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Chapter

Research and Development Activities of Ocean Thermal Energy-Driven Development in Malaysia

A. Bakar Jaafar, Mohd Khairi Abu Husain and Azrin Ariffin

Abstract

The search for potential investors in the conversion of ocean thermal energy to power or hydrogen, and its spinoff projects in Malaysia and the region, continues. In the meantime, several pre-feasibility studies have been completed for selected sites, including that of Pulau Layang-Layang and Pulau Kalumpang (Sabah, Malaysia); Timor-Leste, and off Pulau Weh (Aceh, Indonesia). Various research projects have been completed such as the conversion of solar-thermal to the chilled-water system; the cooling of tropical soils for the culture of temperate crops; the design of offshore structure off the continental slope; hydrogen fuel production and distribution, deep seawater properties to reduce obesity, cholesterol and blood pressure; and the legal-institutional framework for the development of ocean thermal energy conversion. UTM Ocean Thermal Energy Centre (UTM OTEC) has entered into the Collaborative Research Agreement with the Institute of Ocean Energy of Saga University (Japan) to undertake joint research for the development of an experimental rig that introduces a hybrid system with stainless steel heat exchanger. Other aspects of this joint research would include a new design for 3 kW turbine, the introduction of nano-working fluids, the eDNA of intake waters, and improved productivity in the culture of high-value marine produce and products.

Keywords: renewable energy, ocean thermal energy, OTEC, Malaysia, sustainable development

1. Introduction

1.1 Establishment of UTM Ocean Thermal Energy Centre (UTM OTEC)

UTM OTEC was established on 3 January 2013, and Emeritus Prof Dr. Md Nor Musa was its first Director, and now, the Director is Prof Dato' Ir Dr. A. Bakar Jaafar, FASc. The main purpose of this Centre is as much to promote investment in the commercialisation of the ocean thermal energy conversion technology, as to undertake its further development, research, innovation, and entrepreneurship.

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1.2 Founding co-chair/director

Prof Dato'Ir Dr. A. Bakar joined Universiti Teknologi Malaysia, first joined the university as a Visiting Professor, UTM Perdana School of Science, Technology, and Innovation on 1 June 2012, and later, became a full Professor on 1 August 2013. Prior to this, he was nominated and elected as one of the 21 Members of the UNCLOS Commission on the Limits of Continental Shelf [https://www.un.org/Depts/los/clcs_new/commission_members.htm#Members] over the three 5-year terms: 1997–2002, 2002–2007, and 2007–2012. He also served as an Adviser to the National Continental Shelf Committee, Secretariat to the National Security Council, Malaysia over that period, and responsible inter alia the Malaysian Marine Survey in the southern part of the South China Sea (2006–2008) (MyMRS).

1.3 Malaysian Marine Survey (MyMRS)

One of the consequential findings of the Survey was the temperature profiling of the deep waters of the States of Sabah and Sarawak, where the temperature drops at the surface from 27° to 4°C at a depth greater than 1200 m. Thus, Malaysia has since established its potential to extract the heat from the waters and convert it into power by deploying the fast emerging and most impactful ocean thermal energy conversion technology [https://issuu.com/asmpub/docs/eset_study_report, pages 92–93].

2. Science and technology research partnership for sustainable development (SATREPS)

The latest development is that, through the Centre, UTM has entered into Agreement with Saga University on 27 March 2019 to undertake joint 'Development of Advanced Ocean Thermal Energy Conversion Technology for Low Carbon Society and Sustainable Energy System: First Experimental OTEC Plant in Malaysia' under the JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS) Programme (https://www.jst.go.jp/global/english/about.html) over the five-year period, 2019–2024. This Project is led by UTM Ocean Thermal Energy Centre (UTM OTEC) under the leadership of its Director and supported by 10 sub-project leaders from five universities: Universiti Kebangsaan Malaysia (UKM), University of Malaya (UM), Universiti Malaysia Terengganu (UMT), Universiti Putra Malaysia (UPM), and Universiti Teknologi Malaysia (UTM) [http://utm.my/satreps].

3. UTM Ocean Thermal Energy Centre (UTM OTEC) activities

3.1 Pre-2013

The idea of 'ocean thermal energy' was cited by the founder in his internship report (**Figure 1**) as part and parcel of fulfilling an academic requirement of Master degree in Environmental Science, Miami University, Oxford, Ohio, USA in June 1976.

In 1981, he took up a course in 'Marine Resources' at the University of Hawaii at Manoa, by which a lecture on 'ocean thermal energy conversion' was given by the late Prof Dr. John P. Craven [https://en.wikipedia.org/wiki/John_P._Craven]. During the period 2006–2008, as part and parcel of the Malaysian Marine Survey of the southern part of the South China Sea (MyMRS), the temperature profiling of the water column in the Northwest Trough or rather Sabah Trough has been

established (**Figure 2**) where the temperature drops to 4°C at a depth beyond 1200 m, and thus, Malaysia has indeed the potential of harnessing its ocean thermal energy resources in its deep waters, deeper than 700 m or more (**Figure 3**).

