UTM Perdana Course MFFT 1053

"Ocean Thermal Energy-Driven Development in the Tropics for Sustainability"

by

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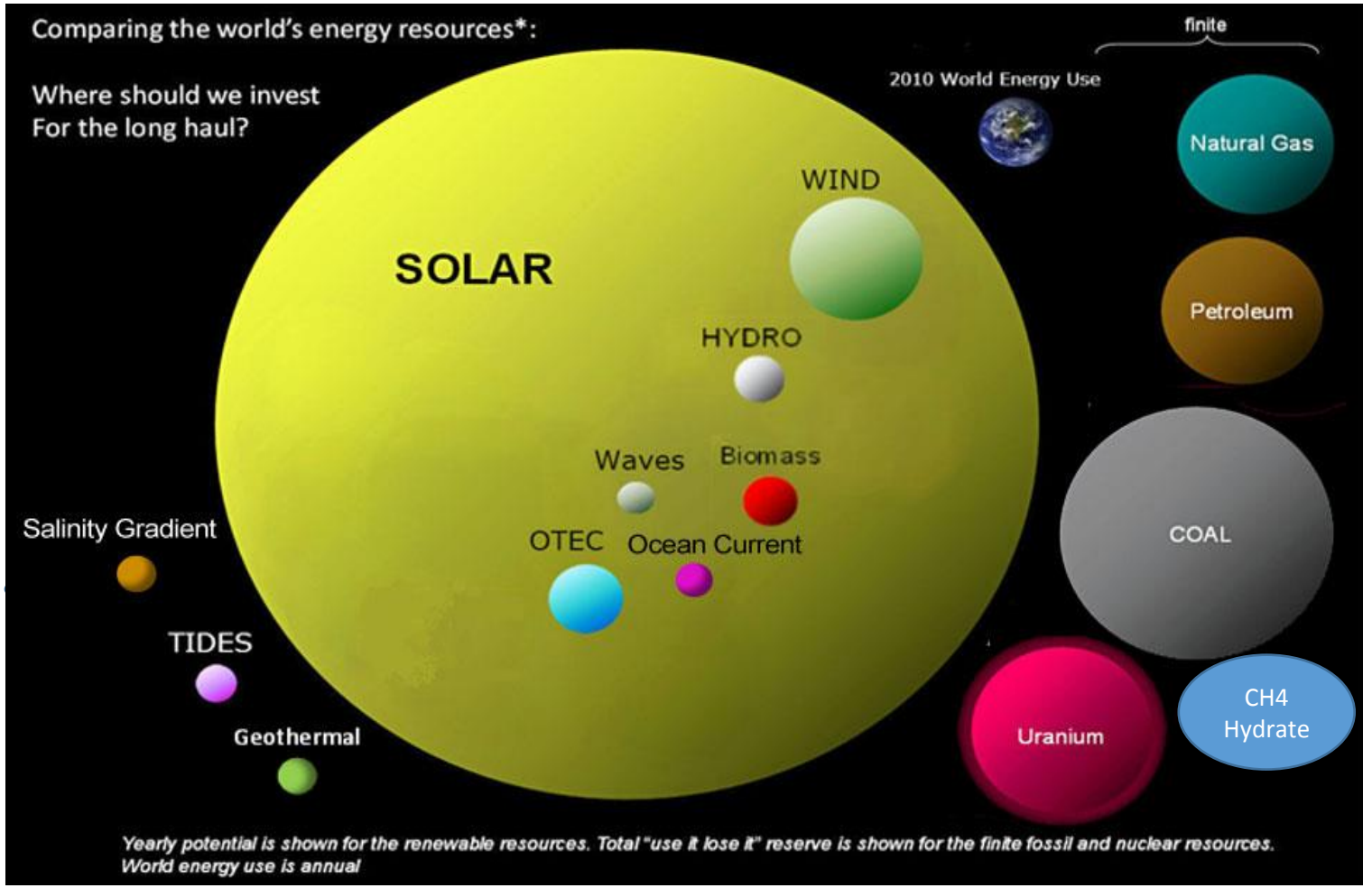
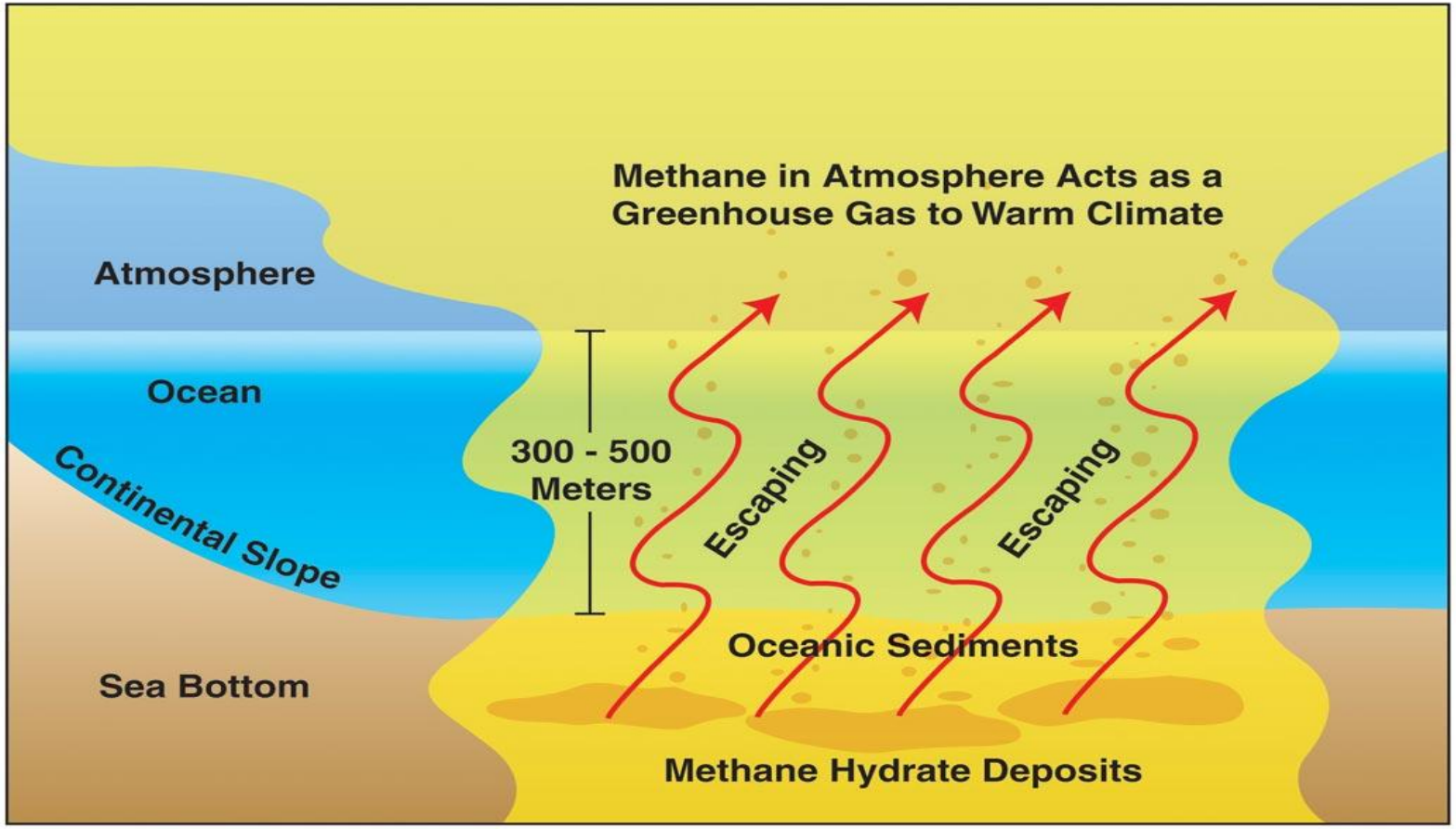
OUTLINE OF PRESENTATION

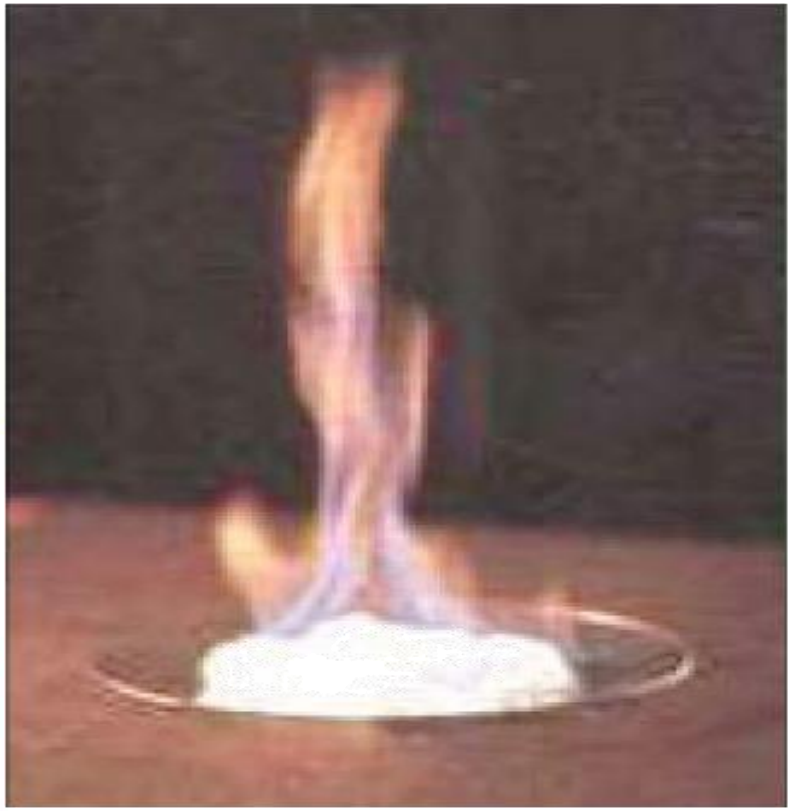
1. INTRODUCTION
2. SOURCES OF ENERGY, RENEWABLE & NON-RENEWABLE
3. THE WAY FORWARD FOR OCEAN ENERGY DEVELOPMENT IN THE TROPICS: ORDER OF PRIORITY
4. OCEAN THERMAL ENERGY CONVERSION (OTEC)
5. OTEC RESOURCE ASSESSMENT & POTENTIAL
6. THE ECONOMICS OF OTEC vis-à-vis FOSSIL-FUELS & OTHER FORMS OF OCEAN ENERGY
7. BENEFITS: SECURITY *[ENERGY, WATER, FOOD, CYBER*], ENVIRONMENT,
8. THE WAY FORWARD

2. SOURCES OF ENERGY: RENEWABLE & NON-RENEWABLE

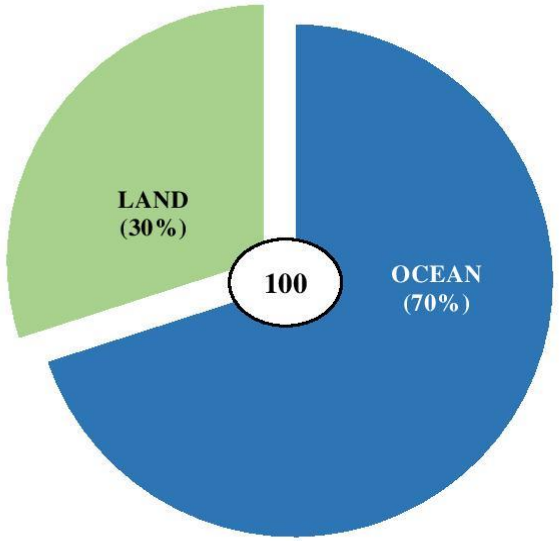


Methane Explosion Warmed Prehistoric Earth

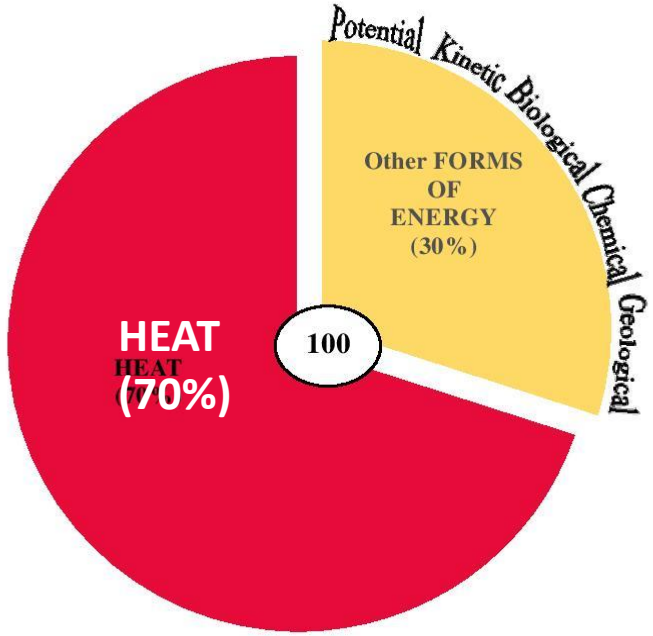




Methane Hydrate: “White Coal”



