Accelerating the Development of Offshore Renewables/Ocean Technologies in Small Island Developing States

Webinar II

Ocean Thermal Energy Conversion (OTEC) – Barbados' Experience

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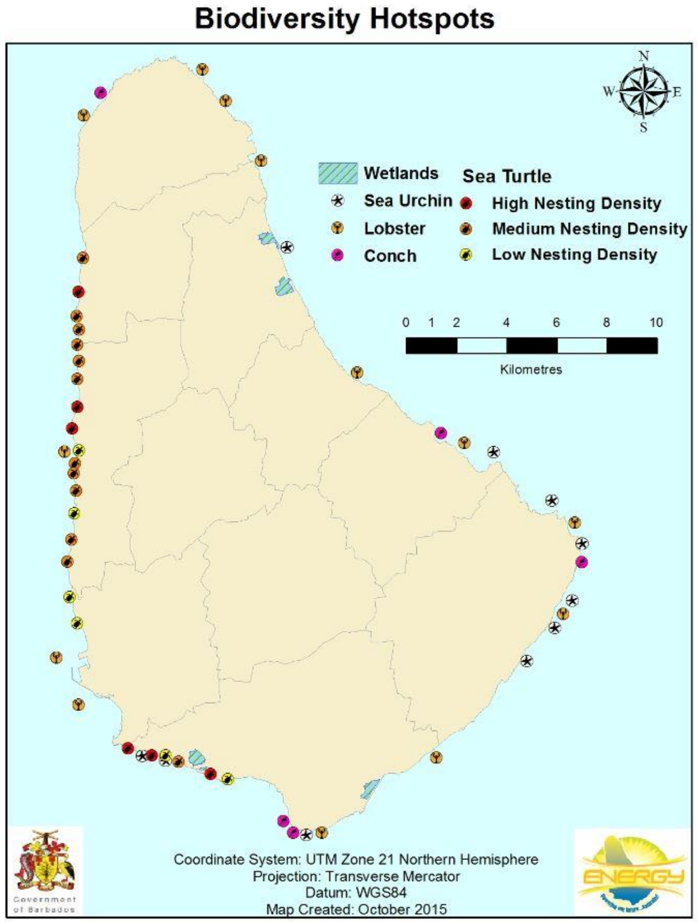
Introduction

- ✓ Ocean energy efforts by the Ministry of Energy and Business Development officially commenced in 2013 under the Public Sector Smart Energy Program (PSSEP)
- ✓ The PSSEP is financed through loan resources of US$17.0 million from the Inter-American Development Bank and a US$7.664 grant from the European Union
- ✓ The projects' aim is to promote and implement the use of renewable energy and energy efficiency measures that are viable in the public sector. Ultimately, the Program will help to reduce Barbados' fossil fuel dependency, promote sustainable energy, and therefore contribute to the country's competitiveness
- ✓ As part of this work, a series of ocean energy interventions were undertaken during the period 2015-2021
- ✓ Ocean energy has the potential to provide an important contribution Barbados' future renewable energy mix. The development of technologies to exploit this resource offers significant opportunities to grow Barbados' 'blue economy' by supporting future sustainable marine and offshore industries whilst ultimately seeking to reduce carbon emissions to ensure a sustainable future which is grounded in the Barbados' National Energy Policy 2019-2021

Overview of Ocean Energy Interventions

Phased Approach - 2015

- **GIS Studies** – preliminary assessments of Barbados' territorial waters to identify, collect, convert and assemble existing coastal, marine, wind and oceanographic data for the marine environment
  - ✓ **Output - a series of GIS maps** featuring five datasets - (i) Biophysical, (ii) jurisdictional, (iii) ecological, (iv) infrastructural, and (v) space use - depicting Barbados' used and unused ocean spaces.
  - ✓ Critical data gaps were identified



Overview of Ocean Energy Interventions

Phased Approach - 2016

Ocean Energy Scoping Study – Evaluated all OE technologies and defined the most appropriate technologies for Barbados

- ✓ The final recommendations for OE deployment given the local environment based on available data were:
  - ✓ OTEC and Fixed Offshore Wind – **High Suitability**
  - ✓ Floating Offshore Wind*, SWAC and Wave Energy – Medium Suitability
  - Ꭓ Ocean Current Technologies and Tidal Technologies – Low Suitability