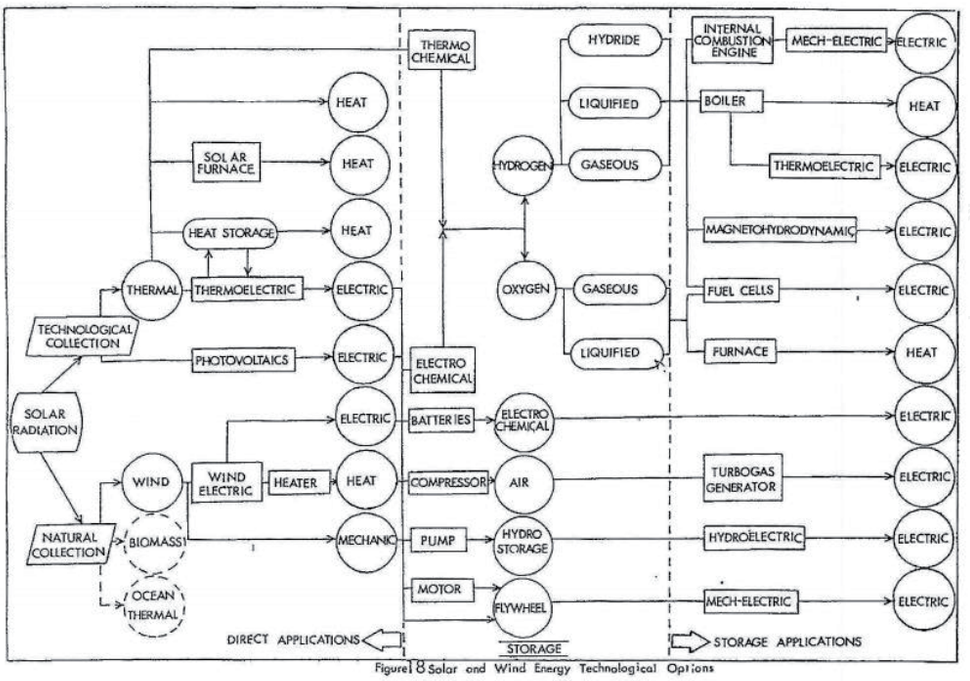
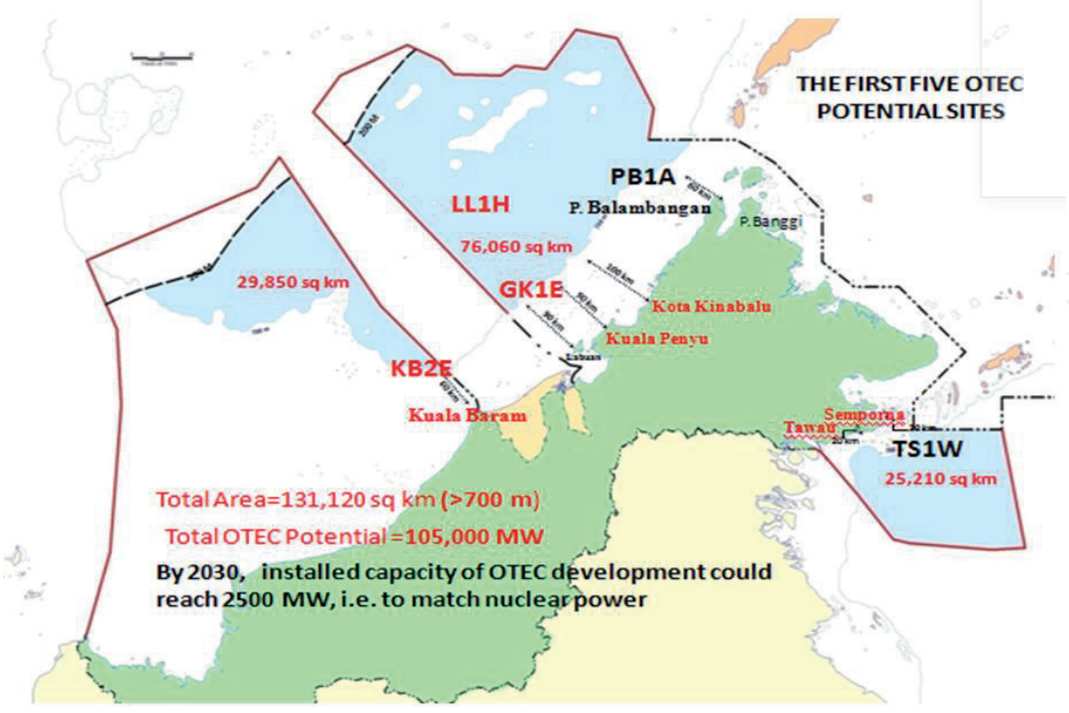


Figure 8 Solar and Wind Energy Technological Options

[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]

Figure 1.
Solar thermal, wind, ocean thermal energy conversions to hydrogen and other energy carriers.



