Environmental impacts of utilization of ageing fixed offshore platform for ocean thermal energy conversion

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Abstract – Most Malaysian jacket platforms have outlived their design life. As these old platforms have outlived their design life, other alternatives must be considered. As several offshore oil and gas extraction installations approach the end of their operational life, many options such as decommissioning and the development of a new source of energy such as wind farms are introduced. The objective of this paper is to investigate the environmental impacts of utilising ageing fixed offshore platform as a source for Ocean Thermal Energy Conversion (OTEC). The environmental impact of utilising an ageing fixed offshore platform as an OTEC source is discussed. OTEC produces energy by taking advantage of temperature variations between the ocean surface water and the colder deep water through cold-water intake piping, which requires a seawater depth of 700 metres. The output of this study shows that OTEC is envisioned to preserve marine life, becoming a new and reliable source of energy, assist clean water production, and reduce the negative impact of climate change. OTEC platforms utilising ageing platforms may lead to 44 % of fish catch in the ocean, remove 13 GW of surface ocean heat for every GW of electricity production per year, generate 1.3105 tonnes of hydrogen per year for each GW of electricity generated. In addition, OTEC platforms can reduce approximately 5106 tonnes of carbon dioxide from the environment for 1 GW of electricity generated per year, and supply 2 million litres of water per day for a 1 MW platform. Since Malaysia's seawater profile allows for installing a fixed offshore platform as an OTEC power plant, Malaysia has many potentials to profit from the OTEC process.

Keywords: OTEC; fixed offshore platform; ageing platform; hydrogen energy; clean water.

1. Introduction

Malaysia’s oil and gas industry began in the early 1900s and has evolved over 115 years. Most of jacket platforms in Malaysia have outlived their design life (1-3). In 2014, 65 % of 191 offshore platforms have exceeded their design life (4). These platforms have been subjected to corrosion and fatigue crack failure, leading to failure over time (5). Meanwhile, more than 300 shallow water-fixed oil and gas platforms have been operating for over 20 years in Malaysia, with 48 % surpassing its 25-year design life (6). Since these platforms have exceeded their design life, several options are needed to be reviewed as these old platforms are no longer within their designed life span. As a result, several options such as decommissioning is becoming a global concern as many offshore oil and gas production facilities approach the end of their operating lives (7). The objective of this paper is to investigate the environmental impacts of utilising ageing fixed offshore platform as a source for Ocean Thermal Energy Conversion.

Understanding the environmental impacts of decommissioning and future alternative usage opportunities of these platforms is a priority as the platforms approach the end of their useful lives (8). This study covers the impacts of using available ageing fixed offshore platform as a renewable energy source. The possible future utilisation of these ageing offshore platforms can be reviewed in Figure 1. Edalat and Bagherinia (9) described that the platform could either be decommissioned or be left in place. As shown in Figure 1, several ways to perform decommissioning depend on various needs and requirements. The first option is to perform decommissioning of the structure where two different methods can be performed: partial removal and total removal. Moreover, the isolated location of the platforms with varying depths and weather conditions may impact the complication and cost of the decommissioning process (6). The second option is that the platforms can be left in place where it could serve as an aquaculture facility, instrumentation facilities used for diving, tourism, or LNG terminal, and as an alternative for power generation using wind, wave, current, and solar potential. Therefore, it is up to the operators to choose whichever options are better for their platform.