** Floating Offshore Wind was subsequently upgraded and included as a '**High Suitability**' technology. This reflects the technical success of early demonstrator projects and rapid progress towards commercialization observed since the first technology review was conducted.*

Overview of Ocean Energy Interventions Cont’d

Phased Approach - 2017

Ocean Energy Project Implementation Roadmap

- ✓ Highlighted key steps for bringing a ocean energy project to fruition in Barbados
- ✓ Culminated in detailed scope of works and budget for an Ocean Energy Consultancy

GIS – Phase 2

- ✓ Identified what areas in the territorial waters of Barbados are best suited to hosting ocean energy technologies based on the three technologies identified
- ✓ Extensive data gathering – physical and human environment plus key designations such as reefs and protected areas
- ✓ **Output - Three Preferred Development Sites (PODs)** identified based on resource conditions and other sea uses

Overview of Ocean Energy Interventions Cont'd

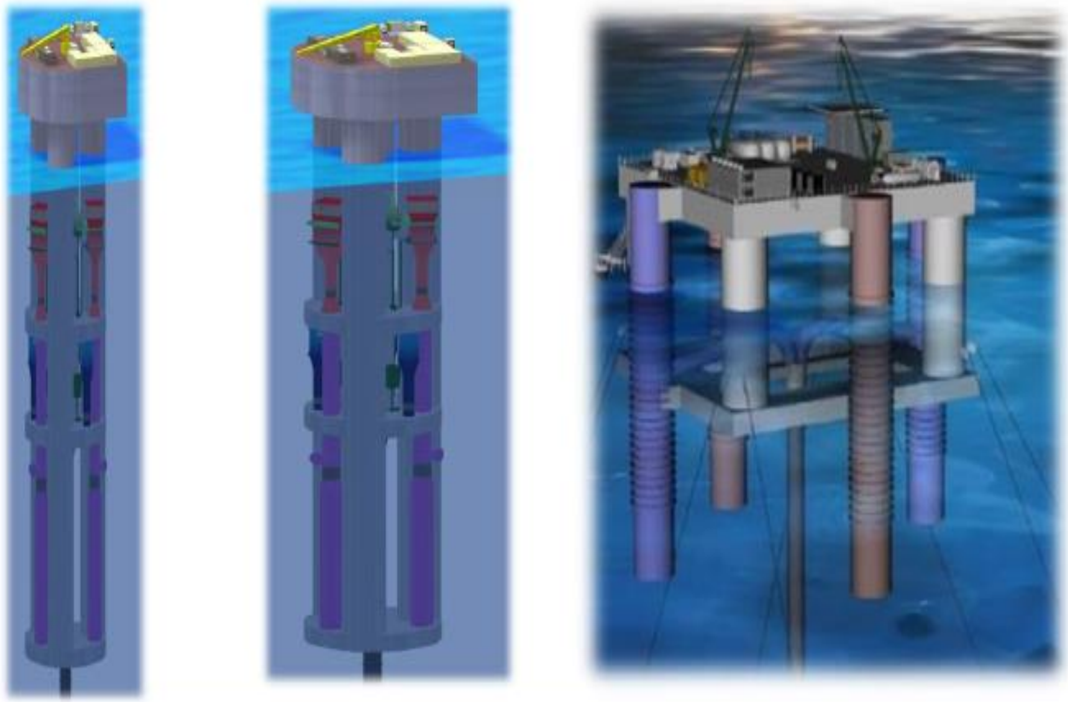
Phased Approach: 2019 - 2021

- ✓ **OE Studies Consultancy** – Consulting firm was procured to undertake a wide range of technical and environmental studies, as well as related capacity building activities, to investigate the feasibility and facilitate the construction of a large-scale Ocean Energy power plant or array in Barbados
- ✓ ITPEnergised (ITPE) along with their team of experts including Ramboll, Makai, CmY Consultants, OREI, J F Clarke Consulting and Loreto Duffy-Mayers commenced in January 2020 to support the Government of Barbados in achieving our 2030 net-zero target. The project was concluded in March 2021

Ocean Energy Consultancy

Ocean Thermal Energy Conversion (OTEC): Barbados Case

- ✓ OTEC is unique when compared to other OE technologies due to its lack of commercial maturity and non-convergence on a single platform design
- ✓ Three sizes of floating OTEC plants were considered:- OTEC plants with annual averaged net power output of 1MW and 10MW were modelled assuming a moored spar type platform, and a 20MW plant was modelled assuming a semi-submersible type moored platform