Source : Tan Ah Bah (JUPEM) & A Bakar Jaafar (MIMA & UTM Ocean Thermal Energy Centre)

Figure 2.
Malaysia: ocean thermal energy resource potential in waters deeper than 700 m. Note: the estimation of OTEC potential energy conversion is 800 kw/km², as recommended by Begamudre [1]. The potential harnessing area is evaluated based on the site of a minimum 700 m water depth. Total OTEC Potential = OTEC Potential Energy Conversion (P) x Potential Harnessing Area (A).

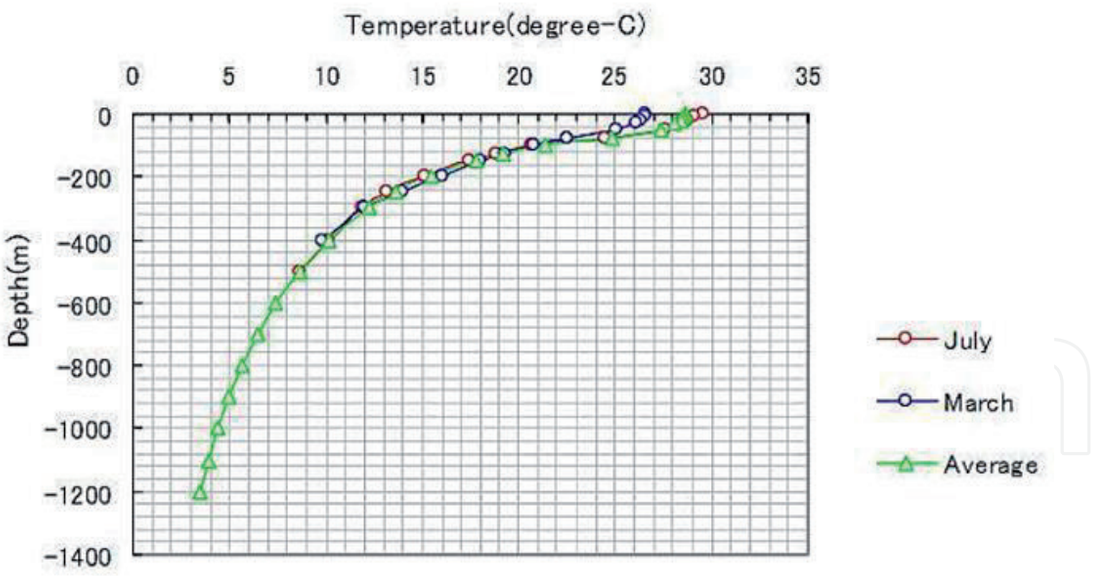


Figure 3.
Variation of seawater temperature with depth at Sabah Trough.

Since then this potential has been promoted among a number of key government agencies (including National Committee on Continental Shelf of the Secretariat of the National Security Council (MKN); Ministry of Science, Technology, and Innovation (MOSTI); Ministry of Energy, Green Technology, and Water (KeTTHA); Maritime Institute of Malaysia (MIMA); Malaysian Industry-Government Group for High Technology (MIGHT); Malaysia's Performance Management and Delivery Unit (PEMANDU); Minister for the Economic Planning Unit, Prime Minister's Department; Academy Science Malaysia-Clean Energy Panel; Malaysian Institute of Economic Research (MIER); Office of the Science Advisor, Prime Minister's Department, Malaysia; Ministry of Entrepreneur Development), potential investors (such as UTM Holdings SdnBhd; Chemicals Company of Malaysia Bhd (CCMB); PASDEC Holdings Bhd; PETRONAS; Lobsters Aquatech Sdn Bhd; FELDA Investment Corporation; Maser Marine Sdn Bhd; Lembaga Tabung Angkatan Tentera (LTAT); Arab Construction Corp (ACC); FELCRA; ANGKASA; APEX; Sabah Economic Development and Investment Authority (SEDIA); Technip Malaysia; FIDES Advisory; Affin-Hwang Capital; MCD Venture Holdings; Brunei Darussalam Economic Development Board; Chiyoda Malaysia; MOFAZ; Master Pack Bhd; Infrakomas Sdn Bhd; Sabah Rural Development Corporation; Black Pearl Energy Sdn Bhd; Prisma Simfoni Sdn Bhd), and other stakeholders (**Figure 4**) and presented at numerous fora, seminars, workshops, conferences, and symposia (i.e. Centre for the Environment, Technology, and Development, Malaysia; UPM Conference on Climate Change; UM 2nd South China Sea Conference; UUM ICOIS 2013: The first International Conference On Innovation and Sustainability; MOSTI: 1st Ocean Renewable Energy Symposium; 1st (Honolulu), 2nd (Goseong), 3rd (Kuala Lumpur), 4th (Amsterdam), 5th (La Reunion), 6th (Okinawa) International OTEC Symposia; MICCI-28th CACCI Conference; EC 6th National Energy Forum; IEM-IET Conference; EUMCCI).