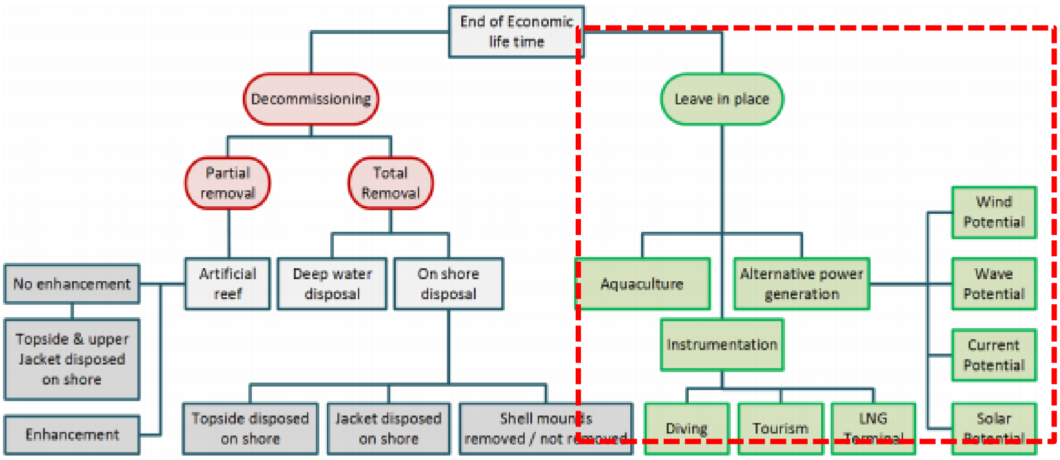

Figure 1. Summary of End of Economic Lifetime for Offshore Platforms
(Source: Edalat and Bagherinia (9))

The modern world primarily relies on fossil fuel supply to meet the global energy demand, yet this source is not environmentally friendly and is rapidly depleting (10, 11). Development of alternative energy sources to substitute the current fossil fuel, such as wind energy, solar, and OTEC, is currently undergoing to minimise the emission of greenhouse gases (9, 12). OTEC has triggered the market of renewable energy as it is a very reliable source of energy and can provide clean water for human interactions (13). Therefore, the utilisation of ageing fixed offshore structures can be considered as these platforms can meet the operational requirements of an OTEC system, which requires both warm surface water and cold deep-sea water.

2. Methodology

This study will be focusing on the environmental impacts of utilising a fixed offshore platform as an OTEC source. Several papers, journals, and reports related to OTEC, fixed offshore platform, and ageing platforms have been collected, reviewed, and analysed in early-stage to investigate the environmental impacts of utilising a fixed offshore platform as an OTEC source. To ensure the quality of the study, a proper framework was developed, as shown in Figure 2, where the impact of the OTEC platform on marine life, climate change, renewable energy, and clean water supply are reviewed thoroughly. These four impacts are the most reviewed and emphasised in previous research and publications related to OTEC in offshore structures.