THE EARTH

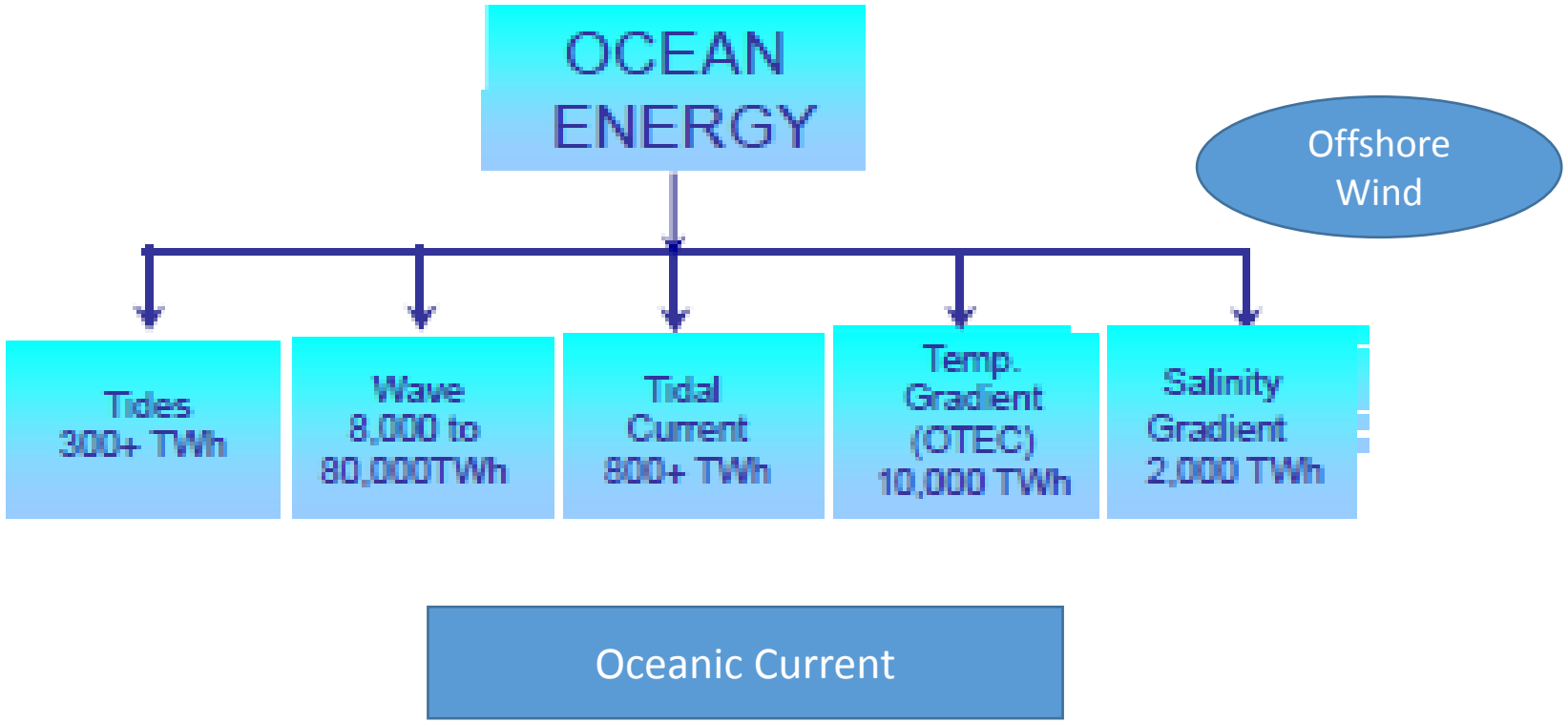


FORMS OF ENERGY

"Among all the forms of energy, we are using today, over 70% are produced in or through the form of heat."

[Ref: Dongsheng Wen et al (2009)]

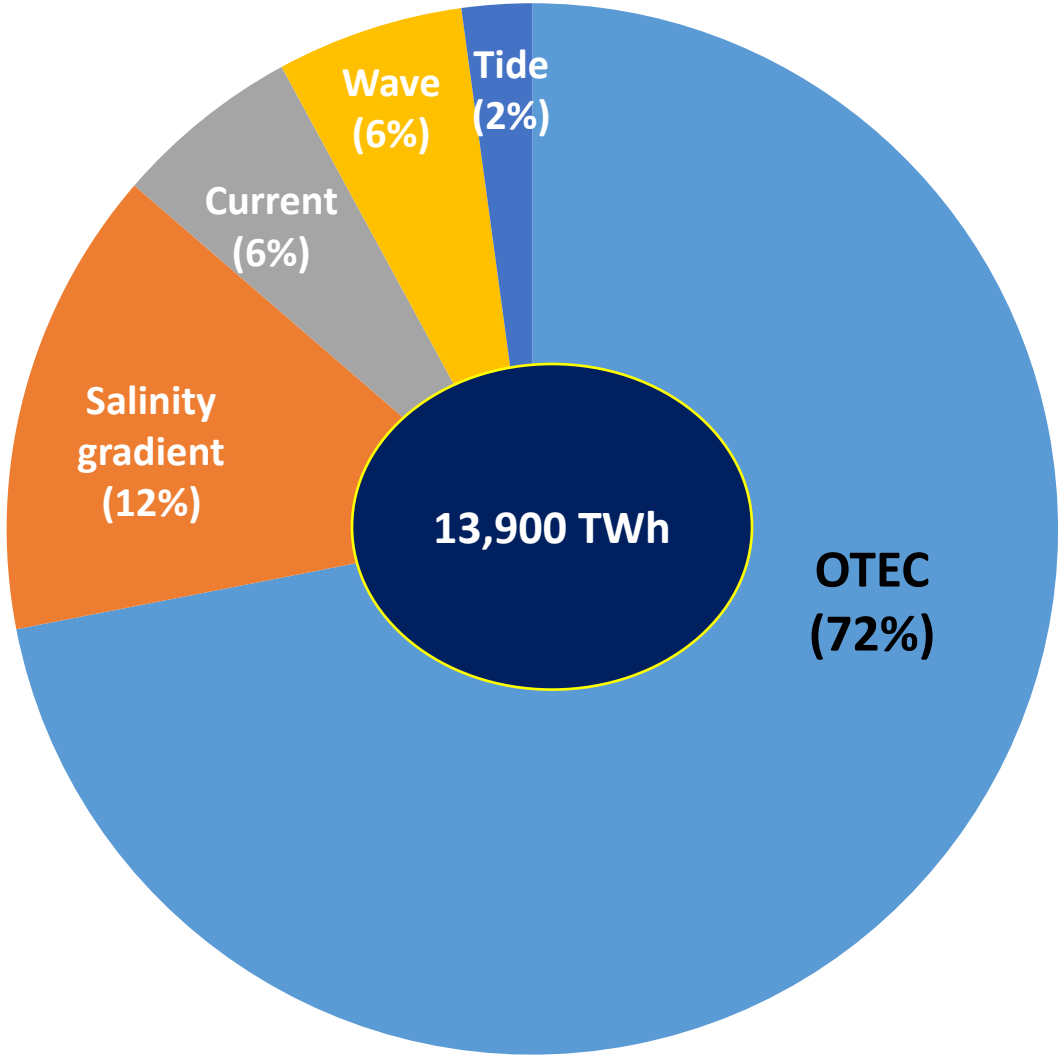
Forms of OE Resources & Corresponding Estimated Global Annual Theoretical Resources



