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APPLICATION OF ALTERNATIVE ENERGIES IN THE AUSTRALIAN OFFSHORE SECTOR

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Abstract

Fossil fuel is not practically renewable and therefore the world is at risk of fossil fuel depletion. This gives urgency to investigate alternative energies, especially for industries that rely entirely on energies for operations, such as offshore industry. The use of alternative energies in this industry has been in place for a while now. This paper discusses the application of various alternative energy sources to assist powering the Goodwyn Alpha (A) Platform, located on the North West Shelf (NWS) of Australia. The three alternative energy sources under discussion are: wind, wave and solar. The extraction devices used are the Horizontal and Vertical-Axis Wind Turbines - for wind; Pelamis, PowerBuoy and Wave Dragon - for wave; and the solar parabolic dish of SunBeam and Photovoltaic (PV) cells of SunPower - for solar. These types of devices are installed within the same offshore platform area. Technical, environmental and economic aspects are taken into consideration before the best selection is made. The results showed that PowerBuoy used for wave energy, is the best device to be used on offshore platforms where operators could save up to 9% of power; $603,083 of natural gas; and 10,848 tonnes of CO_2 per year.

Keywords: Alternative energy, Wind energy, Wave energy, Solar energy, Offshore platform.

1. Introduction

Alternative energies obtained from renewable natural resources are the substitutes to fossil fuels. Australia is home to abundant renewable energy resources such as

Abbreviations

CSP	Concentrated Solar Power
HAWT	Horizontal Axis Wind Turbine
LNG	Liquefied Natural Gas
NWS	North West Shelf
OPT	Ocean Power Technologies
PV	Photovoltaic
VAWT	Vertical Axis Wind Turbine
WA	Western Australia
WEC	Wave Energy Converter

wind, solar, geothermal, hydro, wave, tidal and bioenergy [1]. In order to reduce fossil fuel consumption and gas emissions (CO_2), and at the same time meet Australia's continuous energy demand, alternative energy options needs to be further explored.

Wind energy is the fastest growing renewable energy resource in many countries and is expected to continuously grow at least up to the year of 2030 [2]. Wind is also one of the more advanced alternative energy sectors where approximately 140 gigawatts of capacity were installed worldwide as of 2009 and an additional 300 gigawatts is projected to be installed by 2015 [3].

Waves are generated by wind energy then released into water. A sustainable source of energy provided by waves may be captured and converted into electricity by Wave Energy Converter (WEC) devices. Energy can be extracted using these WEC technologies anywhere from the shoreline to deeper waters offshore. WEC technologies can be categorised into three predominant types which are attenuator, point absorber and overtopping device.

Another source of energy for the future is solar energy. The energy from solar is clean, sustainable, renewable and readily available. The potentially suitable solar energy technologies for use in offshore ocean environments include Concentrated Solar Power (CSP) and Photovoltaic (PV) solar cells. The CSP system uses mirrors to concentrate a large amount of sunlight onto a small area. The heat from the sunlight can be used to run a power cycle to produce electricity. PV solar cells directly convert sunlight into electricity. PV cells are combined into modules called arrays in which the number of arrays used determine the amount of electricity produced [4].

Research on the primary concept was conducted earlier by Larby et al. [5] and the results from the case studies showed that the most viable option among the three cases is wind energy. However, Larby et al. only showed a limited range of alternative devices for each case. In addition, the lack of information in relation to the companies' platform is one of the major issues. Due to these shortcomings, a more extensive analysis on each case of the alternative energies needs investigation. Detailed comparisons are performed between all devices in order to assess their feasibility. This paper discusses the application of various sources of alternative energies to help with powering of the Goodwyn A Platform located on the NWS of

Western Australia (WA). Investigation based on the technical, economic and environmental aspects are carried out to investigate the differences between the use of gas turbines and the alternative energies of wind, wave and solar.