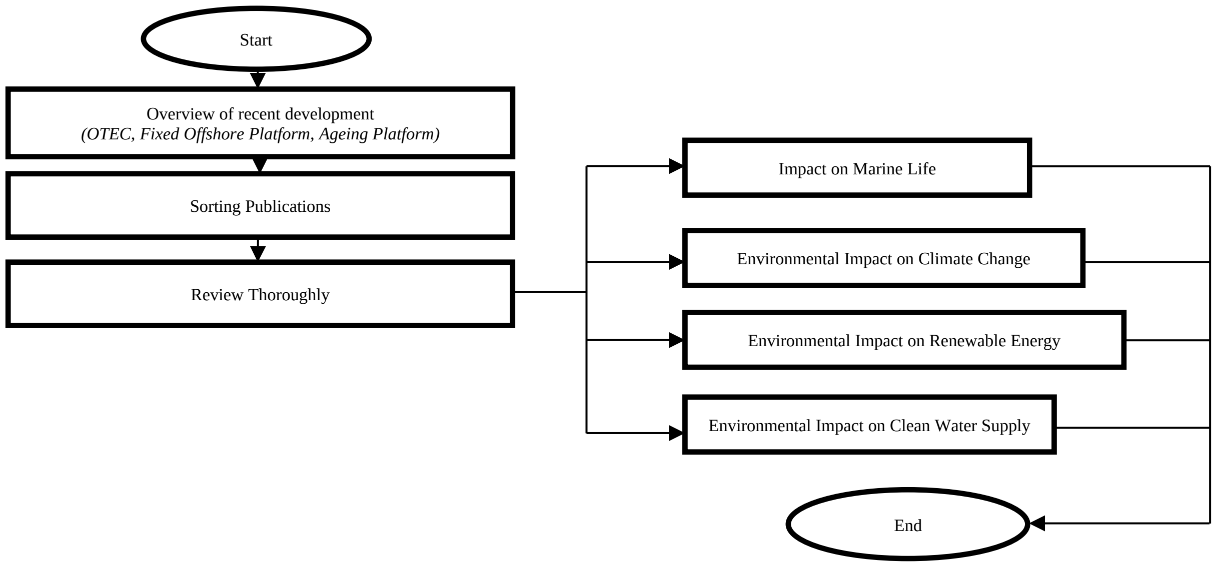

Figure 2. Methodology flowchart used in this review

3.Utilising Fixed Offshore Platform as OTEC Source

3.1 Ageing of Fixed Offshore Platform

Fixed offshore platforms are unique structures built in the sea or ocean and serve to carry industrial equipment for oil and gas production and drilling (14). Until 2020, it is estimated approximately 10,000 offshore platforms have been constructed and installed worldwide (15). According to Zawawi, Liew (6), there are over 300 shallow water-fixed oil and gas platforms in Malaysia which have already served its function for almost 20 years, with 48 % already exceeding their 25-year design life. Referring to the statement, the operators need to ensure that the platforms are safe for future planning. Therefore, realistic requalification methods are used to evaluate life extension opportunities of these structures without sacrificing asset personal safety, integrity, and productivity (4).

Since the fixed offshore platforms have reached their design life, there is a need for the operator to propose alternative usage of the platforms. As stated in Figure 3, the ending of the economic lifetime of a designed platform by decommissioning includes the secure plugging of the void in the earth's crust as well as the removal of offshore oil production equipment. Decommissioning is an increasingly growing consumer segment in the petroleum industry, with significant potential and significant risks. It is a substantial source of risk for municipalities, owners, vendors, and the public, and it must be recognised to be cost-effectively handled (9).

The selection model strategy at the end of the design lifetime is shown in Figure 3. For a fixed offshore platform to undergo either decommissioning or be left in place, various considerations are required to ensure that the platform can still be used in the future, either for aquaculture, instrumentation, or alternative power generation. The considerations must include the overall cost of the process and the platform's potential to be used for alternative applications to ensure that the extended usage of the platform is worth it and safe to be used (9).

The whole idea of the end life of an ageing fixed offshore platform is explained further in Figure 4.

In total removal decommissioning, all parts of the structure are disposed of either onshore or deep water. The facilities are then brought to land to be disposed. Meanwhile, another decommissioning option is to perform partial removal where the leftover of the structure is left inside the deep water to act as an artificial reef for marine life, either by leaving it in place, topping, or horizontal reefing (16). However, decommissioning requires consideration of various challenges such as conservation of marine lives, direct physical disturbance, dispersal of contaminants, and energy consumptions and carbon footprints (16). Therefore, another option of utilising the ageing fixed offshore platform is introduced, such as generating a new source of energy such as wind farms, OTEC, and solar power.