On 3 January 2013, Universiti Teknologi Malaysia (UTM) established its UTM Ocean Thermal Energy Centre (UTM OTEC). The main purpose of this Centre is as much to promote and commercialise (C) the emerging ocean thermal energy conversion (OTEC) technology as to carry out further development (D) and research (R) (CDR Approach).

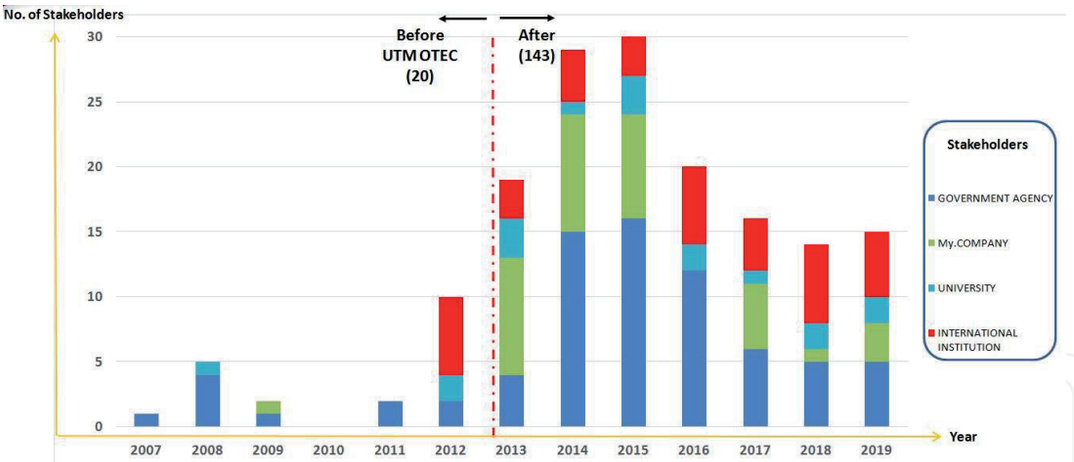


Figure 4.
Malaysia, Ocean Thermal Energy-Driven Development: growth in activities relating to OTEC Policy Advocacy and Promotions of Investment (2007–2019) as on 23 August 2019.

Prior to this, arising from the IOC-WESTPAC Workshop on Marine Renewable Energy held in Melaka, Malaysia on 17 February 2012, a close contact has been made between Prof Dr. Yasuyuki Ikegami, Director, the Institute of Ocean Energy of Saga University, Vice-Admiral (R) Shin Tani, former Chief of Hydrography of Japan, and Prof Dato' Ir Dr. A. Bakar Jaafar, Visiting Fellow of the Maritime Institute of Malaysia (MIMA).

Presentations on OTEC Malaysia at the Secretariat of the Headquarters for Ocean Policy (SHOP), Cabinet Secretariat, the Government of Japan; and to Prof Dr. Tetsuro Urabe's graduate students at the University of Tokyo, and series of Briefings on the Institute of Ocean Energy of Saga University @Imari Plant, and Okinawa Prefectural Deep Sea Water Research Center, Mayor Office of Kumejima, Bade Haus Spa, Point Pyuru Cosmetics, Kumejima Kaiyoushinsousui Kaihatu Co Ltd., Yumairu Museum, Xenesys, Inc., and New Energy and Industrial Technology Development Organisation (NEDO), and not last, Meeting with Mr. Nagamine, Director-General, and Ms. Kato, Director of Ocean Division, International Legal Affairs Bureau, Ministry of Foreign Affairs, Japan.

Upon a successful visit to Japan for various discussions and presentations on OTEC potential and future developments in Malaysia (i.e. at the Secretariat of the Headquarters for Ocean Policy (SHOP), Cabinet Secretariat, the Government of Japan; and to Prof Dr. Tetsuro Urabe's graduate students at the University of Tokyo, and series of Briefings on the Institute of Ocean Energy of Saga University @Imari Plant, and Okinawa Prefectural Deep Sea Water Research Center, Mayor Office of Kumejima, Bade Haus Spa, Point Pyuru Cosmetics, Kumejima Kaiyoushinsousui Kaihatu Co Ltd., Yumairu Museum, Xenesys, Inc., and New Energy and Industrial Technology Development Organisation (NEDO), and not last, Meeting with Mr. Nagamine, Director-General, and Ms. Kato, Director of Ocean Division, International Legal Affairs Bureau, Ministry of Foreign Affairs, Japan), upon the official invitation of the Secretariat of the Headquarters for Ocean Policy (SHOP), Cabinet Secretariat, the Government of Japan, over the period of 1–7 July 2012, Prof Dato' Ir Dr. A. Bakar Jaafar, after having joined the Universiti Teknologi Malaysia, as a Visiting Professor at the UTM Perdana School of Science, Technology, Innovation, and Policy, convened on 10 July 2012 a Workshop on Ocean Thermal Energy Conversion (OTEC) attended by over 15 UTM Academic and Administrative Staff. The Workshop put up a strong recommendation that UTM ought to establish its programme relating to OTEC.