2. Methods

2.1. Offshore system description

The Goodwyn A Platform is located on the NWS of WA. The platform has a dimension of 52 m × 52 m with the main source of power being a 30 MW dual fuel turbine (gas and diesel) [6]. A set of assumptions used in this study are:

- The offshore platform will not always require the full 30 MW power demand, 75% of the constant load of 30 MW is taken as the yearly load to account for platform variables [7].
- Without alternative energies, a platform is operated by dual fuel turbine: gas and diesel, each runs 75% and 25% of the time respectively.
- The amount of transmission losses through cables have not been taken into account.

Based on these assumptions, the platform power demand in a year can be calculated using Eq. (1):

$$\text{Platform power demand} = \left(T_{power} \times T_{hours}\right) \times 75\% \tag{1}$$

where T_{power} is total power of the platform [T_{power} = 30 MW], and T_{hours} is total hours in a year [T_{hours} = 8760 hours]. Thus, the platform power demand can be determined as 197,100 MWh per year. Table 1 summarises the characteristics of a platform load when it operates for a year by relying solely on the power output of turbines.

Table 1. Platform power demand and turbine load characteristics.

Units	MW	75% of load (MWh/year)	75% of Gas (MWh/year)	25% of Diesel (MWh per/year)
Platform Load	30	197,100	147,825	49,275

2.2. Optimisation of features

The use of wind energy in Western Australian offshore is very much plausible as long as the water depth is more than 100 m although it is also subject to several environmental conditions. Once the requirement for the water depth is satisfied, a wind turbine can be constructed where a conventional one is usually associated with a floating structure. Two suitable extraction devices of wind energy have been selected: the Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT).

Observation indicates that offshore wind speed around the platform, which is located 135 km north-west of Karratha reaches 24.2 m/s with average wind speed of 6.74 m/s in a year. The constant wind speed in that particular site has shown that wind turbines can be adopted for power generation. Wind data for the area was provided by BMT Fluid Mechanics global wind and wave statistics [8]. An increase in rotor's size contributes significantly to the increase in the power output. Due to the high costs of installation for each wind turbine on the sea, a concept of semi-submersible floating platform is adopted as the wind turbines are installed on the platform. A hexagon-shaped wind turbines platform is used to maximise the units of wind turbines that can be utilised. Thus, six units of wind turbines are used in the studied case. Even though the highest power produced by the wind turbine is the best selection, the cost, the rotor's diameter and the wind speed at that location have higher weightage in the process of decision making. Based on the requirement, Vestas V34 would be the best choice for that particular site since Vestas V34 has the smallest rotor's diameter, less capital cost and at the same time meeting the power requirement [9]. Vestas V34 may produce a maximum power output of 400 kW.

VAWTs are the new technology in offshore wind turbines in which several companies have managed to develop the best VAWTs that are going to be used in offshore sectors. Due to the limited options available, FloWind 19 m VAWT manufactured by Floating Windfarms Corporation has been chosen [10]. This is a new innovation of VAWT where it has the potential to operate at an annual mean speed of over 8 m/s and may produce a maximum power output of 300 kW. Unlike the HAWTs that use a hexagon shaped of semi-submersible platform, VAWTs use a square shaped platform with the same dimension of the offshore platform of 52 m × 52 m. With the rotor diameter of 19.2 m, more units of wind turbine can be installed. Thus, nine units of wind turbines are used in the studied case.

Renewable energy sourced from waves has been considered to be the most emphasized energy that varies significantly with location and time. Energy produced by waves is convertible via WECs where over 1000 wave energy conversion techniques have been patented worldwide. The variation designs of WECs are generally categorized by location and type [11]. Therefore, it is essential to narrate the current status of the devices to be used for offshore activities. Offshore devices are generally constructed in deep water that is greater than 40 m. NWS which is located in WA coastline offers good resources to implement this technology. With deep water of more than 100 m, it could potentially harvest a greater amount of energy at that location. There are a few WECs that can be used for offshore operations such as the Pelamis, Ocean Power Technology (OPT) PowerBuoy and Wave Dragon.