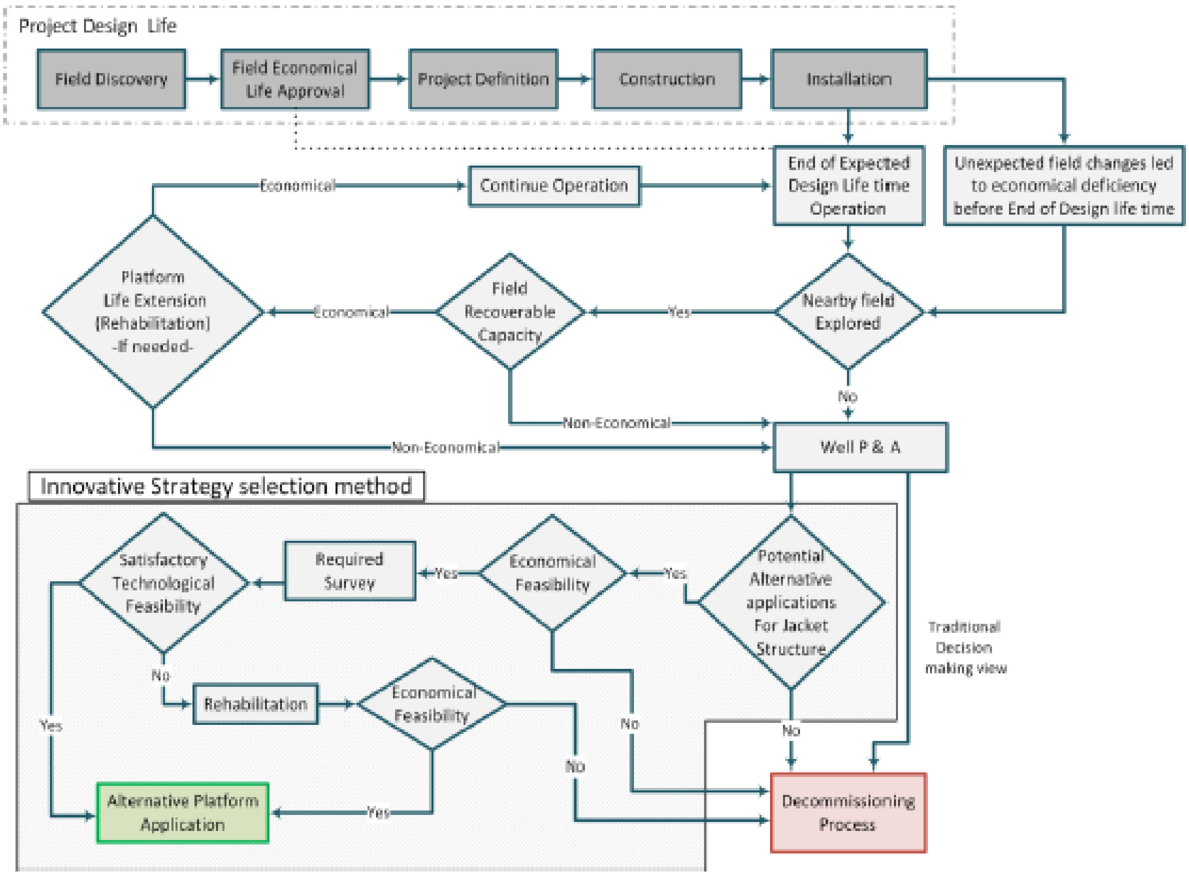

Figure 3. Summary of End of Economic Lifetime for Offshore Platforms
Source: Edalat and Bagherinia (9)