IEA-OES

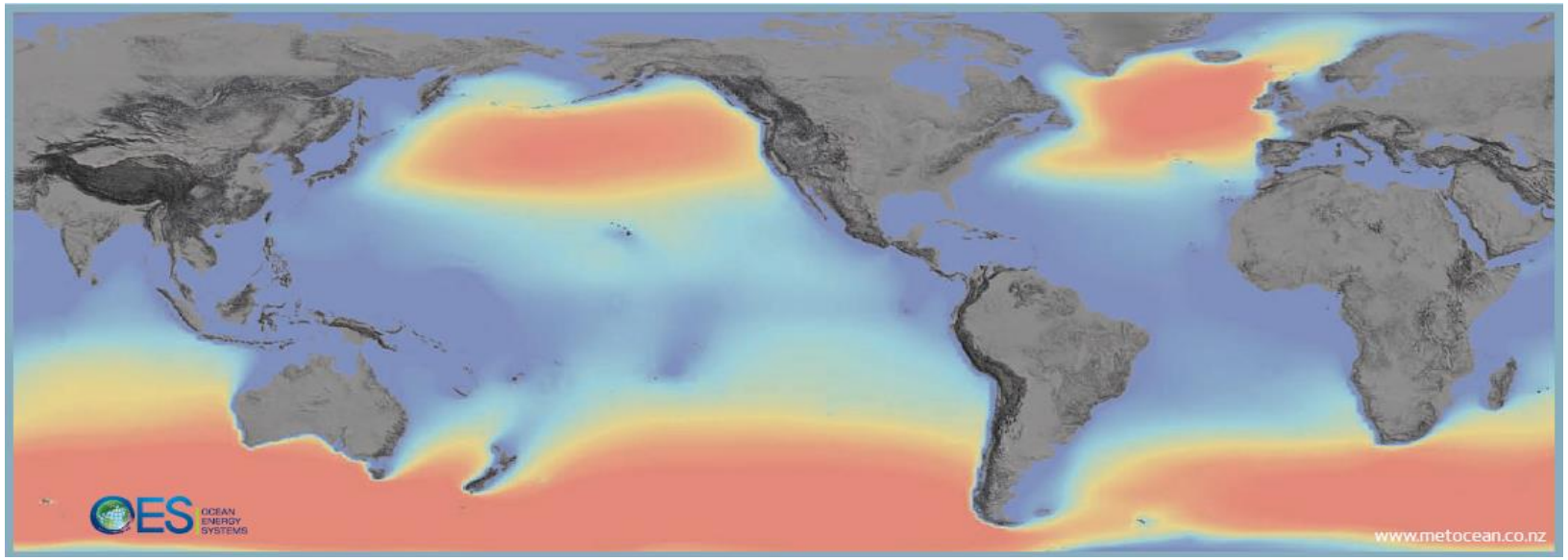
OE = Ocean Energy

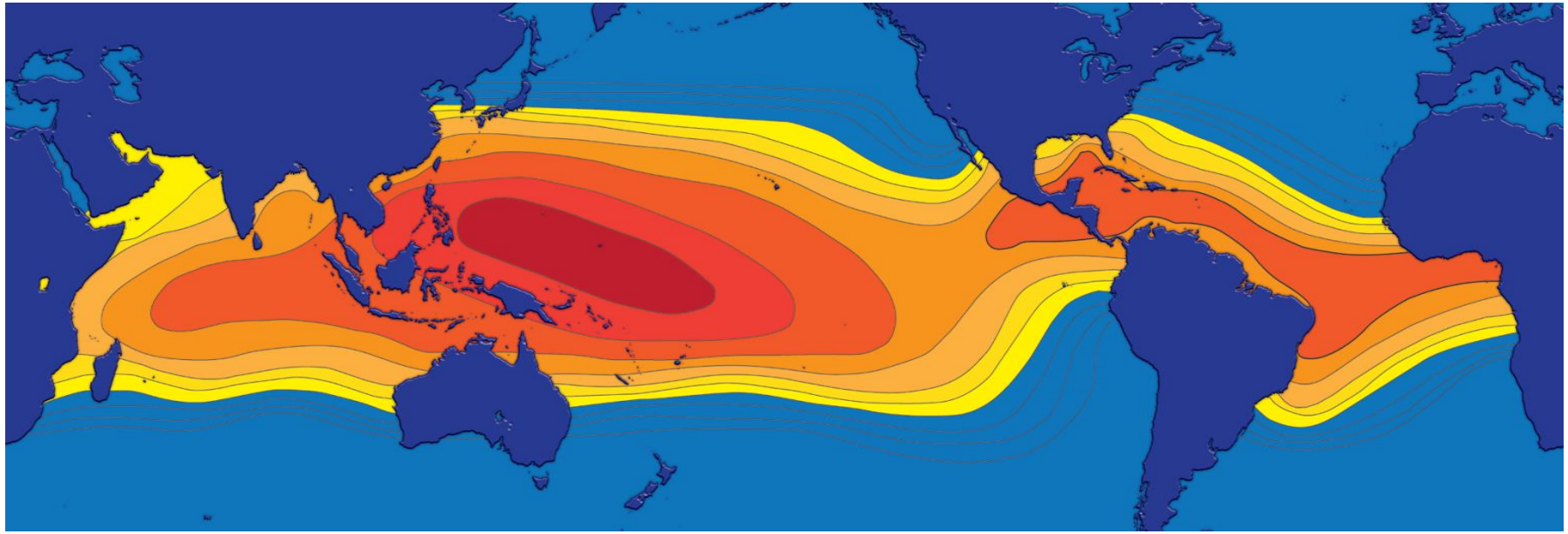
GLOBAL ANNUAL THEORETICAL GENERATION CAPACITY BY FORM OF OCEAN ENERGY



[Data Source: IEA-OES]

Wave Power Potential in Temperate Regions





OTEC Potential in the Tropics & Subtropics

3. THE WAY FORWARD FOR OCEAN ENERGY DEVELOPMENT IN THE TROPICS: ORDER OF PRIORITY

1. Ocean Thermal Energy Conversion (OTEC)
2. Tidal & Ocean Currents
3. Offshore Wind
4. Salinity Gradient, OTEC SpinOff
5. Marine Algae, OTEC SpinOff
6. Wave

OTEC Legal Definition:

"OCEAN THERMAL ENERGY CONVERSION"

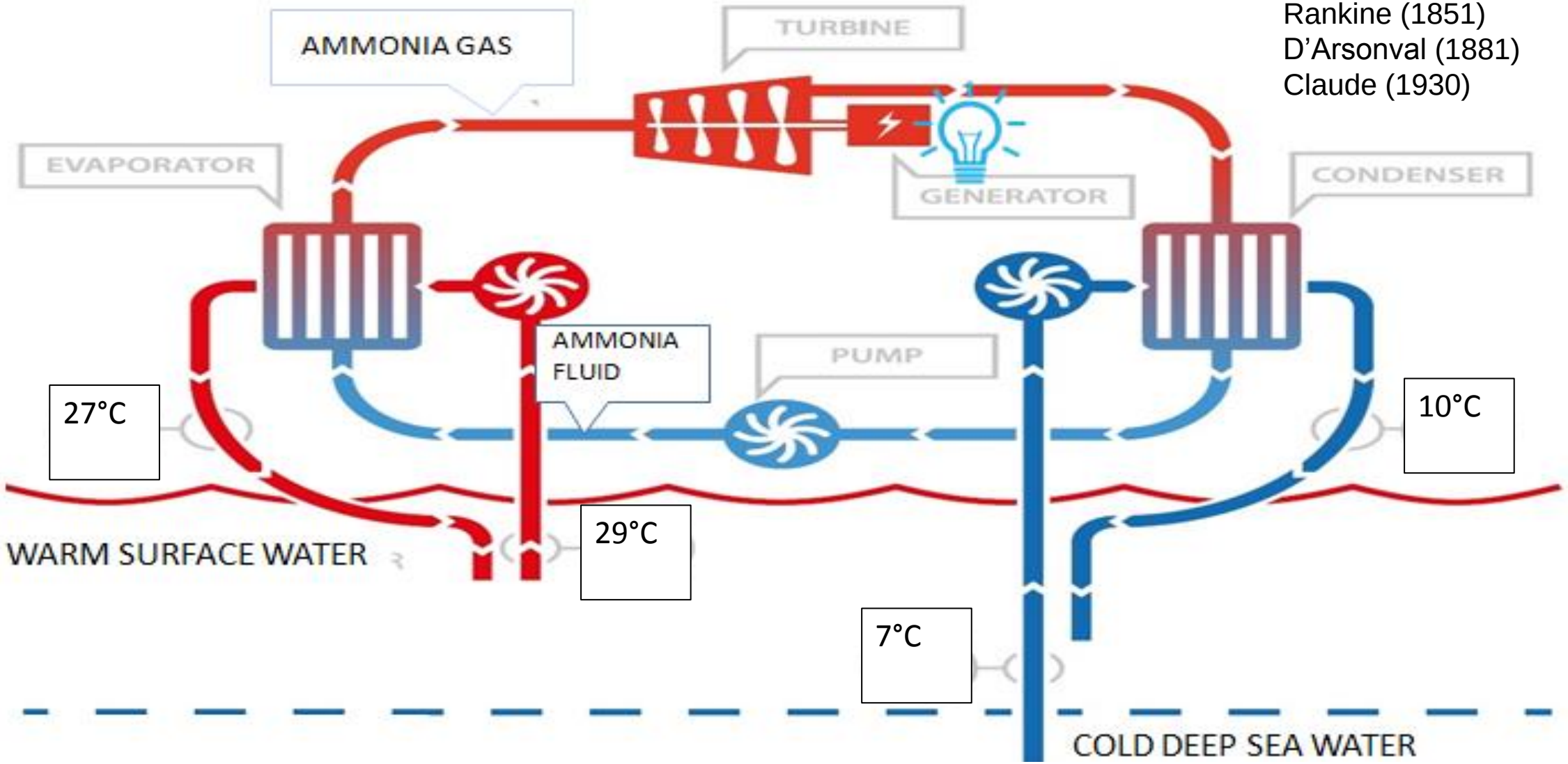
"... a method of converting part of the heat from the Sun which is stored in the surface layers of a body of water into electrical energy or energy product equivalent";

[Pub. L. 96-310, Sec. 9, July 17, 1980, 94 Stat. 946.]

Ref:
http://uscode.house.gov/download/pls/42C98.txt

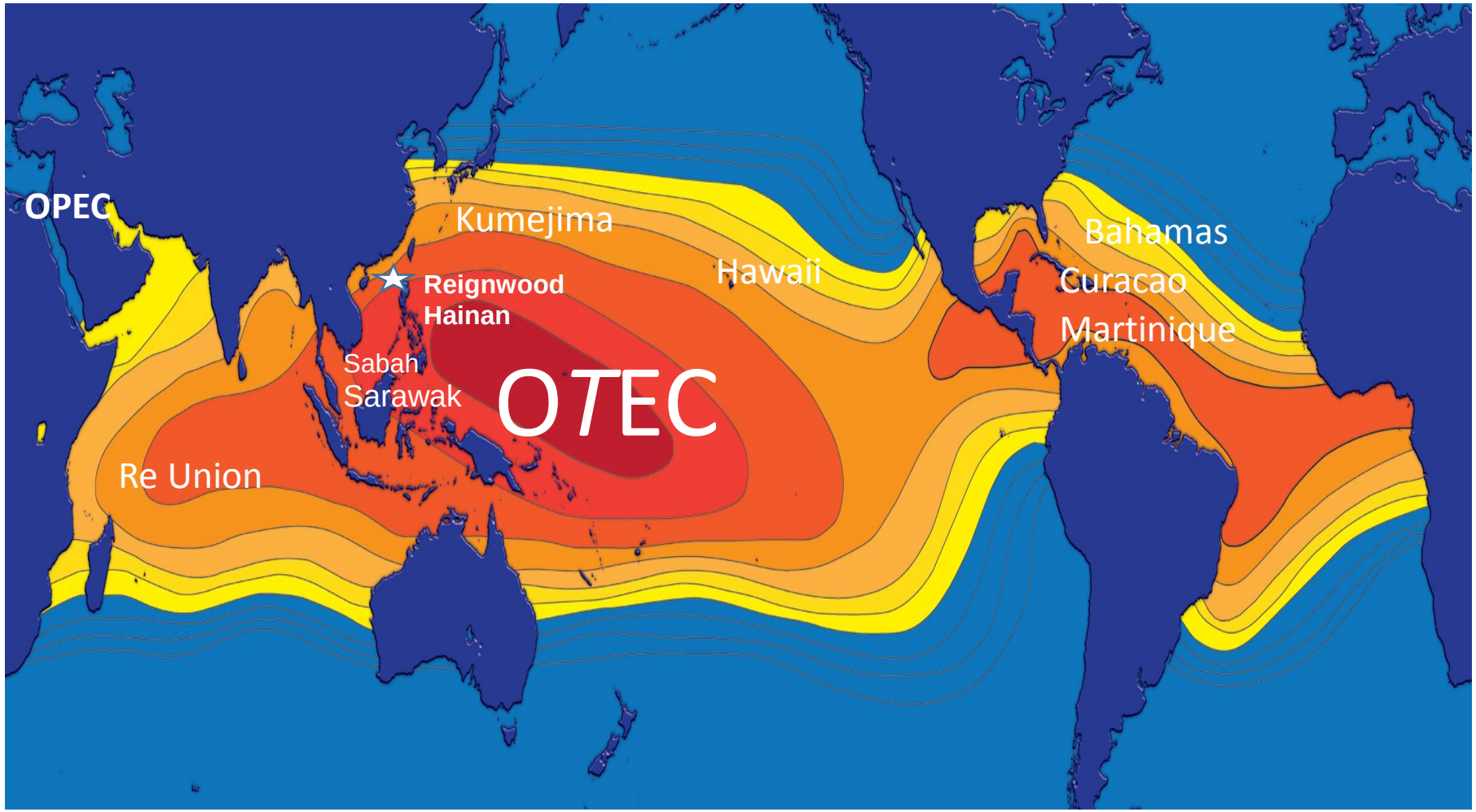
PRINCIPLE OF OTEC

Al-Quran 24:40 (610-632)
Rankine (1851)
D'Arsonval (1881)
Claude (1930)