The efficiency of these devices depends on wave conditions. The optimum position for Pelamis is around 5-10 km offshore and can also be in water depths of more than 100 m. The optimum wave height of around 6-7 m may produce a maximum power output of 750 kW. The power rating is also influenced by the wave period. Thus, these devices can be operated when the wave period is around 7-10 seconds. Accordingly, it is essential to position the Pelamis in an area where the optimum wave conditions can successfully be achieved. The OPT PowerBuoy technology; on the other hand, can be used in water depth of more than 55 m with a minimum wave climate power density of 20 kW/m. This device can generate a maximum power of 866 kW with wave heights in the range of 1 to 6 m, making it suitable for a broad range of wave climates. Previsic [12] showed a few categories that were used to evaluate the WECs at specific locations. The study showed that Pelamis and Wave Dragon are the most suitable devices for use in offshore application. Pelamis and the Wave Dragon, which can be deployed in water depth of more than 50 m, produce power ranging from 750 kW to 7 MW depending on wave climate. The application of these devices could potentially be located in deep waters and the best location would be NWS of WA.

The number of units of alternative devices to use is highly dependent on the constraint surface area of 52 m × 52 m, the same area of the offshore platform. For Pelamis, five units of the device are used producing a total power of 3.8 MW. For OPT PowerBuoy, 15 units of device are used to generate a total power of 13 MW and for Wave Dragon, one unit of the device is used as it generates 7 MW of power. The other consideration is the dimension of the devices. Even though the Pelamis only has a diameter of 3.5 m, the length is one of the main issues. With the length being 150 m long, it requires extra space for installation. Compared to the OPT Powerbuoy which has a surface area of 10 m each, more number of units can be installed. Only one device of Wave Dragon was used since the size of the device is 300 m × 170 m.

Radiation sourced from the sun that is convertible into electricity is called solar power. The potential for using solar energy at a given location depends largely on the solar radiation, the proximity to electricity load centers and the availability of suitable sites. Generally, there are two types of solar power which are commonly used in either land or offshore: CSP and PV solar cells. CSP technology use mirrors to reflect and focus sunlight onto receivers that collect solar energy and transform it into heat while PV converts sunlight directly into electricity by using semiconductors. The configurations of CSP technologies are divided into a few categories: parabolic trough, linear Fresnel collector, solar towers and parabolic dish reflectors [13]. Meteorological data of the site obtained shows that, on a monthly basis, the average global solar irradiance is about 6.5 kWh per m^2 while the average temperature is 36°C [14]. Therefore, these two technologies would have enough sunlight radiation to enable them to operate efficiently.

The other factor to consider is the limitation of spacing on an offshore platform. Due to the function of the offshore platform, which is to produce liquefied natural gas (LNG), limited space is available. The complexity to incorporate storage capacity into their design is also an important factor to consider. Hence the parabolic trough and linear Fresnel collector are not suitable for electrical powering especially for offshore platform where limited space is available and the installation could be difficult. A solar tower requires multiple central receiver collectors or heliostat around the tower where a big space for installation is needed.

Based on these characteristics, the parabolic dish reflector has the potential to be used for offshore application. Due to salty environments and the limitation with the wave’s size offshore, the innovation of a semi-submersible platform of solar power could be the best solution. Based on this analysis, the parabolic dishes of SolarBeam and the PV solar cells of SunPower were chosen for this case study. The parabolic dishes of SolarBeam has a reflector diameter of 7 m which continuously track the sun using a dual axis tracker enabling the system to harvest up to 25 kW per hour of thermal fluid energy from early sunrise to late sunset. The PV cells manufactured by SunPower Corporation are known to be the highest efficiency solar cells in the world and provide panel conversion efficiencies of up to 20.1% [15]. With the nominal power of 327 W per panel, SunPower E20 provide outstanding energy delivery per peak power watt and are the most the most reliable solar energy systems [16]. The area of a module of PV cell is 1.632 m^2. 70 units of SolarBeam and 1600 units of arrays are required to be installed on the solar power's platform. The power losses of each device are taken into account. The assumption made is that each device produced up to approximately 80% of the total rated power in a year.