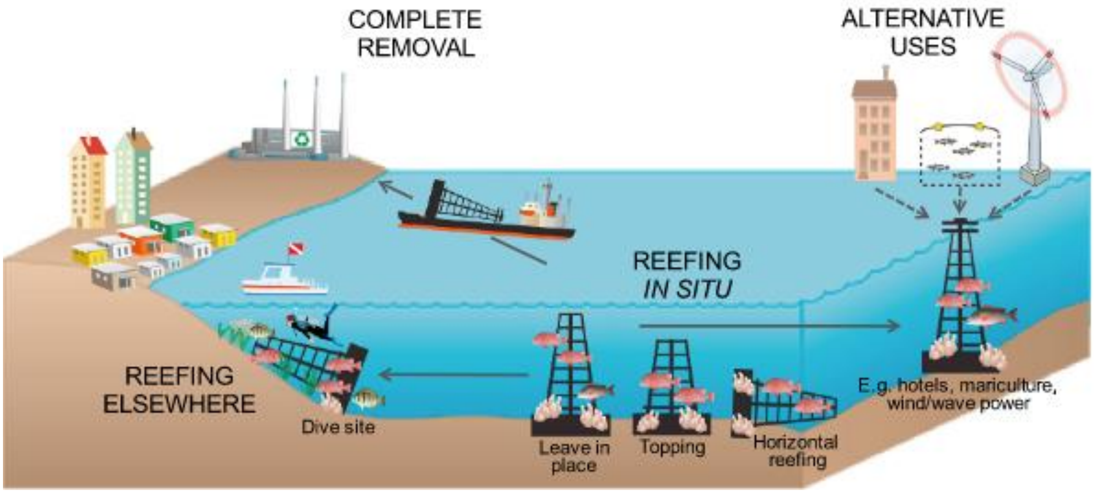

Figure 4. Conceptual process of decommissioning options, including 'complete removal', 'reefing in situ' (including leave in place, topping, and horizontal reefing), 'reefing elsewhere' and 'alternative uses (Source: Sommer, Fowler (16))

3.2 Ocean Thermal Energy Conversion

Ocean thermal energy conversion (OTEC) is becoming a viable energy source in Malaysia due to recent technological advancements. OTEC generates energy by using temperature differences between ocean surface water and colder deep water (10, 13, 17, 18) through cold-water intake piping, which needs seawater depth of 500 - 1500 metres (13, 19). In other industries, fixed offshore platforms have been well-established and validated, resulting in offshore oil, offshore windfarm, and various renewable energy sources. The working principle of OTEC is shown in Figure 5, where the warm water from the ocean surface is pumped through a boiler, making the steam expand and spins a turbine connected to a generator to generate electricity. To complete the cycle, cold water is pumped from the depths of the sea through a condenser, which condenses the working fluid back into liquid.

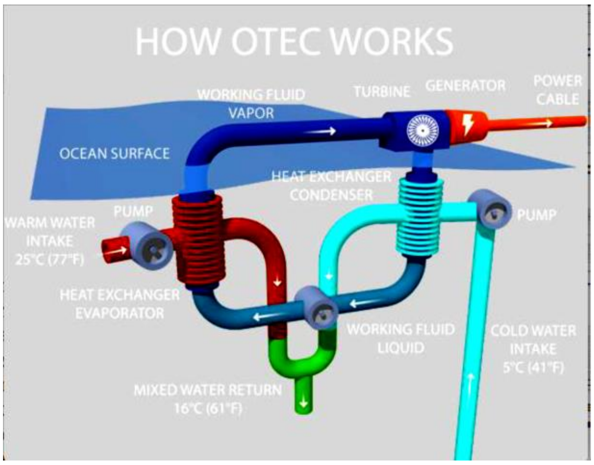

Figure 5. Working Principles of OTEC (Source: Aldale (17))

Referring to the conceptual design of a fixed OTEC power plant in Figure 6 by Mukhlas, Zaki (13), the topside structure's two decks house the OTEC plant's machinery, which includes a working fluid evaporator and condenser, a water output evaporator and condenser, a turbine, and a generator. The equipment can produce 1MW of electricity, which can be supplied to nearby oil and gas platforms.

Despite generating electricity, OTEC platforms can produce clean water through the generation of hydrogen. The OTEC power plant is estimated to provide up to 2 million litres of water per day for every megawatt of electricity produced. Furthermore, no combustion products are generated during the operation, making it more interesting to explore as a perfect renewable energy source.