5. OTEC RESOURCE ASSESSMENT & POTENTIAL

Global OTEC Potential & Development: From OPEC to OTEC



OTEC Resource Assessment & Potential in The Tropics

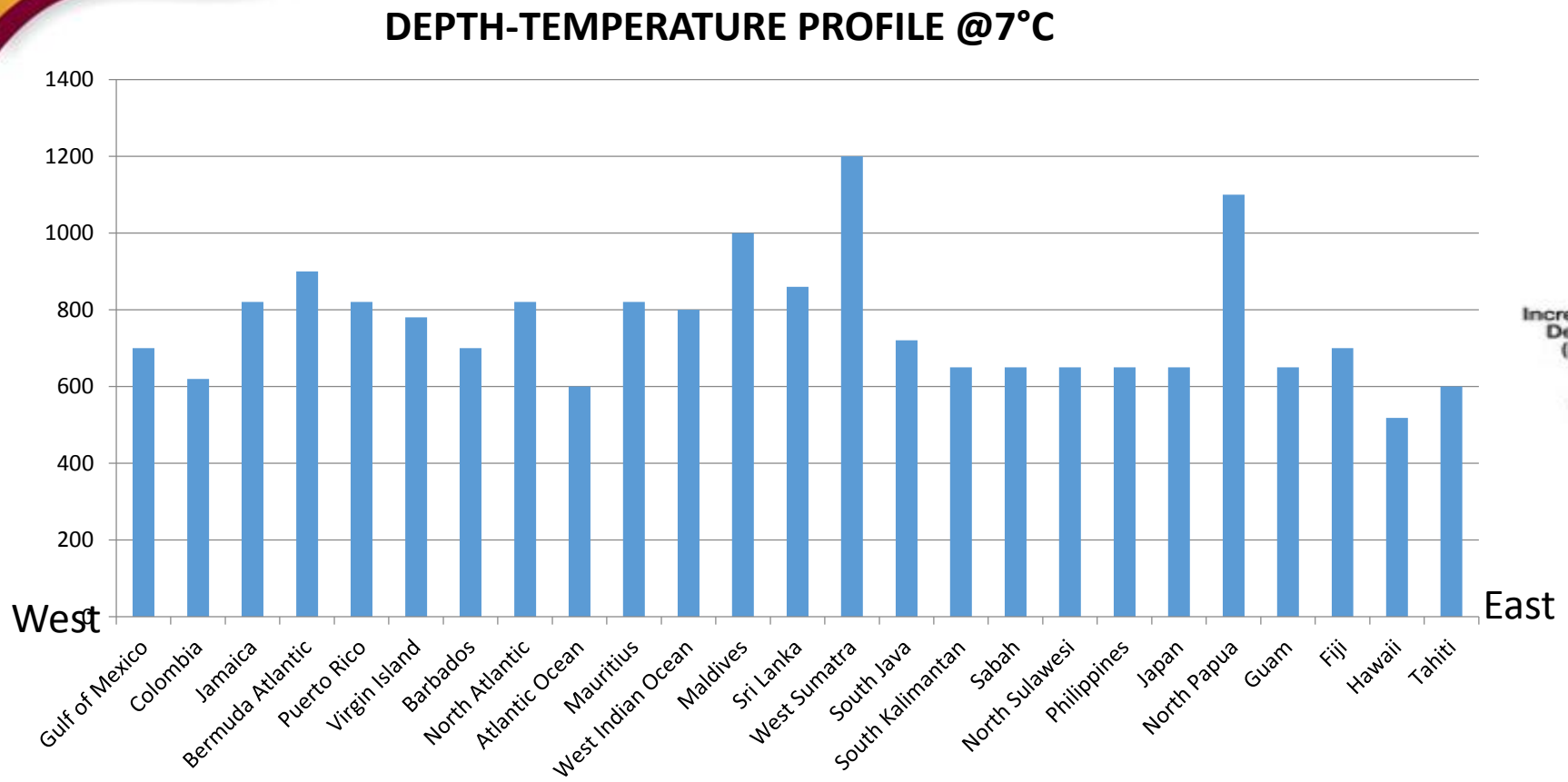


Figure1. Depth-temperature profile of different locations at 7°C

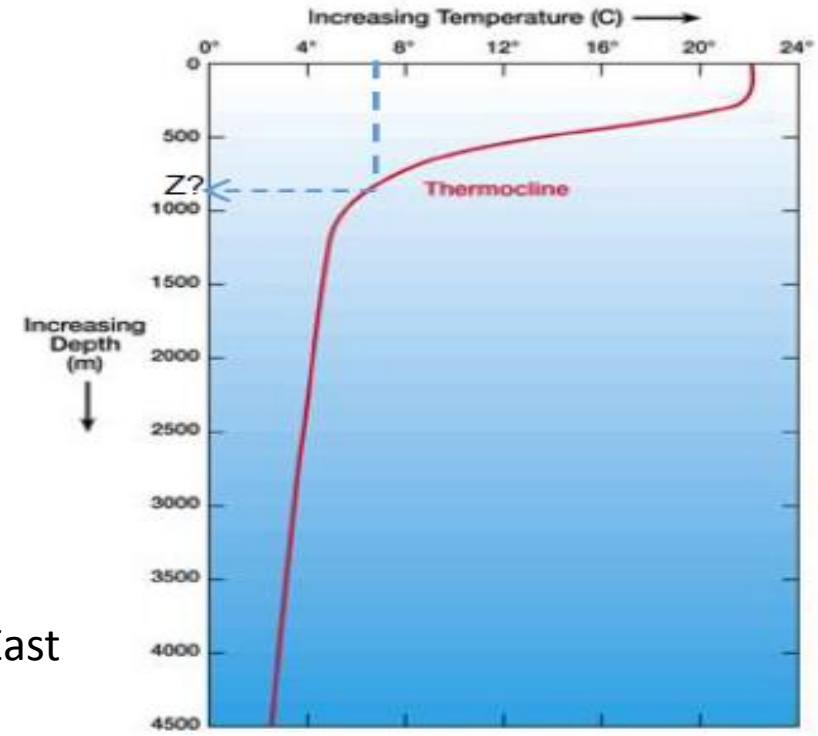
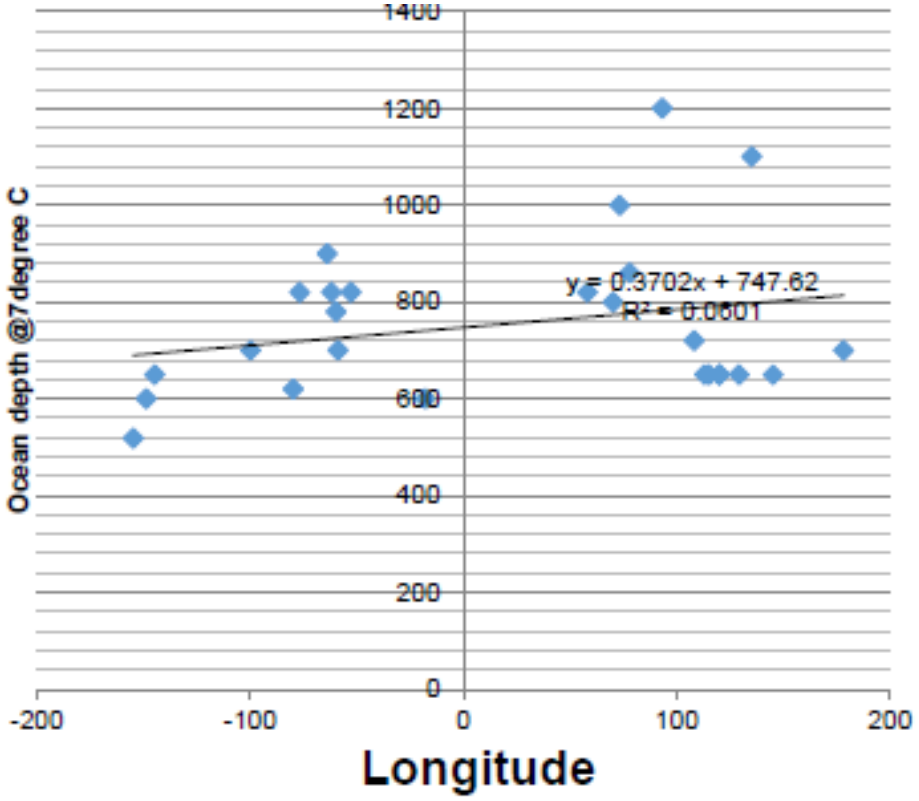
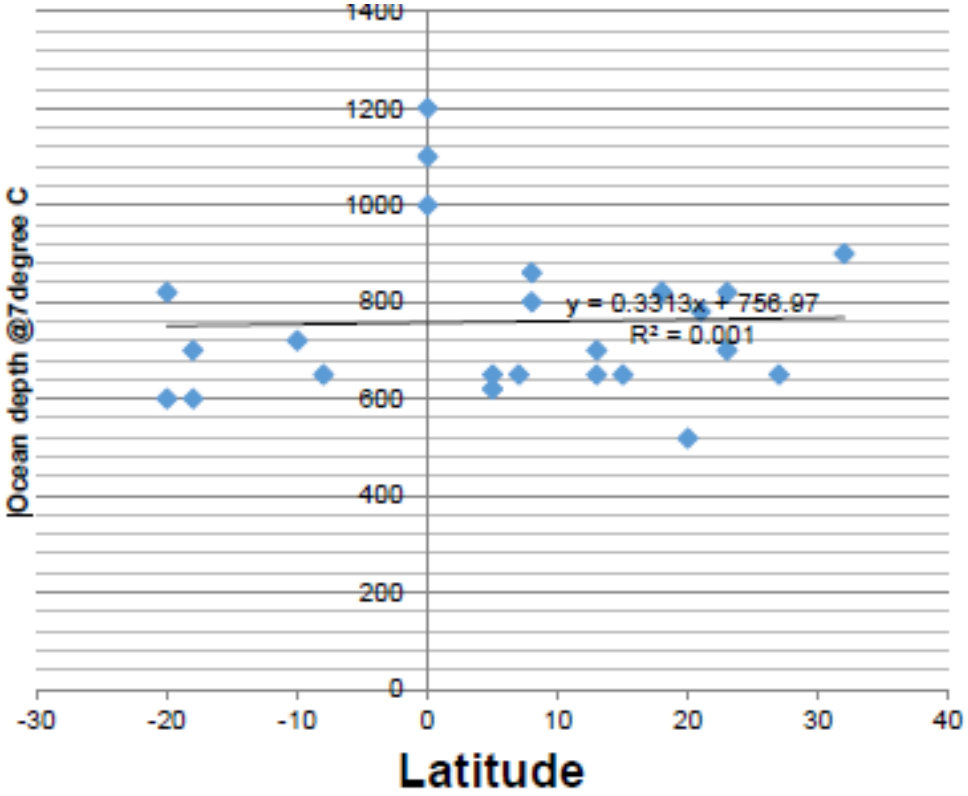


Figure 2. Depth @ 7°C surface temperature

References:
Avery, 1994, pg421; A Devis-Morales, 1994, pg762; Al Binger,2007; pg5; BATS Frye, 1981, pg16; Maul, 1999, pg67; O'Connell, pg5; Maul, 1999, pg67; Brandon, 2016, Figure 7; Al Binger,2007, pg5; Bassett, 2015, pg2; O'Connell, pg6; Ikegami and Mitsumori, 1998, pg141; Octaviani, 2016, pg69; Ikegami, 2009, pg39; Syamsuddin, 2015, pg221; Bakar, 2016, pg10; Syamsuddin, 2015, pg221; ADB Report, 2014, pg49; Shpilrain, 2009, pg211; Ikegami, 2009, pg39; Al Binger,2007, pg5; Leraand, 1995, pg1100; Sea Semester Lassuy,1979, pg23

Distribution of Ocean Depths @7°C by Longitude & Latitude





Y = 0.370x + 747.6

Y = 0.331x + 756.9

We could predict the depth of the ocean @7^{o}C using the regression analysis equation as above with given coordinates