2.3. Case Study

The arrangement and installation of each device at the site location is shown in Fig. 1. The HAWTs and VAWTs platform (a, b) and SolarBeam and SunPower platform (f, g) use a centralized turret mooring system to enable the entire platform to turn into the direction of the wind. The wave energy devices of Pelamis, PowerBuoy and Wave Dragon (c, d, and e) are connected to one another by umbilical cable. The umbilical cables (DC transmission) from these devices are connected directly to the offshore platform through an underwater substation. The maximum distance between these devices to the offshore platform is 1000 m.

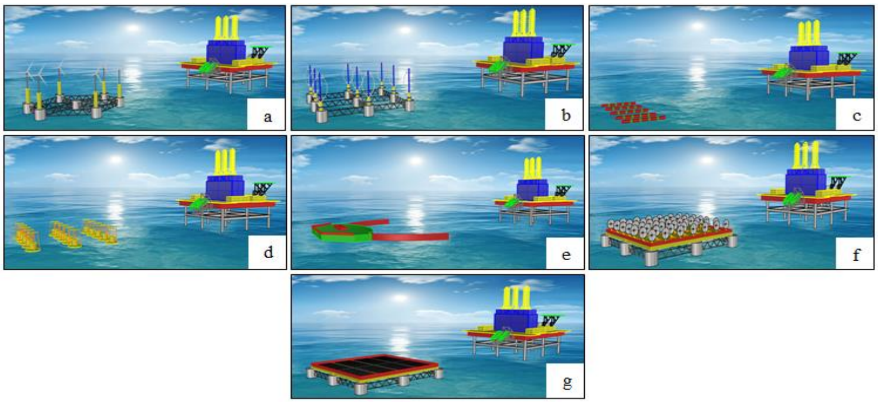

Fig. 1. Arrangement of each device at the site location.

3. Results

3.1. Power analysis

A power analysis is undertaken to find the total power produced over one year by each device. Using wind and wave data from BMT Fluid Mechanics global wind and wave statistics, the average power of each device can be determined. The power analysis can be performed by using Eq. (2):

$$P_{output} = \left(\left(P_{average} \times T_{hours} \right) \times \eta \right) \times T_{units} \tag{2}$$

where P_{output} is the total power output of the device, $P_{average}$ is the average power produced by the device in a year and T_{hours} is the total hours in a year. As solar energy is solely sourced from sun radiation, solar irradiation generating process can only be carried out during the day because of the absence of sun radiation at night. Hence, the maximum period for this generating process is only 12 hours per day which is a total of 4,380 hours per year. η is the efficiency for each device, where the assumption has been made that each device would produce at most 80% of the total rated power across a year (η = 80%) and T_{units} is the total number of units used in the case study. A summary of the calculated power outputs over a year for all three alternatives case is shown in **Table 2**.

Table 2. Power outputs for each case.

Studied case		$P_{average}$ (MW)	T_{hours}	T_{units}	P_{output} (MWh/year)
Wind	HAWT	0.16	8,760	6	6,728
	VAWT	0.03	8,760	9	1,892
Wave	Pelamis	0.21	8,760	5	7,358
	PowerBuoy	0.17	8,760	15	17,870
	Wave Dragon	0.95	8,760	1	6,658
Solar	Solarbeam	1.75	4,380	70	6,132
	SunPower	0.52	4,380	1,600	1,822

Based on the power outputs per year for each case, the percentage of power savings for each device can be determined using Eq. (3):

$$\text{Percentage of savings} = \left(\frac{P_{output}}{\text{Platform power demand}}\right) \times 100\% \tag{3}$$

The percentage of power savings over a year for all alternative cases are shown in Fig. 2. The results show that PowerBuoy is the most viable alternative energy device with 9% of savings. Meanwhile, the results for VAWT show that it has a savings of only 0.8%. Based on the results, the power produced from the wave energy device PowerBuoy has the greater potential in generating more power compared to alternative devices.