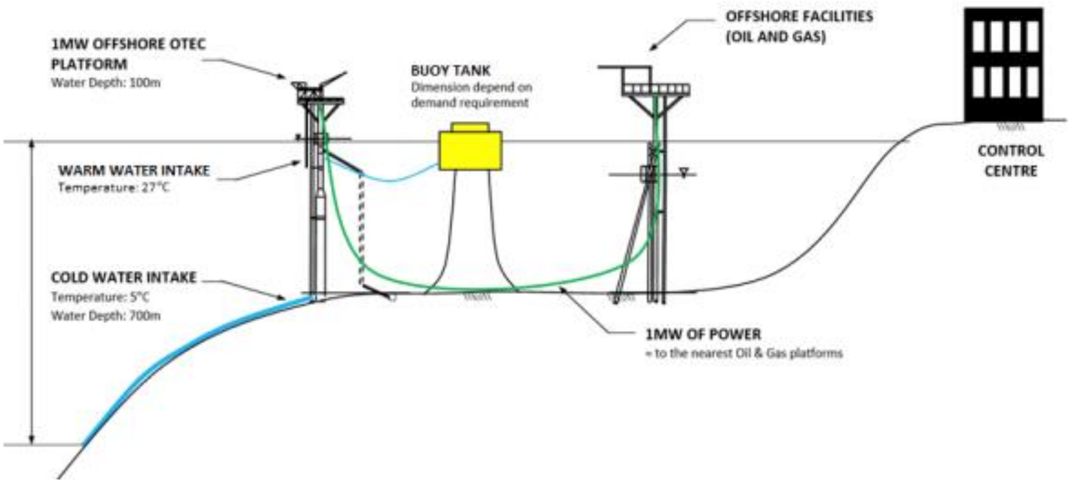

Figure 6. Conceptual Design of Fixed OTEC Power Plant (Source: Mukhlas, Zaki (13))

Referring to Figure 7, the number of OTEC related activities by different stakeholders has increased by 143 from the year 2013 to 2019, while previously only 20 OTEC related activities were recorded before the introduction of UTM OTEC. Therefore, this result supports the idea of bringing new renewable energy sources to Malaysia as profitable and impactful projects as different stakeholders put their money to develop the technology.

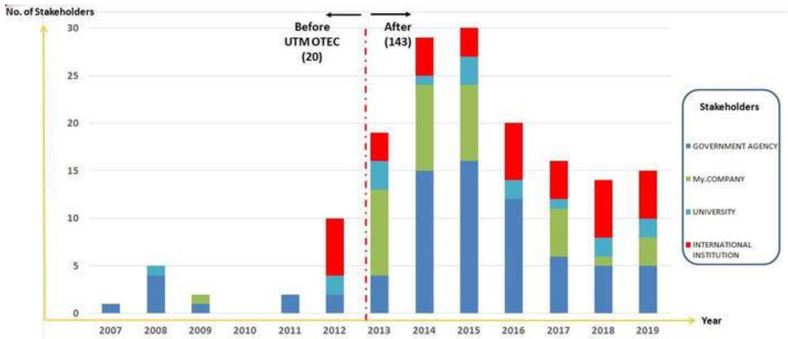

Figure 7. Malaysia, Ocean Thermal Energy-Driven Development: growth in activities relating to OTEC Policy Advocacy and Promotions of Investment (2007–2019) as of 23 August 2019. (Source: Jaafar, Husain (18))

4. Environmental Impact of Utilising Fixed Offshore Platform as An OTEC Source

The use of fixed offshore platforms as a source of OTEC could benefit the environment since the detrimental impacts of constructing new offshore systems for OTEC purposes and the side effects of decommissioning are huge. The positive impact of the utilisation is discussed in this section. The use of fixed offshore platforms as renewable energy sources is not unusual. The utilisation of fixed offshore platforms as renewable energy source has been used in many countries as offshore oil, offshore wind farms, and other renewable energy sources.