1MW OTEC Plant
Cell Spar Platform

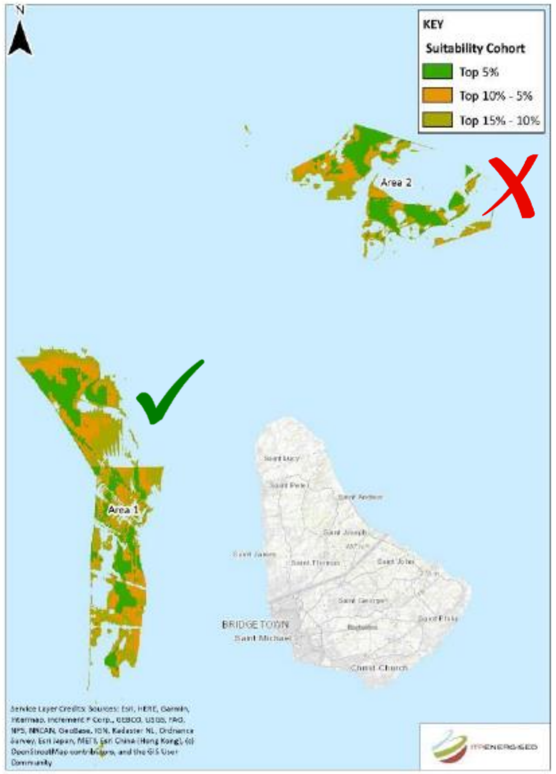
10MW OTEC Plant
Cell Spar Platform

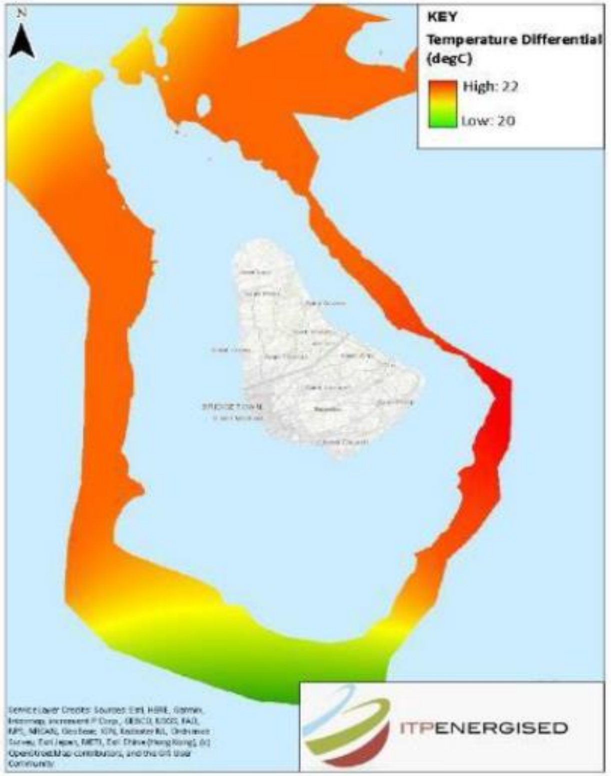
20MW OTEC Plant
Semi-submersible Platform with side spars

OTEC: Barbados Case Cont'd

Location of OTEC Plants in Barbados

Two potential areas of high OTEC suitability was determined. Area 1 lies on the western coastline of Barbados. Area 2 of high suitability lies approximately 25km off of the northern tip of Barbados. However, due to numerous difficulties relating to the depth and slope of the seabed located at Area 2. Only Area 1 was considered for possible OTEC developments





OTEC Challenges

- ✓ Landing sites
- ✓ Identification of areas of suitable sea depth within acceptable distance to shore
- ✓ Lack of commercial maturity
- ✓ High up-front cost
- ✓ High risk

OTEC Build Out and Costs

OTEC Buildout Program

- The key operations/tasks for developing an offshore OTEC plant have been considered for generating the Gantt charts starting from early phase permitting processes until final decommissioning of the project
- Main assumptions:
  - The regulatory and permitting periods are based on experience from European and U.S. marine renewable projects and may be different for OTEC and Barbados specific conditions.
  - The cell spar hull production and transport rates are assumed on best engineering judgement and limited ship building experience. The rates are highly dependent on potential shipyard capabilities, location, and time of construction.
  - Transport and installation vessel availabilities are assumed to not be an issue. This is expected to be a valid assumption if the vessels are not chartered on a spot market, but roughly a minimum of 24 months in advance.
  - The geotechnical and geophysical survey durations are based on experience from European and U.S. marine renewable projects and may vary based on existing data and project scope.
  - The period for other site measurements and metocean data is flexible and has varied in the past on other projects (such as offshore wind) between several months and several years. The longer the measurements, the higher the confidence level in the environmental conditions. In this study, 12 months are included for wind and wave measurements, and 12 months is considered a suitable period for current and temperature measurements (providing information on seasonality).