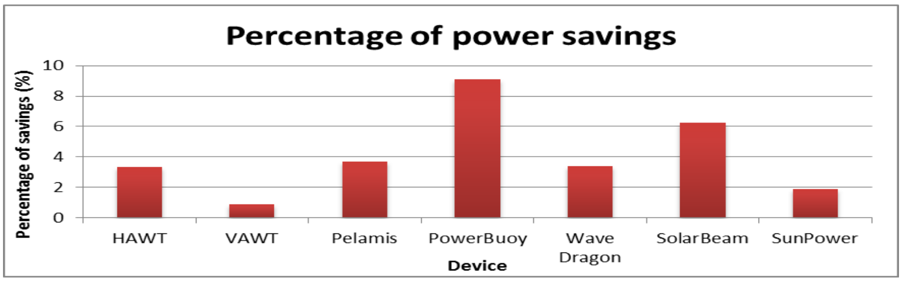

Fig. 2. Power savings with alternatives case.

3.2. Gas consumption analysis

In order to power the platform, natural gas produced from the reservoir is used to operate the turbine. The gas saved could instead be sold if the turbine does not need it. Therefore, it is essential to determine the possible earnings that could be made from selling this gas. The worldwide current price of natural gas fluctuates considerably over time but was found to be $4.31 AUD per MMBtu (million British thermal units) at the time of writing [17]. This value is used to determine how much gas could be saved using the alternatives. As the turbine runs on 75% of gas all the time, the consumption of natural gas is 147,825 MWh per year, which is equal to 1,539,450 MMBtu per year. Therefore, the gas usage in a year without the alternatives can be determined using Eq. (4):

$$\text{Gas usage} = \text{Natural gas consumption (without alternatives case)} \times \text{Cost} \tag{4}$$

The total gas usage incurred by the operators in a year is shown in Table 3. The operators would lose around $6.63 million AUD without the alternatives case.

Table 3. Gas usage without alternatives case.

Without Alternatives Case	Consumption (MMBtu per year)	Lost gas sales ($ per year)
Natural Gas	1,539,450	6,635,028

The gas usage savings using complimentary alternatives can be determined using Eq. (5):

$$\text{Gas Savings} = \text{Gas usage (without alternatives case-with alternatives case)} \tag{5}$$

The gas savings with the alternatives case is shown in Fig. 3. The operators would be able to save around $603,083 AUD per year if the PowerBuoy wave energy is used as an alternative to the existing energy supplies. However, VAWT operators would only save around $56,494 AUD per year.

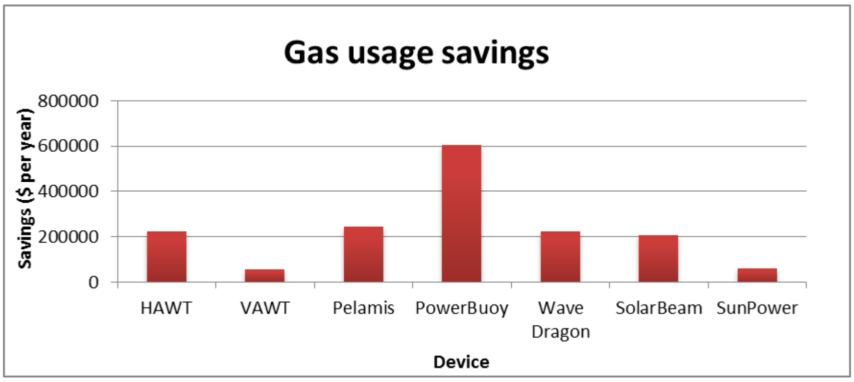

Fig. 3. Gas usage savings with alternatives case.

3.3. Fuel consumption analysis

The price of diesel was found to be $1,050 AUD per tonne at the time of writing [18]. This fuel price was applied when the fuel consumption of diesel has been calculated. Without alternatives case, the consumption of 75% natural gas was found to be 147,825 MWh per year which equates to 32,478 tonnes per year while the consumption of 25% diesel was found to be 49,275 MWh per year which is equal to 12,551 tonnes per year. Therefore, the cost of the diesel would be $13,178,997 AUD per year. This is obtained using Eq. (6):

$$\text{Diesel cost} = \text{Consumption (without alternatives case)} \times \text{Cost} \tag{6}$$

The fuel savings with complimentary alternatives case in a period of a year can be determined using Eq. (7):

$$\text{Fuel savings} = T_{\text{fuel}}\left(\text{without alternatives case - with alternatives case}\right) \tag{7}$$

where T_{fuel} is the total fuel consumption. The annual fuel savings with complimentary alternatives case is shown in **Table 4**.