4.1 Life Under Water

OTEC plants should be properly selected to avoid harming the marine ecosystem. Structures in the North Sea, for example, enable the existence of the mollusc Mytilus edulis, which further modifies the environment to allow other species to thrive (16). The release of nutrient-rich deep sea water from an OTEC plant's condenser right below the surface of the surrounding sea water would encourage the growth of planktons which can attract marine species (20). The utilised structure can be used as artificial juvenile fish habitats, hence boosting local fisheries (21). Smaller fishing vessels may operate in and around the structure with adequate precautions, and aquaculture farms may be installed around the structure. The implementation of a fixed OTEC plant would contribute to the achievement of the Sustainable Development Goals, which are mainly the preservation of marine life and resources and could prevent the extinction of wildlife. Natural upwelling zones have been reported with high primary bio-productivity and fish production when nutrient-rich deep ocean water flows upward from the deep ocean to the surface. According to Liu (22), natural upwelling areas cover less than 0.1 % of the world's ocean surface, yet account for about 44 % of fish harvest. Therefore, having fixed offshore structures as an OTEC source could increase the potential of natural upwelling areas to further increase the number of marine species living in the area near the structure.

4.2 Climate Change

The construction of new offshore structures for OTEC platforms will require a lot of emissions with a very high embodied energy due to the need to produce parts and components of the structure (15). Embodied energy includes the total energy consumption during the processes of raw material extraction, production, operation, and final disposal at the end of the structure's lifetime (23). The environmental impact of an offshore wind farm is shown in Figure 8, which presents the data of various environmental impacts to generate 1 kWh of power during the manufacturing, transportation, operation, and dismantling processes. The utilisation of fixed offshore platforms as alternative functions can reduce the risk of producing unnecessary embodied energy, which can generate pollutants in the air. The generation of electricity through the OTEC system for 1GW can avoid the generation of 1.1106 tonnes of carbon dioxide emissions per year compared to other energy sources (24).

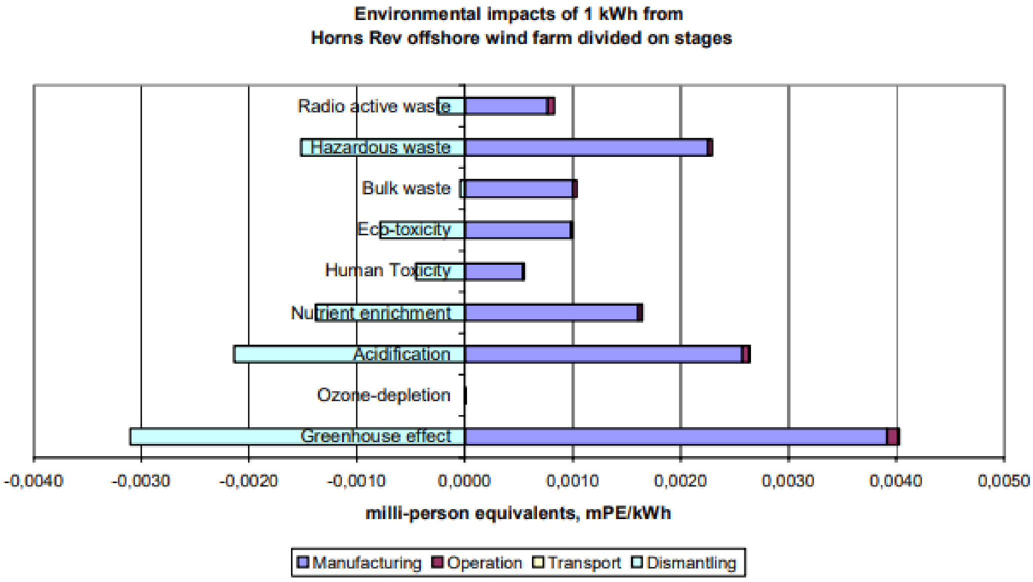

Figure 8. One kWh of power generated by offshore wind farms, divided by life stages. (Source: A/S. (25))