OTEC Build Out and Costs Cont'd

- ✓ Cost estimates were presented for the three plant sizes and each considered at three sites along west of the island
- ✓ Based on total project cost, the 10MW OTEC Plant was most favourable of the three sizes considering risk and cost. The total cost of a 10MW OTEC plant was estimated at approx. US$243M

Site	Project Capacity [MW]	Total Project Costs [k$USD]	Total Project Costs /MW [k$USD/MW]
North	20	451,813	$22,591
	10	242,756	$24,276
	1	92,221	$92,221
South - Spring garden connection	20	455,075	$22,754
	10	243,526	$24,353
	1	92,493	$92,493
South - Southern connection	20	460,011	$23,001
	10	243,081	$24,308
	1	90,972	$90,972

Financial Analysis

A financial analysis of the projects was undertaken and the six best performing projects were taken and analysed further:

Scenario	Capacity (MW)	LCOE (US$/ MWh)	Capital grant (% of capex)	Base case equity IRR	Proposed Rank
Fixed North	48	$99	0%	**27.3%**	1
Floating North	96	**$95**	0%	25.0%	2
Floating North	48	$99	0%	23.8%	3
Floating South Nearshore	96	$104	0%	22.1%	4
Floating South Farshore	96	$107	0%	21.3%	5
OTEC South Spring Garden	10	$312	**65%**	**18.0%**	6

The Finance rank is based on the IRR as an indicator for investors. Notwithstanding, the LCOE indicated that Offshore Wind would be financeable with the existing renewable FIT of US$ 120/MWh

Financial Summary

Scenario	Capacity (MW)	Capex (US$k]	Lifetime Opex (US$k)	Connection cost (US$k)	LCOE (US$/ MWh)	Capital grant (% of capex)	Base case equity IRR	Highest sensitivity IRR	Lowest sensitivity IRR	Proposed Rank
Fixed North	48	$120,313	$216,225	$18,886	$99	0%	**27.3%**	**43.1%**	12.8%	1
Floating North	96	$341,137	$313,650	$35,540	**$95**	0%	25.0%	39.2%	12.2%	2
Floating North	48	$171,796	$167,385	$19,909	$99	0%	23.8%	37.4%	11.4%	3
Floating South Nearshore	96	$377,231	$313,650	$72,715	$104	0%	22.1%	35.4%	10.1%	4
Floating South Farshore	96	$384,711	$313,650	$78,093	$107	0%	21.3%	34.4%	**9.5%**	5
OTEC South Spring Garden	10	$224,915	$3,087	$10,483	$312	**65%**	**18.0%**	26.9%	10.4%	6

Project Ranking of Preferred Projects

- ✓ A weighting exercise was undertaken to facilitate project ranking
- ✓ Weighted from 1 to 3 where 1 is most important

	Weighting	Description
Finance Rank	1	Based on LCOE, IRR and financial risk assessment as it defines the investability of the project
Local Content	3	Based on value of local content
Emissions savings	2	Based on lifetime CO2 savings
Tourism	3	Basaed on estimated value to the tourism industry
Consenting risk A	1	Basaed on distance to shore as visual impact is expected to be the most important factor in gaining consent
Consenting risk B	1	Based on percieved resistance from locals and tourists
Deliverable by 2030	2	Based on the time required to develop and construct the project
Environmental impact	2	Subjective view based on the Environmental scoping report and the technical reports