Prior to this, on 24 April 2012, in Mansassas, Virginia, USA, Prof Dato' Ir Dr. A. Bakar Jaafar accompanied Mr. Arham Abdul Rahman, Director of MIDA, New York met Mr. Jeremy Feakinsof Chairman of The Board at Ocean Thermal Energy Corporation, and his senior Officials. The former managed to have made an appointment for Mr. Feakins and his technical advisor, Dr. Ted Johnson to meet up with YAB Prime Minister of Malaysia, Dato' Seri Mohd Najib Tun Abdul Razak, on 16 May 2012 at Mandarin Oriental Hotel, Mid-Manhattan New York. The Corporation was interested to invest in an OTEC Project in Malaysia but wanted to know what would be the amount of royalty payment to be imposed and the relevant laws applicable. As an outcome, a Cabinet paper was drafted by MIMA after having successfully conducted an Inter-Agency Stakeholders Consultation Workshop on 10 May 2012, and presented it to an ad-hoc Inter Agency Steering Committee Meeting on 20 June 2012, and to the Minister of Transport since then.

3.2 Post-2013 activities

While continuing its promotion for investment in OTEC, UTM Ocean Thermal Energy Centre managed to secure a number of research and study grants, including the following:

i. UTM-PDRU of MYR 65,000.00 [23 February 2015–2022 February 2016]: "Techno-Economic Analyses of OTEC-RELATED Industries" [2].

ii. UTM-GUP of MYR 49,650.00 [1 May 2015–2026 January 2017]: "Solar Thermal Chilled Water Systems for Temperate Agriculture" [3].

iii. UTM-FRGS of MYR 71,000.00 [2 November 2015–1 December 2017]: "The Regulatory Framework on the Implementation of Ocean Thermal Energy-Driven Development within Malaysian Waters" [4].

iv. UTM-OTEC & DCNS-Naval Energies Pre-Feasibility Studies of OTEC Project off Pulau Layang-Layang under the Ministry of Defence, Defence Industry and Ministry of Finance, Technology Development Agency (TDA) Offset Programme 2016–2017 [5];

v. UTM-SF of MYR 274,300.00 [1 May 2015–2031 July 2017]**:** "Integration of Rankine Power and Absorption Refrigeration Cycles for Low Load Optimized Solar Thermal Chilled Water Soil Cooling System" [6].

vi. UTM-PDRU of MYR 75,350.00 [1 July 2017–2030 June 2018]: "DNA Barcoding for Marine's Flora and Fauna Keystone Species in Pulau Layang-Layang Sabah" [7].

vii. UTM-JASTIP of JPY300,000.00 [16 October 2017–2030 September 2018]: "Conceptual Design of Fixed Ocean Thermal Energy Conversion Offshore Power Plant". This is a joint research collaboration between Universiti Teknologi Malaysia and Saga University (Japan) funded by the Japan-ASEAN Science, Technology and Innovation Platform (JASTIP-Net 2017). The outcome has been presented at the 5th JASTIP Symposium, Kuala Lumpur, Malaysia.

viii. UTM-Infrakomas Sdn Bhd Joint Pre-Feasibility Studies of OTEC Project off PulauWeh, Aceh, Indonesia of MYR 322,195.80 [1 April 2017–2031 March 2018 extended to 31 December 2019]. This is a University-Industry collaboration

program which provided the financial support to Mohammad Shafiq Rahmat, contract Research Officer, who continued his PhD programme on eDNA of Deep Waters under the supervision of DrSuriyanti Su Nyun Pau, former Post-Doctoral Fellow, Senior Lecturer of Universiti Kebangsaan Malaysia (UKM).

ix. UTM-GUP of MYR 50,000.00 [1 February 2018–2031 January 2020]: "Conceptual Design of Fixed Ocean Thermal Energy Conversion (OTEC) Offshore Power Plant in Malaysia". This project is a University-Industry collaboration research programme, namely, between Universiti Teknologi Malaysia, Sarawak SHELL Berhad, and Technip FMC Malaysia Sdn Bhd. The primary outcome from this programme is an operable design of the first fixed offshore OTEC pilot power plant consist of single-legged structure and dual-level production decks. This initiative allows OTEC technology becomes more viable by massive reduction of the capital expenditure (CAPEX) of OTEC facility compared to the current OTEC Floating plant.

x. UTM-LRGS&SATREPS-OTEC Project of MYR 6,000,000 under the Ministry of Education of Malaysia + USD4,000,000 in kind from Japan Science and Technology Agency (JST) for the period 1 July 2019–2030 June 2024: "Development of Advanced Ocean Thermal Energy Conversion Technology for Low Carbon Society and Sustainable Energy System: First Experimental OTEC Plant in Malaysia".