Table 4. Fuel savings with alternatives case.

Studied case		With alternatives case (tonne/year)		Fuel savings (tonne/year)	
		Natural gas	**Diesel**	**Natural gas**	**Diesel**
Wind	HAWT	31,392	12,132	1,086	419
	VAWT	32,202	12,445	276	106
Wave	Pelamis	31,274	12,086	1,204	465
	PowerBuoy	29,526	11,411	2,952	1,140
	Wave Dragon	31,386	12,129	1,092	422
Solar	Solarbeam	31,468	12,161	1,010	390
	SunPower	32,176	12,435	302	116

For natural gas, the results showed that the use of PowerBuoy consumed 2,952 tonnes per year while VAWT is still ranked as the lowest alternative device in fuel savings of 276 tonnes per year. On the other hand, for diesel, it showed that the use of PowerBuoy consumed 1,140 tonnes per year while VAWT consumed 106 tonnes per year. The cost of diesel in a year of operation for PowerBuoy and VAWT was found to be $11.3 million AUD and $12.3 million AUD respectively. This is approximately $1.9 million and $878,000 respectively savings in fuel compared to when the alternatives case is absent.

3.4. CO_2 savings

The gas emission of the Goodwyn A Platform produces 119,353 tonnes of CO_2 per year without the alternatives case, as shown in Table 5. The total amount of CO_2 produced per kilowatt-hour when generating electricity with natural gas and diesel is 0.5 kg of CO_2 per kWh and 0.8 kg of CO_2 per kWh respectively [19]. Therefore, the total CO_2 produced per year for natural gas and diesel can be determined using Eq. (8):

$$\text{Total } CO_2 \text{ produced} = T_{load} \times CO_2 \text{ per kWh (natural gas/diesel)} \tag{8}$$

where T_{load} is the total load of natural gas and diesel in MWh per year.

Table 5. CO_2 produced by the Goodwyn Platform without alternatives case.

Without Alternatives Case	CO_2 per kWh (kg)	MWh per year	CO_2 per year (tonne)
Natural gas	0.5	147,825	81,804
Diesel	0.8	49,275	37,549
		Total	119,353

The total CO_2 savings over a year with a complimentary alternative device case can be determined using Eq. (9):

$$CO_2 \text{ savings} = T_{CO_2}\left(\text{without alternative case - with alternative case}\right) \tag{9}$$

where T_{CO_2} is the total CO_2 produced in a year.

The total CO_2 savings with complimentary alternative device case is shown in Fig. 4. The offshore platform produces approximately 108,505 tonnes of CO_2 per year and 118,337 tonnes of CO_2 per year when the PowerBuoy and VAWT are utilised, where approximately 10,848 tonnes of CO_2 per year and 1,016 tonnes of CO_2 per year respectively could be saved in comparison with the total CO_2 produced by the offshore platform without alternatives case.

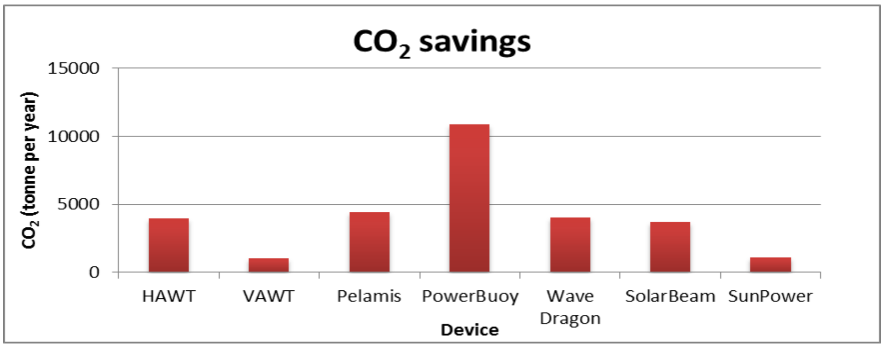

Fig. 4. CO_2 savings with alternative device case.