STATISTICS & DISTRIBUTION of OCEAN DEPTH @ 7°C

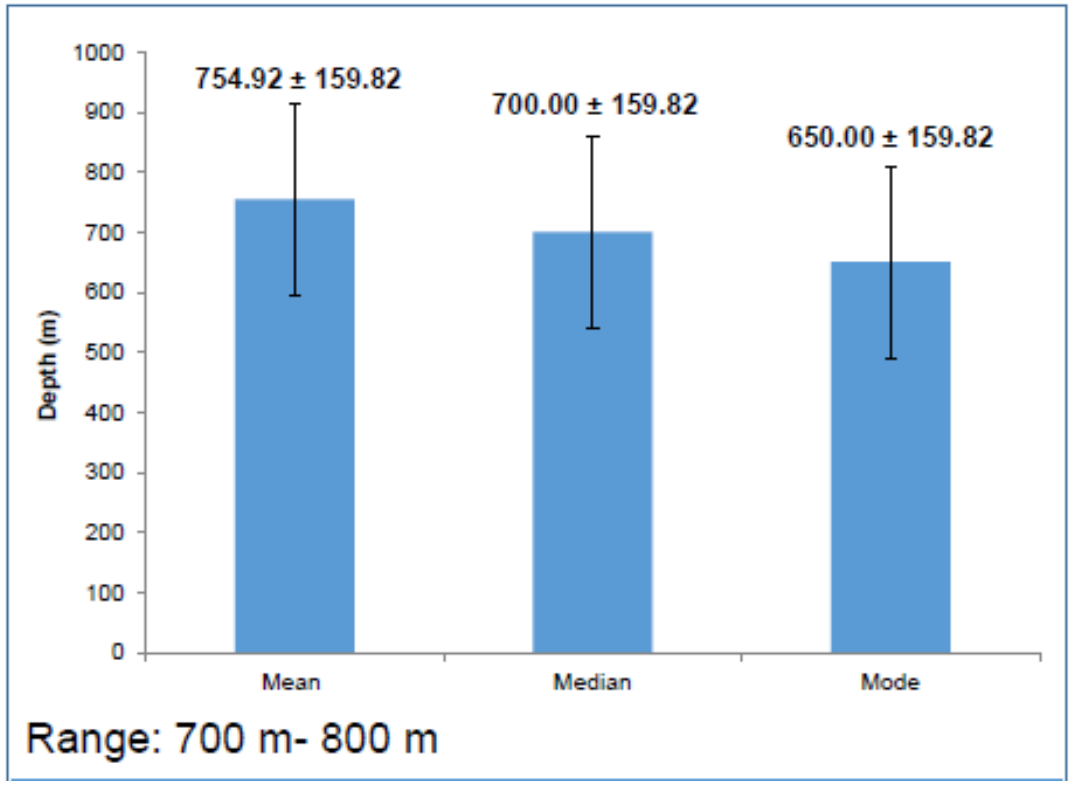


Figure 8. Statistics of the ocean depth at 7°C

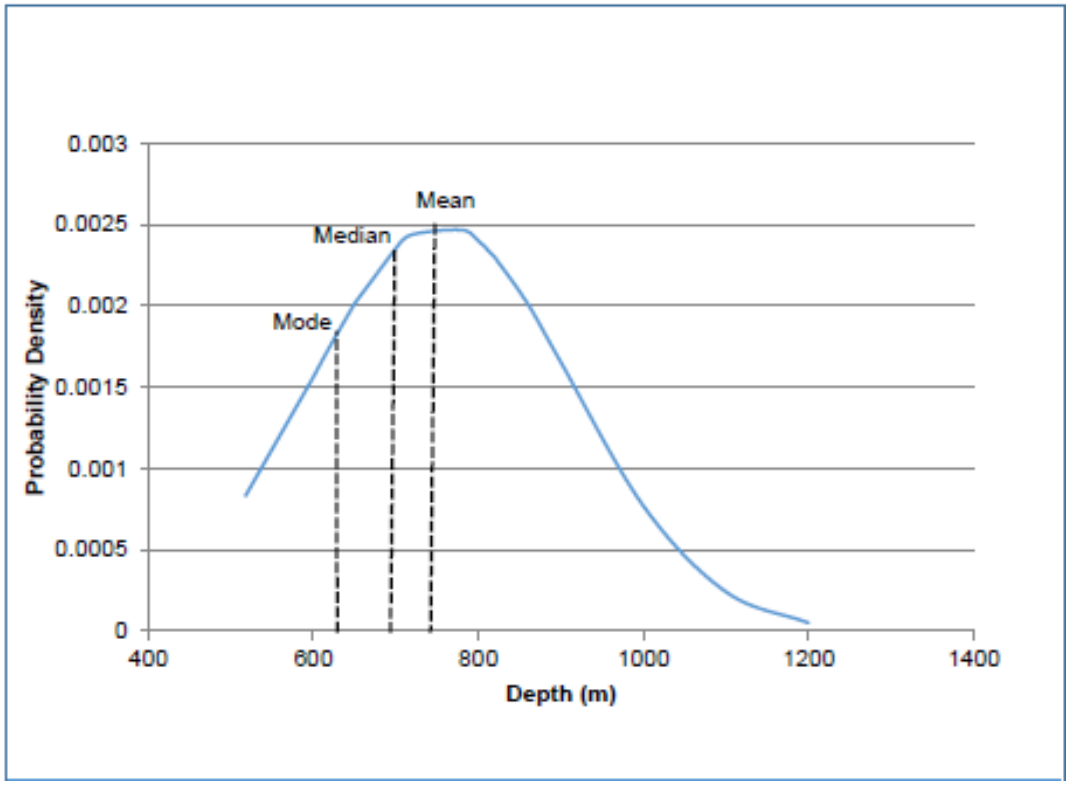
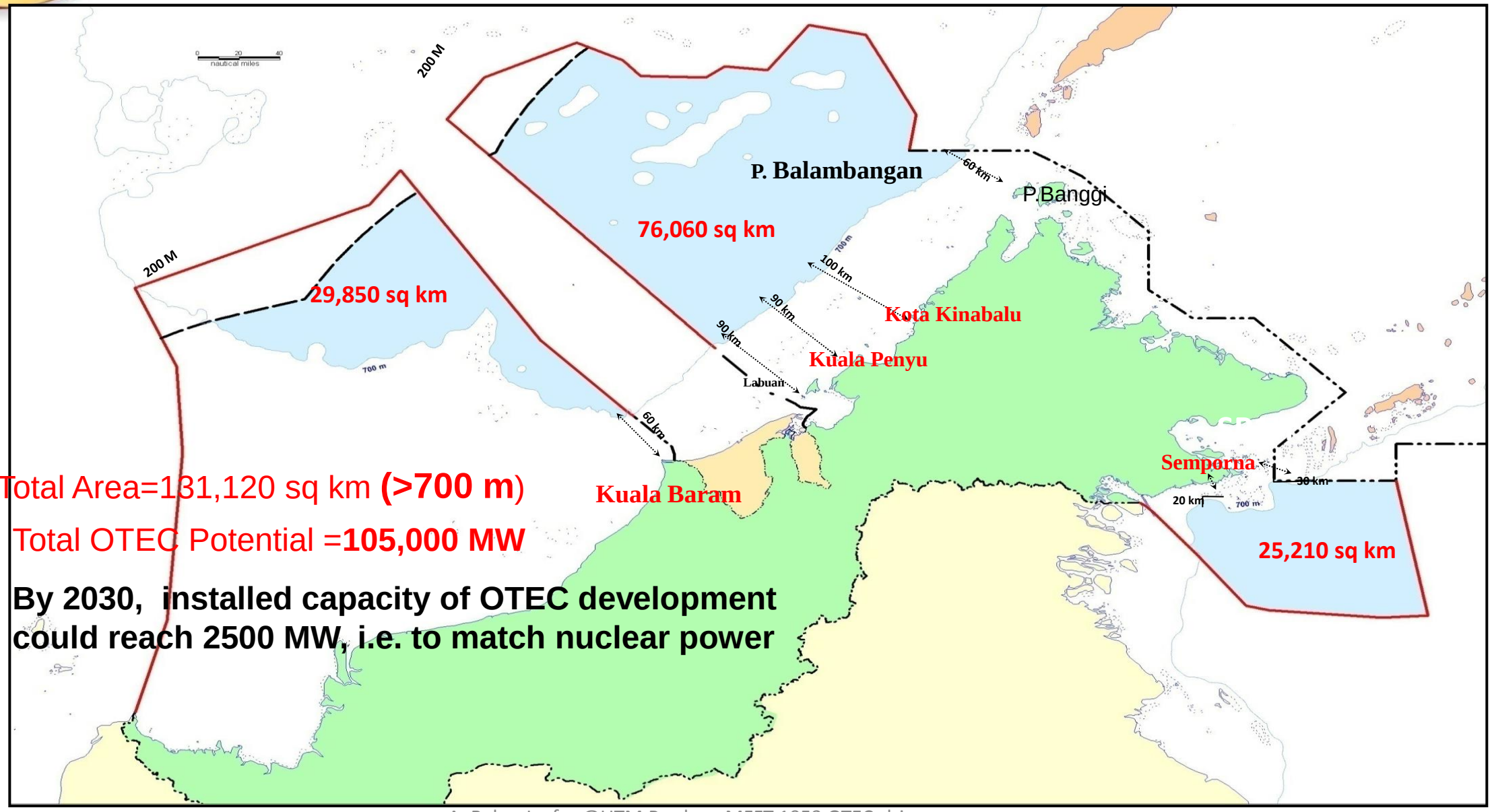


Figure 9. Distribution of Ocean Depths @7°C

OTEC POTENTIAL IN MALAYSIA



Total Area=131,120 sq km **(>700 m)**

Total OTEC Potential =**105,000 MW**

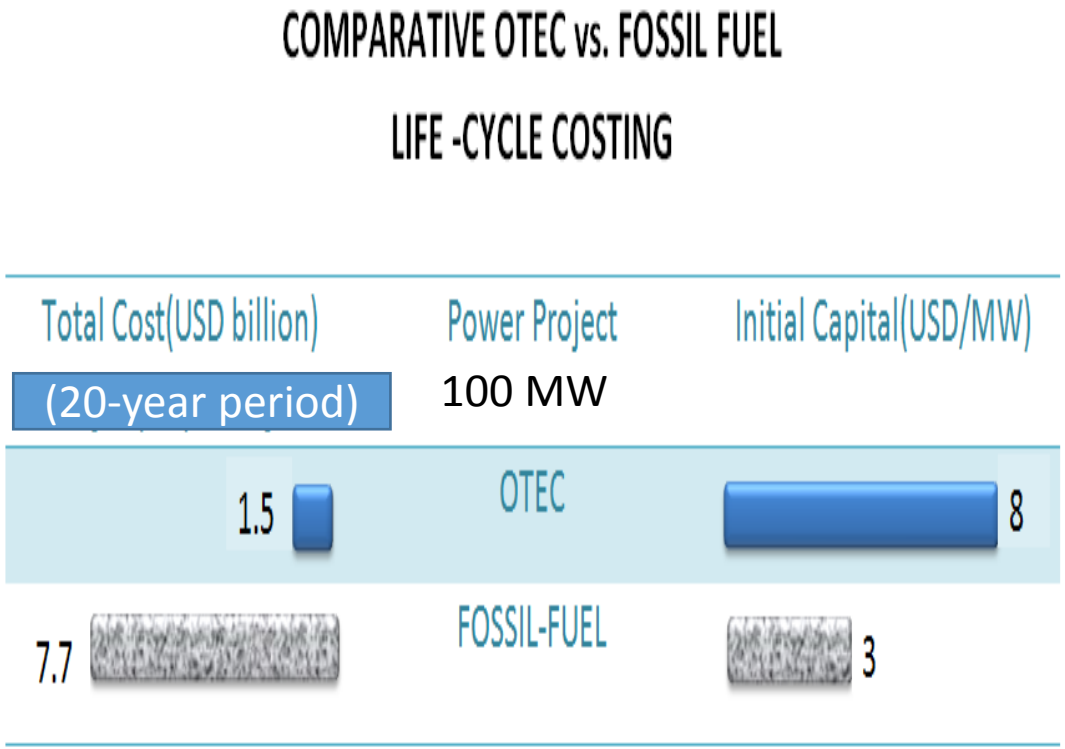
By 2030, installed capacity of OTEC development could reach 2500 MW, i.e. to match nuclear power

6. THE ECONOMICS OF OTEC vis-à-vis OIL & OTHER FORMS OF OCEAN ENERGY

6.1 Investment in OTEC will save more money than that of oil-fired power plant, by 5 times over

6.2 The price of oil does not matter, not only that "oil & water" do not mix, but also OTEC generates power & very valuable utilities and commodities

