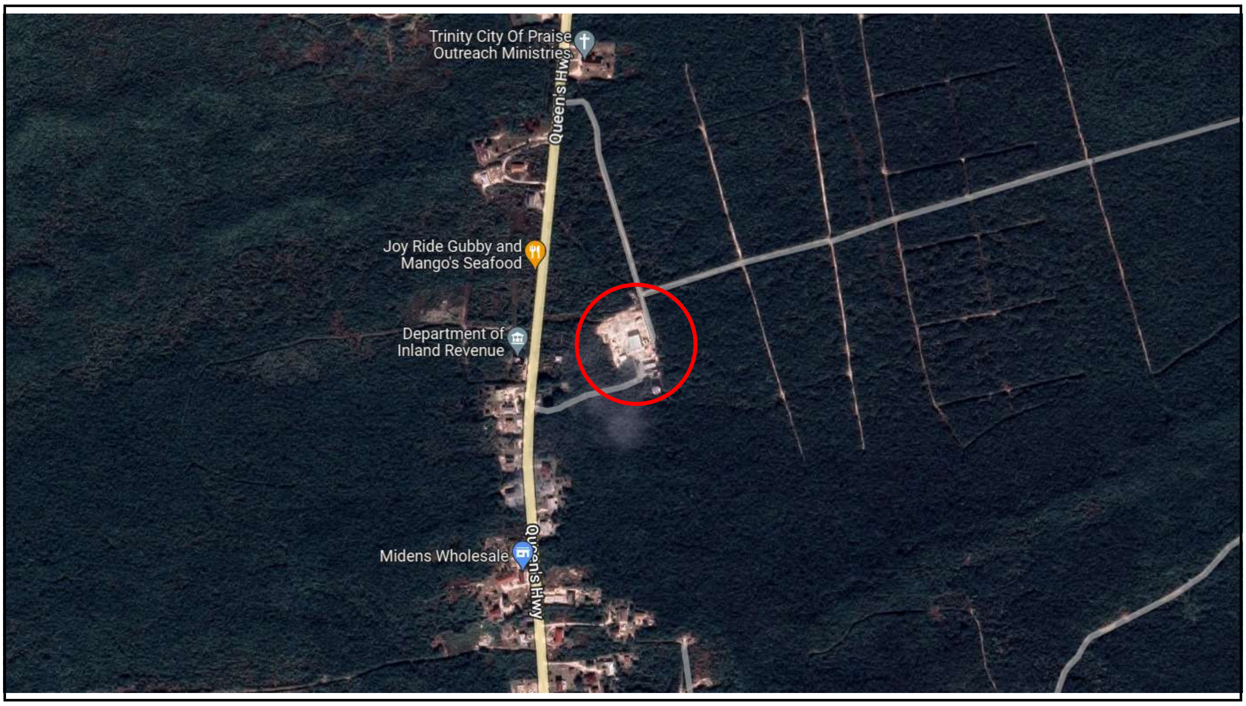
10


Power grid
Diesel back-up
Hot water tank
OTEC
> 47 °C
27 °C
SWRO
Fresh water
Fresh water tank
Solar Thermal
27+? °C
Brine & reject water
Feed water
50 ft
150 ft

11


Power grid
SDC
Diesel back-up
OTEC
27 °C
SWRO
Fresh water
Fresh water tank
? °C
Brine & reject water
Feed water
50 ft
X000 ft
150 ft

12


Trinity City Of Praise Outreach Ministries
Queen's Hwy
Joy Ride Gubby and Mango's Seafood
Department of Inland Revenue
Midens Wholesale
Queen's Hwy

13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14