3.3 Annual workshops

The UTM Ocean Thermal Energy Centre has been organising its annual or special workshops in 2016 [8], 2017 [9], and 2018 (**Figure 5**) as part and parcel of its objectives as much to promote the subject of 'ocean thermal energy' as to explore further opportunities for research and investment. A special workshop [10] on ocean energy was held in December 2017, jointly with the EU-Malaysia Chamber of Commerce and Industry.

3.4 3rd International OTEC Symposium (IOSKL2015)

The UTM Ocean Thermal Energy Centre convened the 3rd International OTEC Symposium [11] at UTM Kuala Lumpur Campus on 1–2 September 2015.The

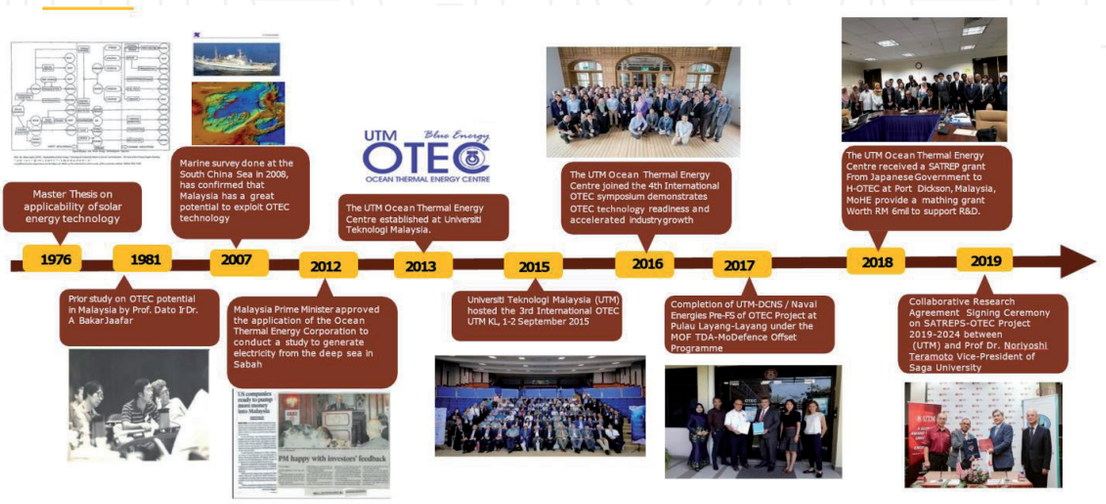


Figure 5.
UTM Ocean Thermal Energy Centre: key activities prior to and post 2013.

3rd IOSKL2015 saw 200 OTEC experts, speakers, and participants from all over the world including France, Indonesia, Japan, Korea, Netherlands, Philippines, Singapore, Sudan, Sweden, USA and Malaysia. There were 15 topical presentations at plenary, two videos, and 20 paper presentations during two parallel workshop sessions. All contributions have provided an up-to-date knowledge sharing among the researchers and set the direction to the OTEC community for future research and development including commercialization.

3.5 International exchange of young researchers

The Institute of Ocean Energy (IOES), Saga University, Japan has been sponsoring two young researchers below 35 of age from UTM OTEC to participate at the Annual Program of International Platform on Ocean Energy for Young Researcher since 2015. The researchers of UTM OTEC who had participated were as follows: Nor Amyra Hana Mohd Yusoff and Mohd Alshafiq Tambi Chik (1st Program 2015), Nur Hidayah Nong Nazari and Samihah Zura Mohd Nani (2nd Program 2016), Mohd Khairi Abu Husain and Nurul Syazwani Mohd Sabri (3rd Program 2017), Suriyanti Su Nyun Pau and Nurul Azizah Mukhlas (4th Program 2017), and Mohammad Shafiq Rahmat and Meng Soon Chiong (5th Program 2018). Among them, Nurul Syazwani has won the Best Presentation Award at the 3rd Program of International Platform on Ocean Energy for Young Researcher in 2017.