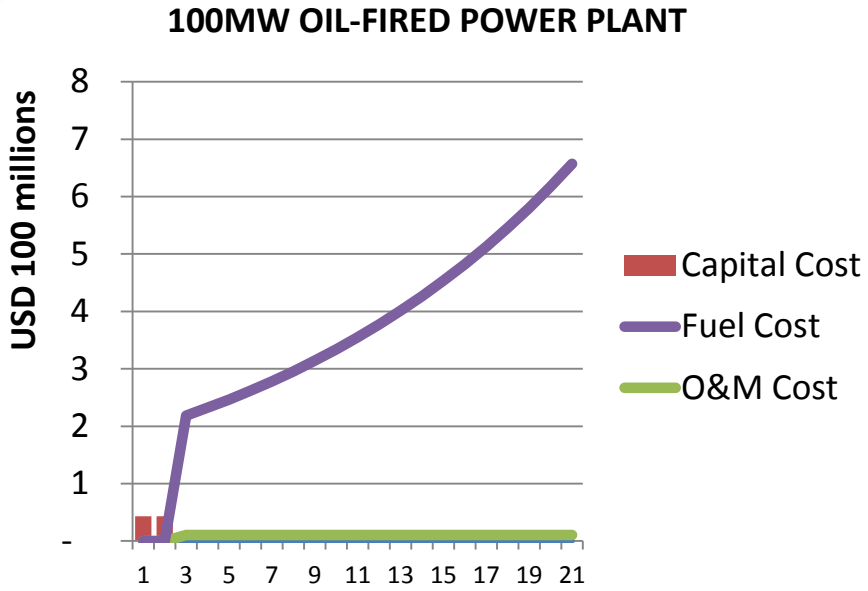
OVERCOMING BARRIERS: HIGH INITIAL CAPITAL REQUIREMENT

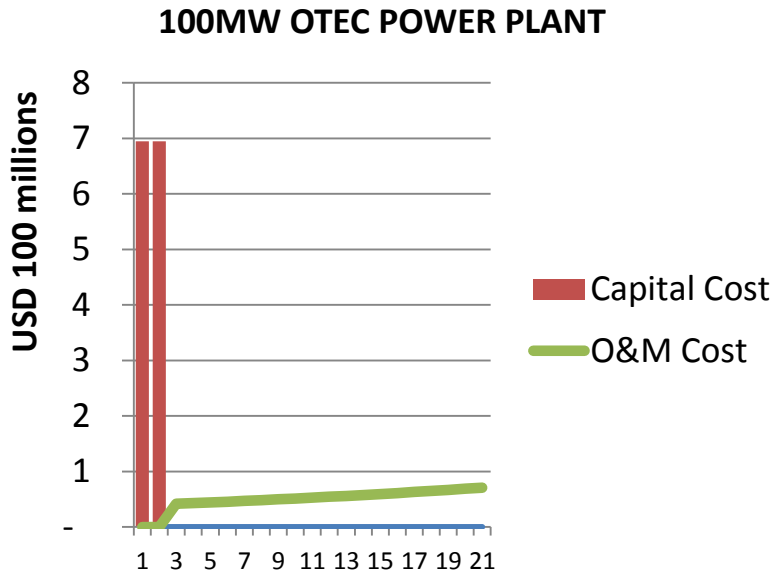


Note: Price of Oil : USD 100/barrel

- By introducing project-life costing;
- By realising that “renewable”, “virtually free”;
- By highlighting “cost-saving” over project life;

COMPARATIVE CAPITAL & OPERATING COSTS OVER PROJECT LIFE CYCLE

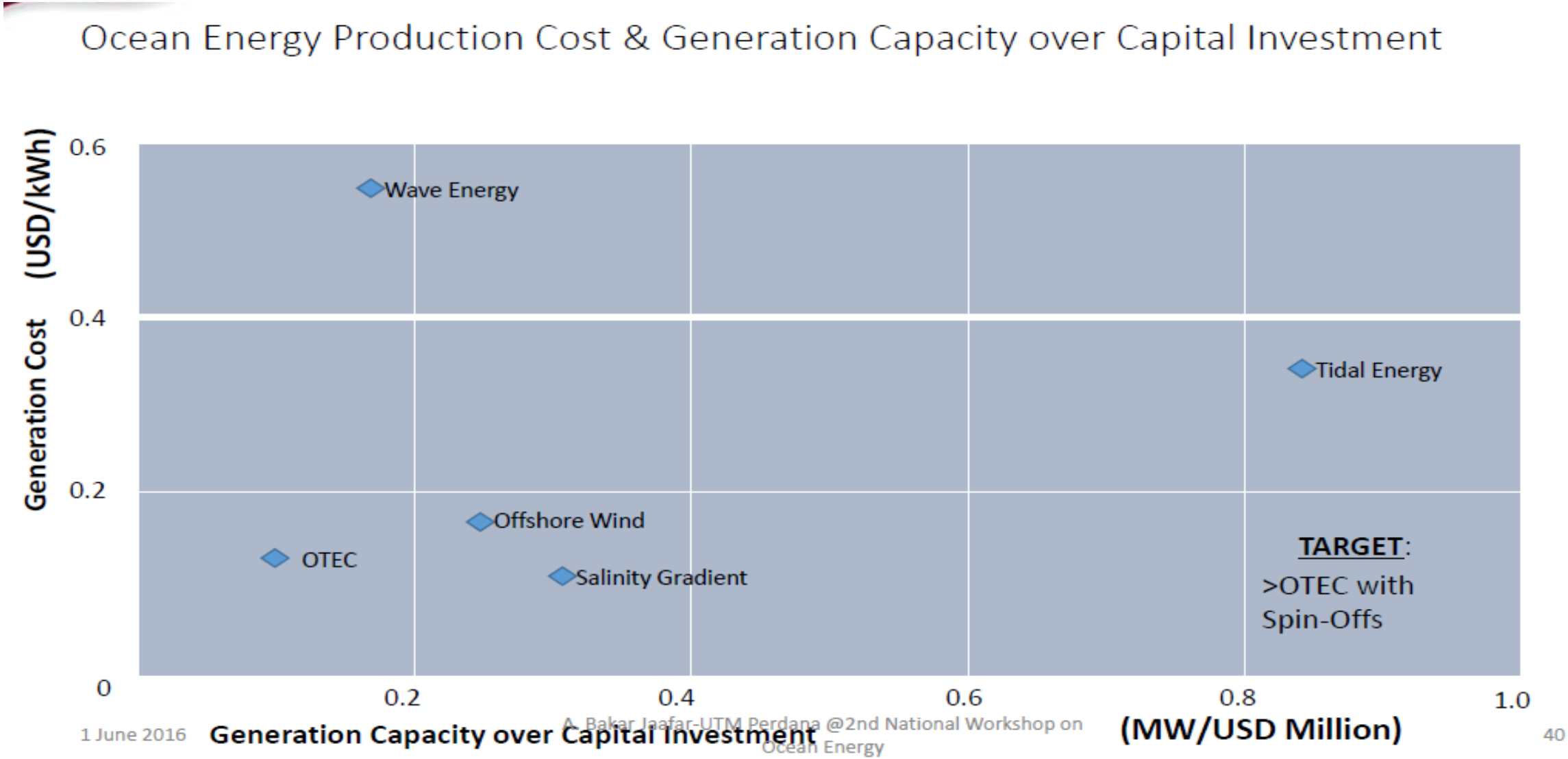




Total costs (USD) over 21 years of operation

OIL-FIRED POWER	OTEC-POWER
USD 7.5 billion	USD 1.5 billion

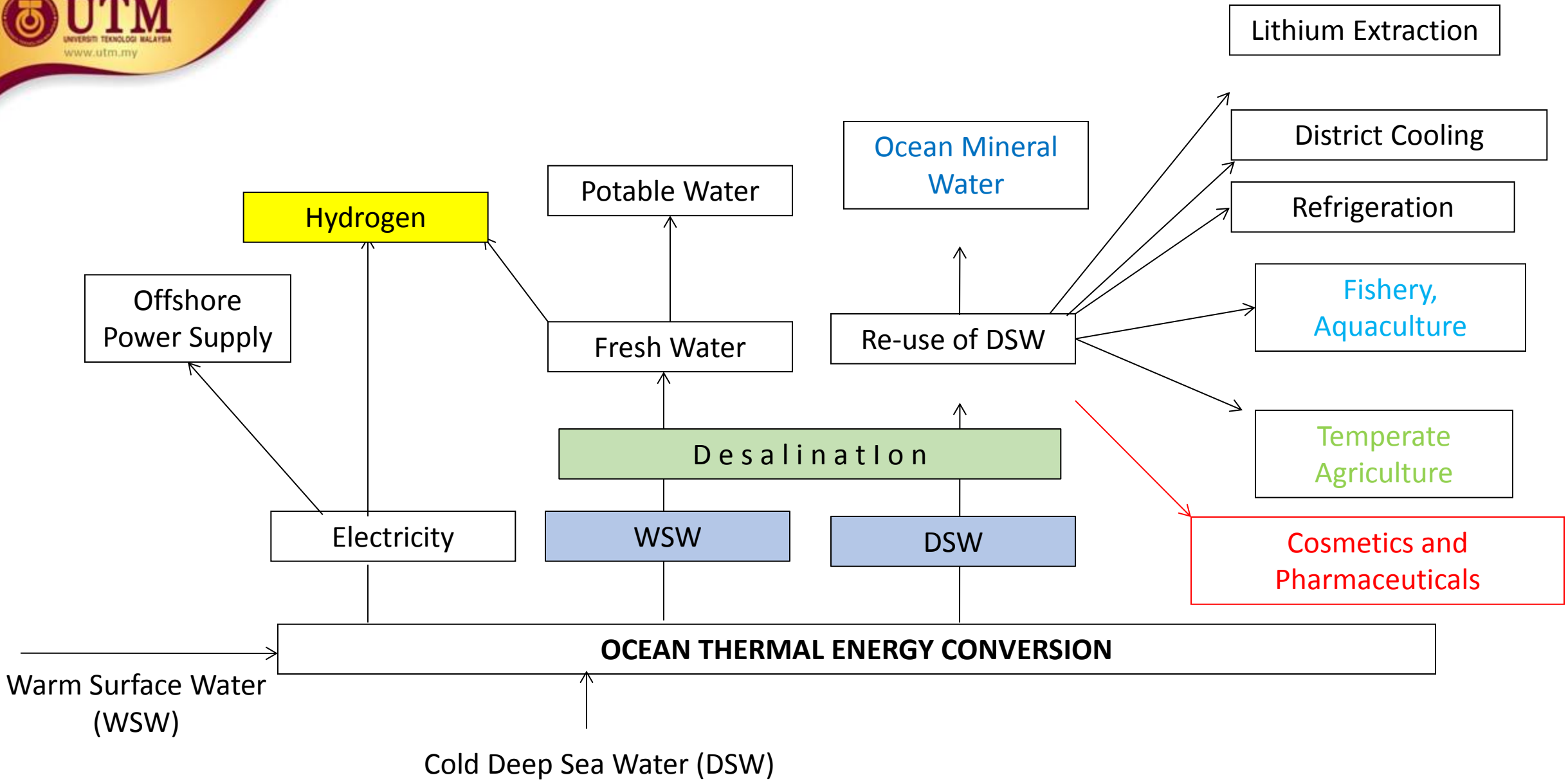
… AN OVERVIEW OF OCEAN ENERGY BY TYPE



Ocean Energy	Input			Capacity factor	Output Cost of Ocean Energy (USD/KWh)
	Generation Capacity (MW)	Capacity Investment (Million USD)	MW/Million USD		
Wave Energy	10	63	0.16	30%	0.56
Tidal Energy	254	298	0.85	20%	0.28
Offshore wind	10	40	0.25	42%	0.17
OTEC	53	451	0.12	95%	0.13
Salinity gradient	200	600	0.33	80%	0.09

kWh: Kilowatt-hour, MW: Megawatt

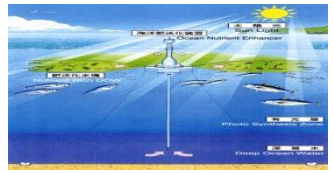
[Data Source: IRENA (2014), ADB Report (2015)]


Lithium Extraction
District Cooling
Refrigeration
Fishery, Aquaculture
Temperate Agriculture
Cosmetics and Pharmaceuticals
Ocean Mineral Water
Potable Water
Hydrogen
Offshore Power Supply
Fresh Water
Re-use of DSW
Desalination
Electricity
WSW
DSW
OCEAN THERMAL ENERGY CONVERSION
Warm Surface Water (WSW)
Cold Deep Sea Water (DSW)

Temperate Produce

"Import Substitutions"