3.6. Environmental analysis

This section discusses the use of all forms of energy generation which significantly affects the environment. The environmental impact can be categorized into two; the impact on the human environment and the natural environment. The impact on the human environment includes gas emissions and noise effect, while the natural impact involves climate change and habitat disturbance.

The noise impact is due to moving of mechanical parts during operation. Mechanical noise of wind energy of HAWT and VAWT are significantly produced by the gear box and the turbines. These problems can be reduced by inserting damping material in between the gear box casing and the power house module. However, the rotation of turbine still remains a major problem for wind turbines and this can only be overcome by choosing a suitable size rotor for both HAWT and VAWT. In terms of the natural environment, the ecosystem of animal habitat is disturbed mainly by the installation requirements, such as wind turbines platform, transmission lines and the underwater substations.

The use of wave energy devices could affect marine species such as dolphins and whales. The most disruptive is noise and vibration during construction and decommissioning of WECs. The electromagnetic fields around devices may be problematic to marine species such as sharks, skates and rays that use electromagnetic fields for navigation. The other consideration is chemical leakage during operation. Chemical leakage, for example oil leaks from hydraulic power take-off systems, contributes to water pollution and could cause changes in sedimentation.

Solar power has great potential in reducing environmental impacts from greenhouse gases and air pollution emissions. However, the noise from the generating plant can cause disturbance to human life. Noise from the device is only produced during the day and the system is shut off and unable to operate at night.

3.7. Economic analysis

The economic analysis reviews current costs of three forms of renewable energy; wind, wave and solar. The estimation made for the purpose of this study is the economic lifetime for the project of 25 years. The calculation of present value cost analysis consists of investment and payment analysis. Investment determines the total cost of each project including the installation and total cost of the device used in the studied case while the payment is determined by the total expenditure over the expected lifetime [20]. The calculations of the investment and payment can be obtained using Eq. (10) and Eq. (11):

$$T_{investment} = (\text{Device cost} \times \text{unit}) + \text{installation cost } (30\%) \tag{10}$$

$$T_{payment} = T_{investment} + \left(\text{O\&M } (1.5\%) + \text{expected lifetime } (25 \text{ years})\right) \tag{11}$$

where $T_{investment}$ is the total investment while $T_{payment}$ is the total payment for the project. The assumptions made to determine the total cost for each alternative energy device used in the case study are:

- For wind case, cost for HAWT and VAWT is $4,400/kW and $1,467/kW. The price for VAWT is to be one-third of HAWT price [21].
- For wave case, cost of all devices is $2,650/kW [22].
- Cost for each parabolic dish and PV cell is $250,000 [23] and $5.62/W respectively [24].

- The installation cost is to be 30% and the operation and maintenance (O&M) is to be 1.5% of device price [25].
- The semi-submersible platform cost is $500,000 [26].

Based on these assumptions, the total costs for each alternative energy devices can be determined as shown in **Table 6**.

Table 6. Total cost of each alternative device.

Studied Case		Total costs ($million AUD)
Wind	HAWT	24
	VAWT	9
Wave	Pelamis	22
	PowerBuoy	71
	Wave Dragon	55
Solar	SolarBeam	882
	SunPower	6

4. Discussion

The HAWTs and VAWTs are not suitable for powering the offshore platform since more units are required in order to supply the same power of 30 MW. Technically, the HAWTs could be installed pointing into the wind direction since the turbines can only rotate if the wind comes from one direction. The HAWTs are mounted on the tower to produce maximum power during maximum wind speeds. The VAWT or Darrieus type vertical-axis wind turbine is designed to improve the efficiency of existing HAWTs. The VAWTs are mounted on the ground and can be operated close to ground level. From the comparison, it clearly shows that HAWTs require massive structures which are very costly for the operators. The wind energy devices are not environmental friendly since it produces noise from the turbines during operation. The cost for stand-alone applications of wind turbines is one of the main concerns since it requires mooring lines and foundations to keep them stable. With water depths of more than 100 m on the site location, it is impossible to install the wind turbines individually on the sea. However, these issues can be overcome by using a semi-submersible platform where it reduces the use of mooring lines and foundations. The costs for these devices are not relatively expensive, but the power produced is one of the key factors to consider in selecting the best alternative energy device for that site location.