3.6 JST-MoE SATREPS project (2019–2024)

On 2 July 2019, at Dewan Seminar UTM KL, Universiti Teknologi Malaysia (UTM) and Saga University of Japan entered into the Collaborative Research Agreement (CRA) on the Development of Advanced Ocean Thermal Energy Conversion Technology for Low Carbon Society and Sustainable Energy System: First Experimental OTEC Plant in Malaysia. This Agreement would essentially cover the provisions of an experimental rig that allows for the running and testing of stainless-steel evaporator with warm sea-surface water that has gone through flash distillation chamber in order to eliminate totally the problems of biofouling of the said heat-exchanger; introduction of various designs of 3 kW turbo-generator that would run on ammonia and other alternative working fluids, including nano-fluids (ORC system with different combination of nanoparticle infused liquid (nano-liquid) as the working medium), plant operational performance analysis, techno-economic analysis, the generation of chilled-water system in improving the culture of high value fish and other marine products, including seaweeds, the like of umi-budou. The quality of surface and deep waters would also be characterised, including the determination of its contents of flora and fauna by eDNA technique.

Essentially, there would be a set of 10 sub-projects, under the Development of Advanced Hybrid Ocean Thermal Energy Conversion (OTEC) Technology for Low Carbon Society and Sustainable Energy System: First Experimental OTEC Plant of Malaysia, as follows:

i. Facility: [led by Prof Dato' Ir Dr. A-Bakar Jaafar, FASc of Universiti Teknologi Malaysia];

ii. Operational: [led by Ts. Dr. Sathiabama T. Thirugnana of Universiti Teknologi Malaysia];

iii. Heat Exchanger: [led by Dr. Chiong Meng Soon of Universiti Teknologi Malaysia];

iv. eDNA: [led by Dr. Suriyanti Su Nyun Pau of Universiti Kebangsaan Malaysia];

v. Turbine: [led by Prof Ir Dr. Shuhaimi Mansor of Universiti Teknologi Malaysia];

vi. Seaweed: [led by Prof Dr. Phang Siew Moi, FASc of University of Malaya];

vii. Fish: [led by Prof Dr. Aziz Arshad of Universiti Putra Malaysia];

viii. Sea Water Quality: [led by Prof Dr. Fatimah Md. Yusoff, FASc of Universiti Putra Malaysia];

ix. Nanofluids: [led by Assoc. Prof Dr. Nor Aswadi Che Sidik of Universiti Teknologi Malaysia]; and

x. Business Development: [led by Assoc Prof Dr. Mas Bambang Baroto of Universiti Teknologi Malaysia].

The experimental rig of the said hybrid-OTEC System and related-research would be installed and conducted at the Universiti Putra Malaysia (UPM)-International Institute of Aquaculture and Aquatic Sciences (I-AQUAS), Port Dickson, Negeri Sembilan, Malaysia.

4. Commercialization of ocean thermal energy conversion technology

Prior to and beyond the establishment of UTM Ocean Thermal Energy Centre in 2013, it has been quite a challenge to attract an anchor partner to undertake the development of the first Pioneer Ocean Thermal Energy-Driven Development Project in Malaysia. The first five [12] promising potential sites have been identified and promoted to various parties or stakeholders, including deep-water production of oil & gas operators the like of PETRONAS; FELDA Investment Corporation Sdn Bhd; FELCRA Holdings Sdn Bhd; MoD Defence Industry; and Sabah Economic Development & Investment Authority (SEDIA).

The pre-feasibility study of the first site at Pulau Layang-Layang, conducted jointly between UTM OTEC & DCNS Naval Energies under the MoD Defence Industry-MoF TDA Offset Program was completed on 12 September 2016, and jointly accepted on 27 September 2019 at the 4th International OTEC Symposium, Amsterdam, the Netherlands.

In-house pre-feasibility studies also completed for two other sites: (i) 15 km off Pulau Kalumpang, Tawau-Semporna, Sabah, Malaysia, and (ii) off Pulau Banggi, Kudat, Sabah. It is quite likely the first site would be taken up by a local engineering group at the end of 2019.

A regional investor, based in Singapore, has set up a local company, and is seriously looking into the prospects of supplying OTEC power to the existing and future deep-water production not only in Malaysia, but also in Brunei Darussalam and Indonesia.

The fifth deep water site off Kuala Baram had been offered to the State Government of Sarawak, but the subject has been deferred simply because Sarawak has big surplus of hydro-power. This surplus power would be converted to hydrogen fuel, as the State of Sarawak has embarked toward 'hydrogen economy' by having installed the first hydrogen fuelling station in Kuching on 27 May 2019, and by deploying the first three hydrogen-fuelled buses, and two standard utility vehicles [13].