High Value Produce



Capture-Fisheries

Health & Cosmetics

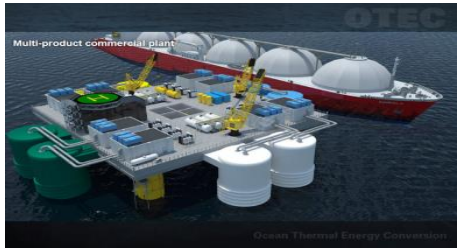
Ms Earth Japan, 2012

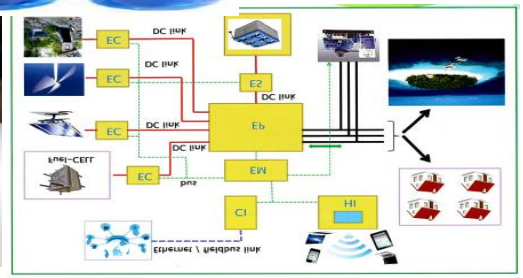
Lithium Production

Picture 5: Lithium extraction facility

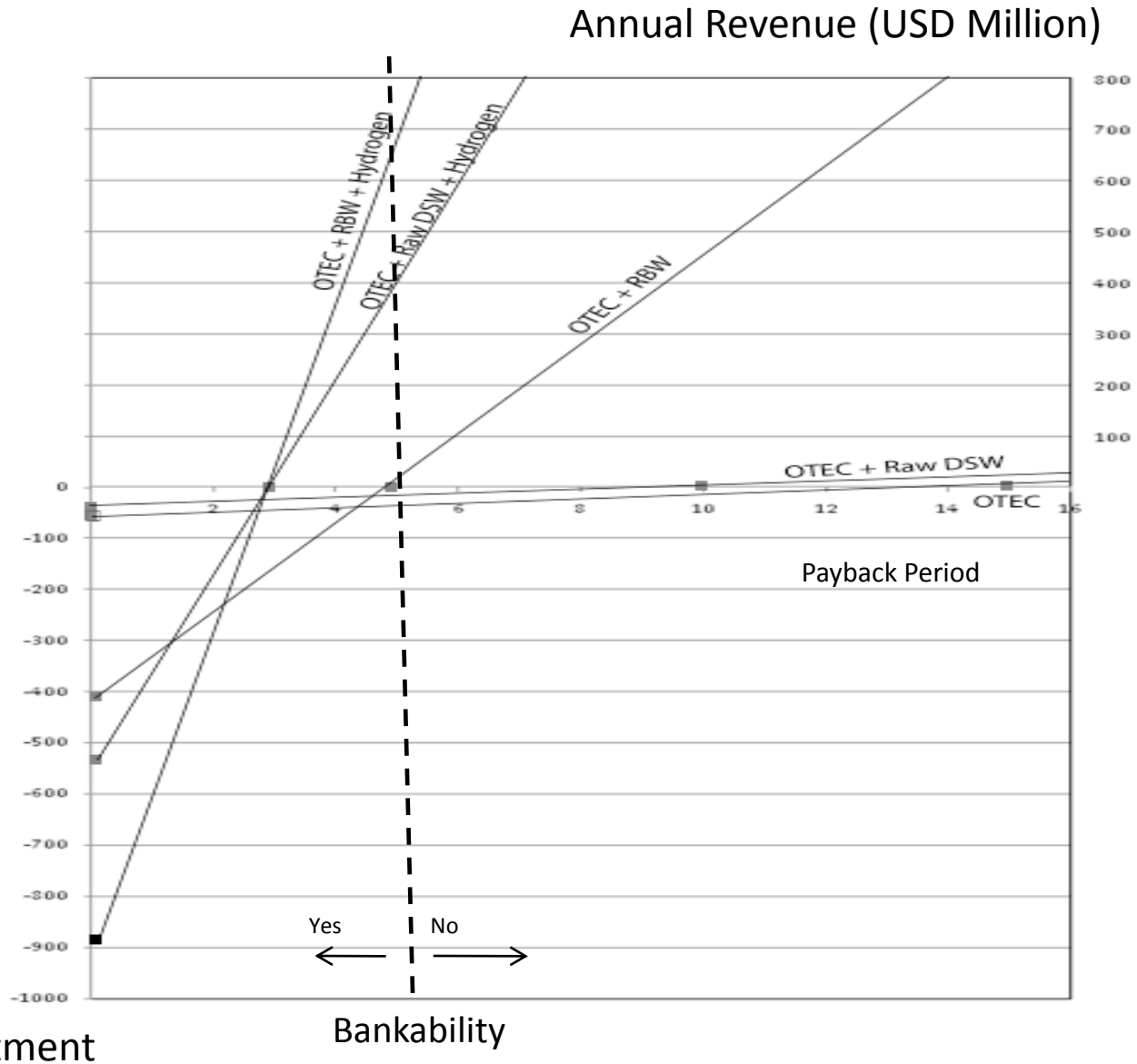
Mineral H20

OTEC-H2





Smart-Grid With All Renewables


Annual Revenue (USD Million)
OTEC + RBW + Hydrogen
OTEC + Raw DSW + Hydrogen
OTEC + RBW
OTEC + Raw DSW
OTEC
Payback Period
Yes
No
Bankability
Capital Investment (USD Million)

Payback Period of Investment in OTEC Project [with and without Spinoff(s)]

Business venture	OTEC Plant (Net MW)	OTEC Plant Investment ($USD/KW)	TOTAL Investment USD	Annual Revenue USD	Payback Period (Year)	Remarks
OTEC	1.35	.41,542	56,081,700.00	7,481,160.00	15	Power Only
OTEC + Raw Water	1.35	41,542	56,234,381.00	11,246,876.20	10	Power + Raw Water (RW)
OTEC+ RBW	1.35	41,542	409,302,900.00	163,721,160.00	5	Raw & Bottled Water (RBW)
OTEC + Raw Water + Hydrogen	1.35	41,542	534,316,081.00	356,210,720.67	3	RW + Production of Liquid Hydrogen
OTEC + RBW + Hydrogen	1.35	41,542	887,384,600.00	591,589,733.33	3	RBW+ Production of Liquid Hydrogen

[Data Source :A Detailed Cost Analysis for Starting a Water Bottling Plant; Fauziah SH, 2014; Ryzin et al., 2014

Case I: Payback Period of Investment in OTEC Project ONLY for Power Supply

Capacity of 1 MW = 1000 kW

Power/year = 1000 kW x 8760 (hours/year)

Annual Revenue = 8.76 m kWh x (USD 0.10/kWh) = USD 0.876 million

Payback period = 2 [(Capital/Annual Revenue)] years

= 2[USD (43.8 m/0.876 m)]

= 100 years

Bankability? = 5-10 years

Case II: Payback Period of Investment in OTEC Project for Raw Deep Sea Water (RDSW) Supply

Capacity of 1 MW of OTEC producing 2.5 m^3/s:

Volume, V = 2.5 x 3600 x 8760 m^3/yr = 78.84 million $m^3/year$

Annual Revenue = (V/year) x (Tariff)

= 78. 84 million (m^3/yr) x USD (0.25/m^3)

= USD 19.71 million

Payback period = 2 [(Capital/Annual Revenue)] years

= 2[USD (43.8 m/19.71 m)]

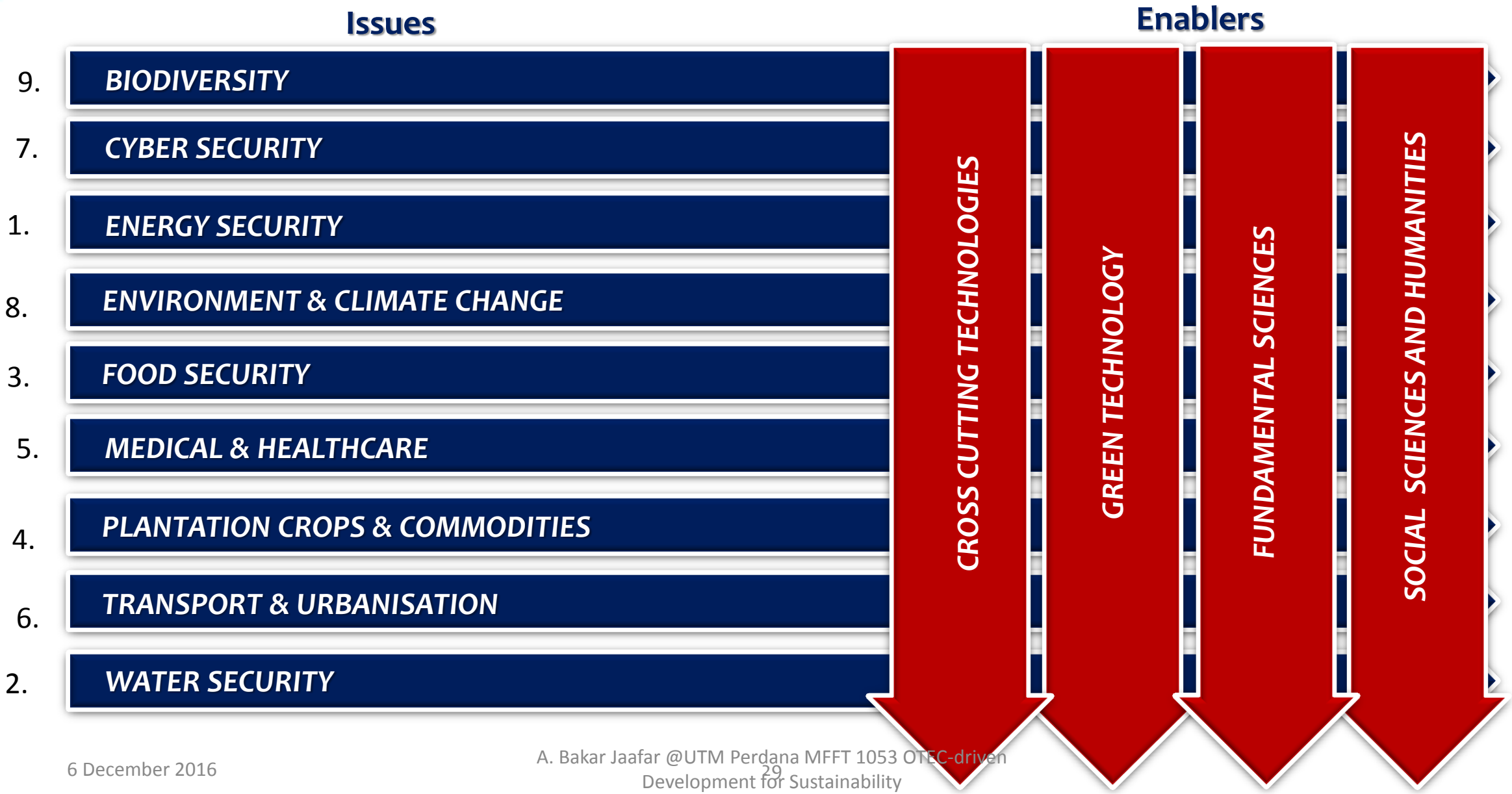
= 4.4 years

Bankability? < 5 years => YES

7. BENEFITS TO THE COUNTRY

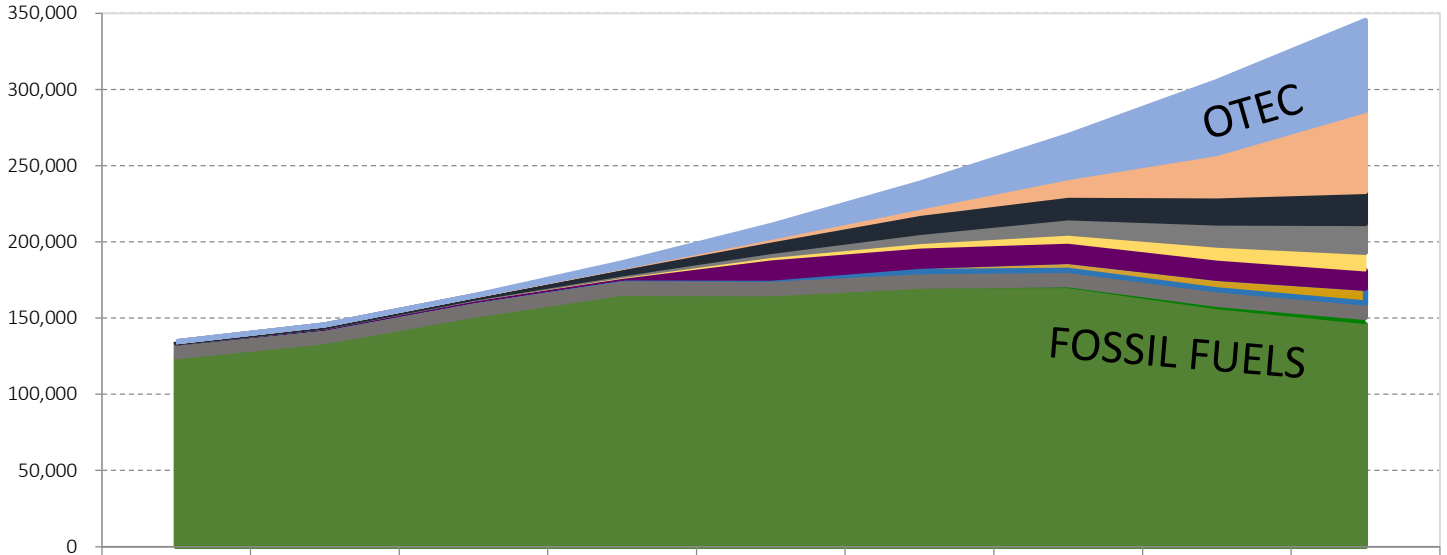
- **SECURITY [ENERGY, WATER, FOOD, CYBER],**
- **BIODIVERSITY, CLIMATE CHANGE, THE ENVIRONMENT *ETC***
- **MEDICAL & HEALTH CARE**
- **TRANSPORTATION & URBANISATION**
- **COMMODITIES**