The wave energy devices are considered to be the most viable option since the wave resources are greatest offshore. The Pelamis and PowerBuoy have the potential in power generation for offshore applications. However, the Wave Dragon is abandoned in the studied case as this device is enormous in size being more than 300 m long. Due to the constraint surface area of 52 m × 52 m, only a limited number of units can be installed. In terms of environmental aspects, the wave energy devices contribute to noise pollution and destruction of marine life during operations. The mooring system for these devices is also one of the main concerns. Unlike the wind energy devices, which used semi-submersible for installation, the Pelamis and PowerBuoy are stand-alone applications and cannot be combined together. This problem leads to high costs of installation where many mooring lines and anchors are needed for each device. The costs for these energy devices are not relatively expensive. However, more units of PowerBuoy are required since each device only has a small surface area.

The parabolic dish of SolarBeam is particularly suitable to be used for supplying power to the offshore platform. The total discharge of greenhouse gases produced by this technology can be considered as negligible. The main concern about this technology is the high capital cost. The cost of a single 327 W unit can be around $250,000. However, few manufacturers of solar parabolic dishes are still investing in the development and commercialisation of the technology. This experiment may take up to 10 or more years to develop in order to become more viable to be used for offshore powering systems. The SolarBeam produces noise during operation and is not considered environmentally friendly. The cost is too high and the operators have to abide with the high cost of installation and maintenance. The PV cells technology of SunPower has the potential to make a significant contribution in power generation and is a suitable option for mitigating the greenhouse emissions. With the small surface area, more units are required during installation. The solar energy devices only operate during sunlight hours and are unable to operate during night time. Even though SunPower is environmental friendly, the power produced is less compared to other alternative energy devices. On the other hand, the SunPower is the most economical with the lowest cost among other alternative devices.

For economic analysis, it is difficult to create an all-inclusive economic analysis of depreciation for all renewable energy devices because each device varies significantly. For example, a Wave Dragon will have different depreciation costs and considerations than a wind turbine. The alternative would be to look at discounted cash flows, making some assumptions about the cost of capital. Typically this might be done by computing a net present value (NPV) where cash flows in the future are valued less (discounted) compared to initial ones. A full life cycle cost analysis will also look at any decommissioning costs (or conversely at residual value).

Based on these analyses, the wave energy of PowerBuoy is the most viable option to be adopted. With the constraint of surface area of 52 m × 52 m, 15 units of PowerBuoy can be used. This device uses a buoy structure that allows it to move freely with the waves. This is a very compact device as the electronic system, electrical generator and the control system are all sealed inside the device. This intelligent device could reduce the maintenance cost due to the power system being housed inside the buoy. The environmental impact is low since only a few cables are required and this may reduce the likelihood of sea animals getting entangled. The cost for each device is considerably lower compared to SolarBeam and HAWT. The other advantages of PowerBuoy are that it acts as a high capacity power station with no exhaust gas emissions; it is easy to deploy and power generated can be fed into the power grid.

5. Conclusions

Alternative energy devices are the best option to be used for offshore powering systems. However, several factors need to be considered before selecting the most suitable device, such as the installation process, capital cost and environmental effects. Previous research showed that no offshore operator expressed interest in adopting any of these technologies as a replacement for fossil fuels. Even though it is widely known that the use of fossil fuels contributes to global warming and greenhouse gases, the lack of initiative to address these issues persists. Furthermore, the cost to install alternative energy devices has always been the main concern for offshore platform operators. Developers of the alternative devices should consider reducing the prices so that these technologies would become more appealing to offshore platform operators.

Wave energy is the most feasible resource as wave is the most concentrated form of renewable energy especially for the offshore environment, while the technology of PowerBuoy is identified as the best option available. In order to facilitate future improvements based on this study, a more detailed investigation should be performed. Future work can be performed by investigating the installation of each alternative energy device for offshore use in detail. The key considerations of costs, efficiency, and technical difficulties would also be worth undertaking.

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