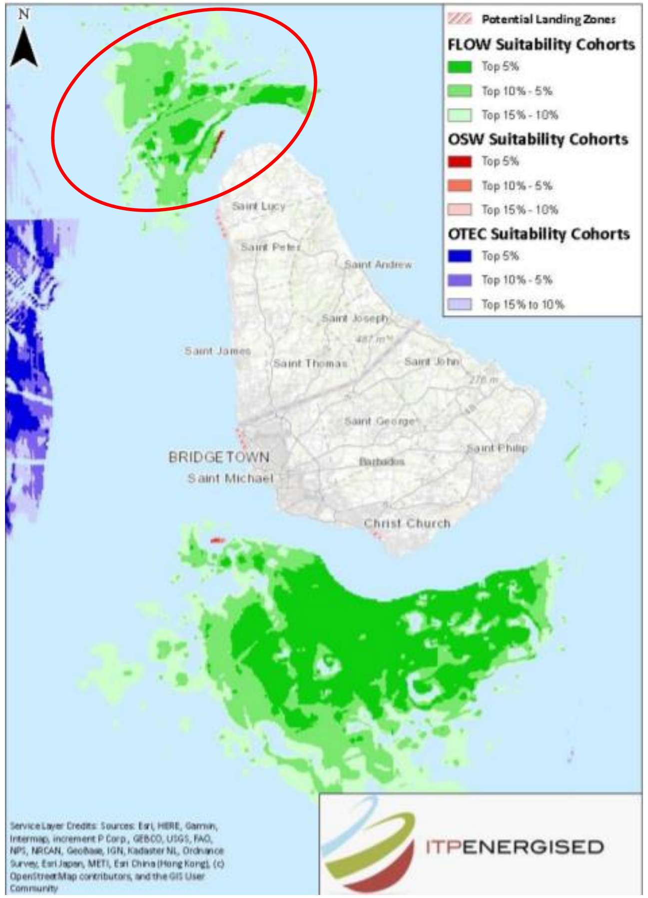
Project Ranking of Preferred Projects

Scenario \ Ranking Criteria	Finance	Local Content	Emissions Savings	Tourism	Technical Risk	Consenting Risk A	Consenting Risk B	Deliverable by 2030	Env. Impact	Weighted Score A	Final Rank A	Weighted Score B	Final Rank B
Fixed North 48MW	1	1	3	3	2	4	4	2	4	27%	4	27%	4
Floating North 96MW	2	1	1	2	2	3	4	3	3	22%	1	23%	1
Floating North 48MW	3	2	3	2	2	3	4	3	3	28%	5	28%	5
Floating South Nearshore 96MW	4	1	1	3	2	2	3	3	3	25%	3	26%	3
Floating South Farshore 96MW	5	1	1	2	2	1	3	3	3	23%	2	24%	2
OTEC 10MW	6	5	5	2	5	3	3	4	4	46%	6	46%	6

Preferred Sites – North Fixed & FLOW

Technology	Location	Scenarios (MW's)	Total number of scenarios	Landing Zone
Floating OSW	North	24; **48**; **96**	3	North
	South (nearshore)	24; 48; **96**	3	Spring Garden
	South (far shore)	24; 48; **96**	3	Spring Garden
Fixed OSW	North	8; 24; **48**	3	North
	South	16	1	Spring Garden
OTEC	West	1; **10**; 20	3	Spring Garden
TOTAL			**16**	

- ✓ Conceptual Design of a generic jacket type bottom-fixed offshore wind foundation
- ✓ Conceptual Design of a generic semi-submersible type floating offshore wind foundation



Project Ranking of Preferred Projects

- The projects deemed to be most desirable and feasible for Barbados are:
  - ✓ Floating Offshore Wind projects particularly those in the north
  - ✓ Fixed Offshore Wind project on the north of the island – high potential for a first project
- The Fixed Offshore Wind in the north only ranked 4th on the final list, but it did rank first on the finance list. It would therefore be useful to keep a fixed farm as an option for a developer to make Barbados as attractive a site as possible for as many developers as possible
- The maximum wind turbines investigated was twelve 8MW turbines totalling 96MW per wind farm site with direct connection to the shore and no offshore substations
- The nearshore ocean space of Barbados could accommodate project(s) of significantly larger scale. A recently published report (Nov 2021) on the wider Caribbean including Barbados identified 8.5GW of theoretical potential with a maximum technically exploitable potential of 7.18GW

Is OTEC Feasible for Barbados?

- ✗ OTEC is not deemed to be a technology of high interest in the period to 2030. The key challenges were found to be the extremely high up-front cost and high levels of technical and commercial risk associated with the technology. Both of these factors indicated that in order for a commercial project of significant scale (i.e. 10MW) to proceed a large proportion of the overall project cost would need to be met by a non-repayable grant

- ✓ Notwithstanding, this technology may be a viable option in the long-term as Barbados continues to decarbonize

Thank you

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