5. Future prospects

The best strategy for realising the potential of OTEC Technology is as much to convert the excess power into hydrogen fuel as to produce drinkable mineral water from the deep sea off the OTEC Plant condensers. There are other revenue streams that could be developed, the like of Kumejima OTEC Park in Okinawa, Japan, and NELHA Kona OTEC Park in Hawaii, USA, in the production of high value seaweeds, fugu fish, prawns, abalone, and temperate cash-crops. There is no other renewable energy conversion technology that could match OTEC, not even salinity gradient, being the lowest cost of power producer with the least investment per unit power produced, as highlighted in **Figure 6** and **Table 1** of an article [14]:

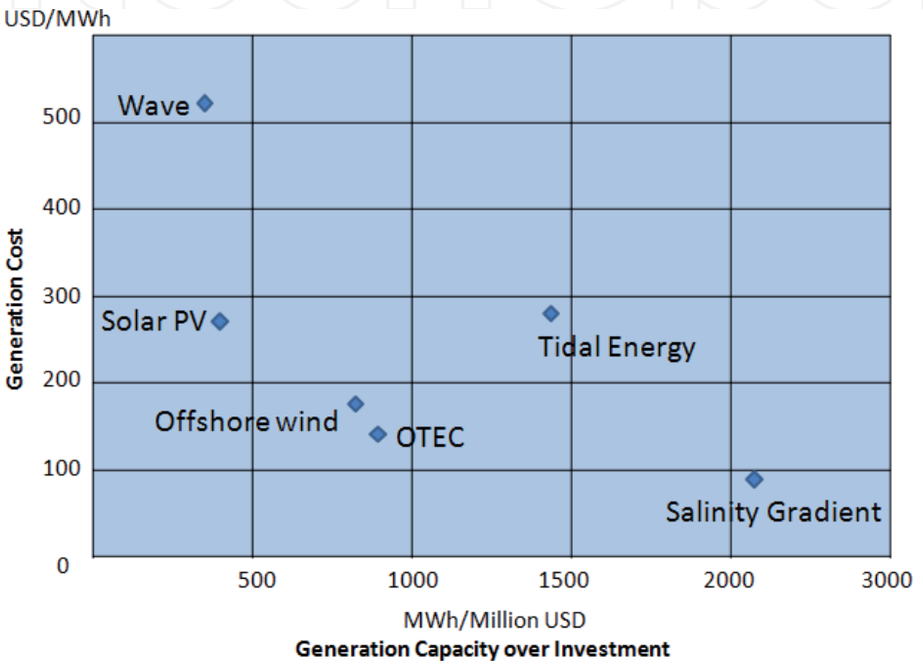


Figure 6.
Comparative analysis of various forms of renewable energy (RE) [14].

Ocean Energy and Solar PV	Input					Capacity factor	Output	
	Generation Capacity (MW)	Annual Power Generation (MWh)year	Capital Investment (Million USD)	Generation Capacity/Capital Investment (MW/Million USD)	Annual Power Generation/Capital Investment (MWh/Million USD)		Cost of Ocean Energy (USD/KWh)	Cost of Ocean Energy (USD/MWh)
Wave Energy	10	24,000	63	0.16	380	30%	0.56	560
Tidal Energy	254	406,400	298	0.85	1363	20%	0.28	280
Offshore wind	10	33,600	40	0.25	840	42%	0.17	170
OTEC	53	402,800	451	0.12	893	95%	0.13	130
Salinity gradient	200	1,280,000	600	0.33	2133	80%	0.09	90
Solar PV	10	16,000	38	0.26	421	20%	0.25	250

kWh: Kilowatt-hour, MW: Megawatt

[Data Source: IRENA (2012, 2014), ADB Report (2015)]

Note: **Table 1** *compares three economic variables that impact feasibility: the capital investment of energy, which is the start-up cost for a project, the net capacity factor, which is the ratio of actual energy output in comparison to full potential of energy generated and the levelized cost of ocean energy (COE), which is the cost to build and operate an energy generation device over its lifetime divided by the total power generated over its lifetime. The ideal energy resource has a low COE and capital cost and a high capacity factor [15].*

Table 1.
Cost of renewable energy generation by capital investment and capacity [14].

Although the amount of capital required for investment in OTEC is high, as shown in **Figure 6**, the generation cost of electricity is the lowest, other than that of salinity gradient, compared to those generated from wave, wind, oceanic current, biomass, tidal current, and solar photovoltaic [16–22]. It is simply because, as outlined in **Table 1**, the capacity factor of OTEC is at least 95%, compared to that of tidal current, only 20%, and where its capital requirement is the lowest per unit of power generated.

OTEC power would become more competitive, than that is stated above, when its total capital investment is spread out across its spinoffs, and that could be covered from the sales of raw deep seawater for mineral water production, marine culture of high value produce, growing of temperate crops. Such OTEC spinoff industries have been well developed.

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This is to thank all former fellows, associates, students and staff who had been part and parcel of UTM Ocean Thermal Energy Centre for their invaluable contributions. This chapter would not have been completed without the continuing support of the current staff, students and fellows. This is also to thank the management of Universiti Teknologi Malaysia, faculty members and staff for their support too.

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