IMPACTFUL FOCUS AREAS



8. THE WAY FORWARD FOR MALAYSIA

Malaysia: Projected Electricity Generation by Energy Source (GWh) 2012-2050



	2012	2015	2020	2025	2030	2035	2040	2045	2050
OTEC	0	0	134	2,848	7,884	15,768	27,594	47,304	59,129
Fuel Cell	0	0	16	354	1,665	4,054	11,603	27,782	53,194
Bioenergy	809	1,455	1,567	4,088	7,553	12,535	14,832	17,823	21,049
Wind Energy	0	0	547	1,095	2,601	5,913	10,052	14,520	18,922
Solar PV	7	437	790	1,579	2,631	3,999	6,314	9,502	11,913
Nuclear	0	0	0	0	12,264	12,264	12,264	12,264	11,650
Wave/ Tidal/ Current	0	0	219	548	751	3,548	5,868	7,603	9,662
Hydropower	9,056	9,084	9,531	9,531	9,531	9,531	9,531	9,531	9,531
Geothermal	0	0	216	382	531	1,264	2,122	3,174	4,318
Fossil Fuel	124,596	134,571	151,656	165,891	165,388	169,623	169,661	155,798	146,047
Total	134,468	145,547	164,675	186,316	210,800	238,500	269,841	305,300	345,417

Source:
ASM TF CFE

Thank You Merci Gracias спасибо 谢谢 شكر
TERIMA KASIH

OCEAN THERMAL ENERGY CENTRE

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- IRENA (2014), Wave Energy Technology Brief, IRENA Ocean Energy Technology Brief 4.
- IRENA (2014), Tidal Energy Technology Brief, IRENA Ocean Energy Technology Brief 3.
- IRENA (2014), Salinity Gradient Energy Technology Brief, IRENA Ocean Energy Technology Brief 2.
- IRENA WORKING PAPER (2012), Renewable Energy Technologies: Cost analysis series, Vol 1: Power Sector

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A Bakar Jaafar (1976):"Applicability of Solar Energy Technology for Industrial Pollution Control and Production: the Case of the Primary Copper Smelting Industry." Master of Environmental Science Internship Report. Miami University, Ohio. June 1976. p. 82.

A Bakar Jaafar (2009): Utusan Malaysia estidotmy, Oktober: 10-11

A Bakar Jaafar (2010). "Exploiting Ocean Thermal Energy Differential as Renewable Energy Source," MIMA Bulletin 17 (3):35-36.

A Bakar Jaafar (2012). "Harnessing Ocean Energy from Temperature Differentials of the Water Depth off the Sabah Trough, Malaysia," MIMA Bulletin 19(1):24-26.

A Bakar Jaafar (2012). "Conversion of Ocean Thermal Energy to Electric Power and Hydrogen Fuel, The University of Newcastle Newsletter, May Issue 20, page 3.

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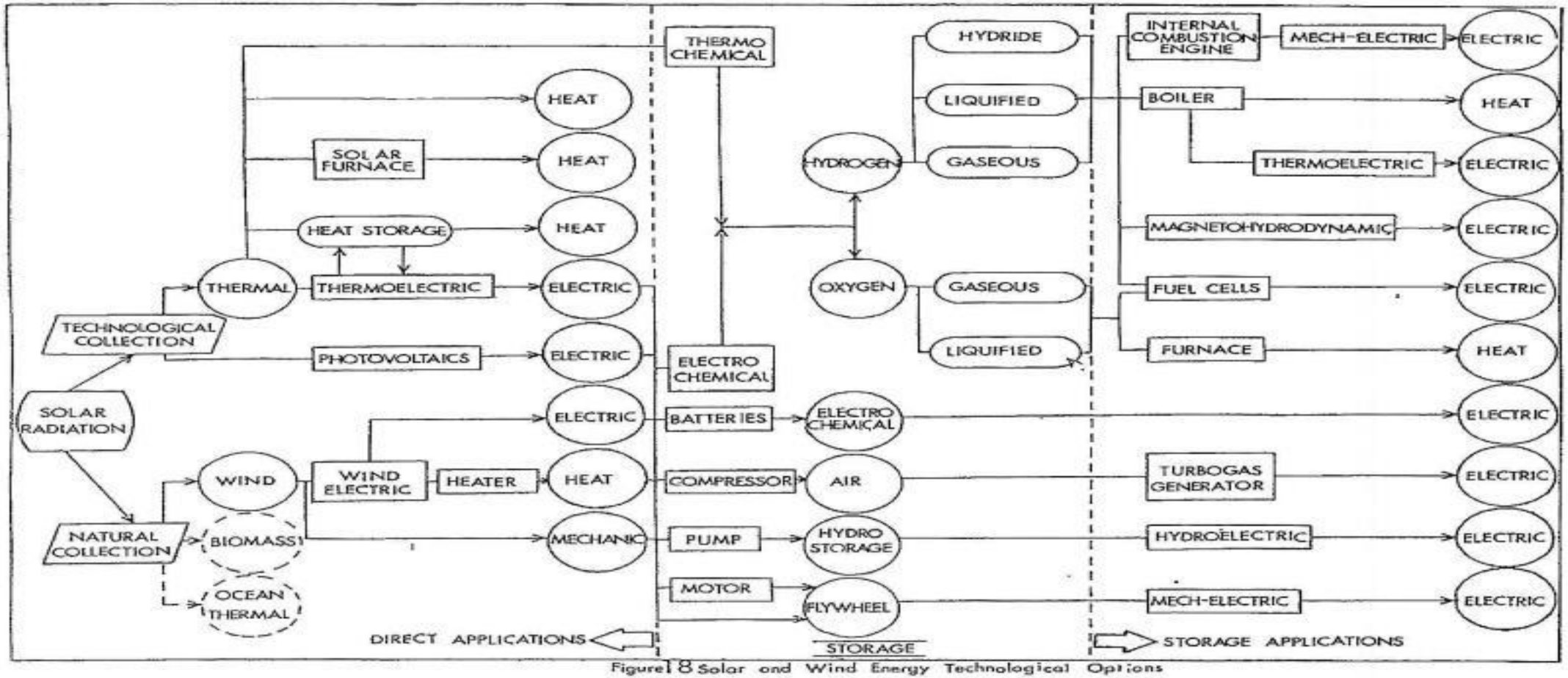
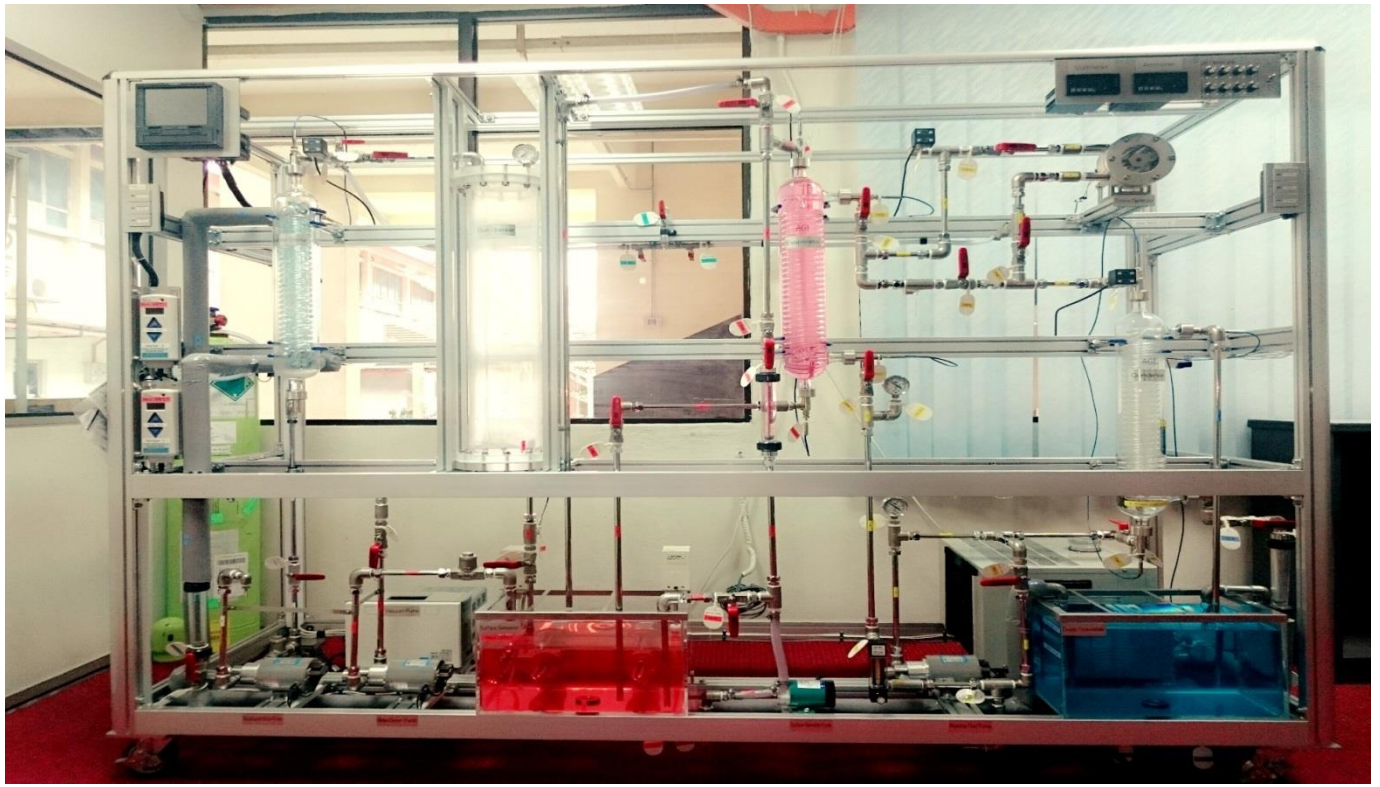


Figure 18 Solar and Wind Energy Technological Options

[Ref: Abu Bakar Jaafar (1976). "Applicability of Solar Energy Technology for Industrial Pollution Control and Production: The Case of the Primary Copper Smelting Industry". An Internship Report. Submitted to the Faculty of Miami University in par tial fulfillment of the requirements for the degree of Master of Environmental Science Institute of Environmental Sciences. Oxford, Ohio. P.82]

3W Micro-OTEC @UTM OTEC Block Q Commissioned on 22 May 2015



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