OTEC platforms can generate electricity and produce water without any environmental emissions (13). The new zero-emission energy could reduce overall greenhouse gas emissions due to electricity generation.The utilisation of fixed offshore platforms as wind farms has provided bigger positive large-scale changes to the marine climate (26), hence supports the idea of applying the same concept of utilising offshore platforms as an OTEC source which may positively influence marine climate change. Moreover, OTEC's environmental effects include potential biological effects connected to reduced surface water temperature and changes in nutrient levels of surface waters (27), increasing algae growth, hence acting as a carbon sink to reduce the climate change impact globally (21). Rau and Baird (24) stated that for 1 GW of electricity generated per year, approximately 5106 tonnes of carbon dioxide are reduced from the environment as it is consumed and stored as dissolved mineral bicarbonate in the ocean near the platforms. Concurrently, for every GW of continuous electric power produced over a year by the OTEC system, about 13 GW of surface ocean heat is removed to deep water. (24). Therefore, the OTEC platform can reduce the effect of climate change where it is able to eliminate heat from the ocean’s surface, reduce the amount of unnecessary embodied energy on constructing new platforms, and reduce the amount of greenhouse gases in the environment by consuming the greenhouse gases and not producing emissions.

4.3 Renewable Energy

Renewable energy has the potential to become a significant source of economic development for countries with relatively high ocean energy resources. One of the most significant benefits of OTEC is that it generates clean, environmentally friendly green energy and can generate power continuously. OTEC can produce power continuously throughout the year because it depends on endless and abundant resources that never run out (17). Unlike solar plants, which cannot generate energy at night, and wind turbines, which can generate energy only when it is windy, OTEC can generate energy at any time of day or night. Since one of the by-products of the OTEC system is hydrogen gases (13, 28), the introduction of OTEC platforms will aid the development of the hydrogen economy, which is projected as a future in which hydrogen fuel is used as a significant energy carrier in the twenty-first century. The OTEC system is expected to produce 1.3105 tonnes of hydrogen for each GW of electricity generated in one year (24). These efforts could lead to Malaysia's National Renewable Energy Policy, where Malaysia is expected to achieve a 20 % renewable energy capacity mix by the year 2025 (29). According to Fahmie, Koto (28), hydrogen from an OTEC plant can be used as a fuel or combined with other chemicals to develop new products in the future. Hydrogen-powered vehicles, energy storage, and better residential or industrial heating are expected outputs of the utilisation of the fixed offshore platforms (Jaafar et al., 2020; Abraham-Dukuma, 2019). Therefore, the utilisation of OTEC platforms can create affordable and cleaner renewable energy which can reduce negative environmental impacts towards the environment.

4.4 Clean Water Supply

OTEC can produce clean water through the distillation process and is able to supply cool subsurface nutrient-rich waters that can also be used to support mariculture installations, chilled-soil agriculture, and air conditioning systems (30). The advantage of the OTEC platform is that after cold-water tanks have been built to draw cold water up from the depths, the cold water can be used for other purposes such as air conditioning and refrigeration. For 1 MW of electricity generation, an OTEC power plant is expected to generate up to 2 million litres of water per day (13). In contrast, an OTEC plant with a net capacity of 2 MW could desalinate 4,300 cubic metres of water per day (21). By having millions of litres produced as by-products, low-lying tropical islands whose freshwater reserves are threatened by sea-level rise may profit significantly from this clean water supply. The negative environmental impacts due to the rise of sea level can be reduced since the OTEC system can supply clean water for drinking, agriculture, mariculture, and cooling system.

5. Conclusion

This paper presented an inclusive review of the environmental implications of utilising fixed offshore structures as an OTEC source. The output of the review suggests using the fixed offshore structures as an OTEC source since it can provide clean water supply, generate new electricity sources, produce zero emissions, and preserve marine life. Malaysia has many opportunities to profit from the OTEC process since Malaysia's seawater profile allows for the utilisation of fixed offshore platforms as OTEC power plants. The method of product distribution must also be considered to ensure the amount of emission generated by the overall system could be reduced as promoted through zero-emission energy source. For future work, this study suggests that oil and gas operators look into the possibility of reusing ageing fixed offshore platforms as an alternative energy source such as OTEC, as this would have lesser negative environmental impacts than developing a new platform.

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