Powering Offshore Structure Using Renewable Energy: A Review Study

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Abstract

Renewable energy is shaping our future due to the ever-growing environmental crises. The world needs purposeful activity to diminish fossil fuel uses and execute carbon relief measures as nonrenewable options cannot be eliminated within a few decades. Offshore structures play a significant role in extracting nonrenewable energy; however, these create environmental hazards and are not cost-effective. In this study, the use of renewable energy for powering the offshore structures is discussed. It also reflects the economic and social awareness perspective that is much needed by any country. The paper compiles all recent innovation, usage limits, efficiency, contribution, and challenges for utilizing sustainable power sources on offshore platforms. The paper finally discusses some ideas to manage the introduction and subsequent growth of renewable energy resources. This research aims to notify concerned individuals about the current capabilities with possible opportunities and challenges. The discussion of this paper will inform future decision-makers and researchers on policies to be taken in this burgeoning sector, along with the path for future research and scope for improvement.

Keywords: Renewable energy, Offshore wind energy, Wave energy, Efficiency, Technical challenges, Economy.

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Introduction

Energy drove the modern industrial revolution during the 1800s, and the key source of this revolution was the steam generated power. Presently, the current energy sources are mainly nonrenewable energy in the form of coal, oil, and other gaseous forms of petroleum. The ever-growing demand for nonrenewable fuel drove the price upward for most of the 20^{th} century. However, a recent trend of reduction in the oil price is being observed. From mid-2014 to mid-2015, the oil cost dropped from over $100 to under $50 per barrel, bringing down the market costs of flammable gas and coal (WEO, 2015). This low cost might be good news for businesses and stakeholders, but this will not give sustainability.

In the 21^{st} century, the biggest problem with nonrenewable energy is environmental hazards and the depletion of such fuel reserves. Due to the high emission of greenhouse gases, the environment is losing its adaptability. As the use of fossil fuels cannot be eliminated, it is better to decrease their usage in various industries. Offshore platforms are big sources for extracting oil and gas. As these immense structures are located in the seas, so powering the offshore structures is a big challenge. Using fossil fuel to power up these sites has several detrimental factors to both the investors and the environment. Because it will continuously increase the environmental hazards and, at the same time, it will decrease the site's profitability. Using fossil fuel will create greenhouse gas emissions, and processing or reducing the emission will further increase the overall costs. Transportation of fossil fuels to such remote locations and the maintenance of such specialized transports is another challenge. However, introducing renewable energy sources to such plants will reduce fuel costs, maintenance, and transport costs. Moreover, it will mitigate the carbon footprint from the offshore oil and gas rigs. It will have the dual impact of saving the environment and decreasing the cost altogether.

This research's motivation was to explore our current renewable resources and efficiently use such resources to power offshore structures. The paper, while supporting the usage of renewable energy, will discuss the possible technology or option that can be used to power up the offshore structure (for example, solar-powered thermal energy, photovoltaic, geothermal energy, tidal force, wave power, wind power, hydropower, biomass power, and power buoy technology, etc.). This paper will also review the limitations of these options alongside the opportunities they offer around the world. These technologies have their own set of advantages, prerequisites, and limitations. The paper highlights such technologies and their respective opportunities and recommendations to follow the discussion.

Available Forms of Renewable Energy

Renewable energy can be harnessed from natural resources like sun, wind, geothermal, biomass, waves, currents, tides, etc. These are sustainable energy sources that do not deplete or can be replenished within a human being’s lifetime. It reduces greenhouse gas emissions, which in result decreases environmental pollution and produces environmentally friendly energy. Therefore, it is also known as clean energy. Because of its possibilities, recent studies impart importance on the use of this energy, and since 2011, renewable energy is growing faster than all other energy forms. The installed power capacity grew more than 200 gigawatts (GW) in recent years, and it has been exploited in different offshore areas to assess resource potential, examine various technical approaches, and install renewable energy devices.

Powering Process of Offshore Structures

An offshore structure or an offshore drilling rig refers to a large structure midst of the ocean, including facilities for drilling to explore, extract, store and process petroleum and natural gas that lies in rock formation under the seabed. Almost 75% of the earth's area is covered with water, and a huge amount of resources exist there, which has not been explored yet.

Unlike the energy requirement for an average house or building, any extraction platform requires an enormous amount of energy. To get this amount of power, traditionally, generators or diesel turbines are used in the offshore platform to meet up the demand, and sometimes multiple sets of generators are applied. This power generation is largely integrated into a platform or a vessel. Such a system has to be more durable than any other land-based exploration structure. Generally, the extraction company uses a barge or tanker to carry diesel/fuel from onshore to offshore structure due to the heavy need for diesel/oil to operate the structure. In 2013, the International Petroleum Industry Environmental Conservation Association (IPIECA) estimated that on average, an offshore structure uses 20-30 m^3 fuel per day (IPIECA, 2013).

Sometimes the amount varies upon what operations are being performed. It depends on the structure's situation, also whether it is moored or in a dynamic position. If the total power is produced inside the structure, an external cable system is not needed (Lo, 2020). It results in a huge cost for the company to carry fuel and the generator emits a gigantic amount of CO_2, which is hazardous for the environment and negatively impacts climate change. Due to this colossal cost and environmental impacts, industries and academia are considering renewable resources to meet up the power demand because of its low cost and environment-friendly nature. It may not be possible to accommodate renewable energy harvesting devices inside the structure so harvesting units may be set near the shore. In this case, the subsea cable is the best option as it is environment-friendly and does not harm the marine ecosystem while being easy to operate (Power Generation for Offshore Environments, 2015).

Solar Thermal Energy

Solar Thermal Energy is a form of energy that captures heat energy from the sun and uses that heat to produce electricity. It is one of the cheapest ways to produce electricity in a large quantity, though there is a high installation cost. But apart from the initial costs, it may be cost-effective for offshore oil and gas business. Moreover, it will provide sustainability to the globe with zero carbon emissions. CO_2 emission is a huge concern for all. Almost 146 million metric tons of equivalents CO_2 emitted in 2013 due to oil and natural gas production. Solar thermal energy has been used in many offshore platforms for powering them up. Solar thermal energy is the wider and very developed form of available renewable energy. Renewable energy might be appropriately utilized to achieve sustainability considering 20-30 m^3 of diesel oil is needed to power up an offshore rig (IPIECA, 2013). The following figure and table show the monthly production for an average solar energy plant.

Table 1: Typical Parameters of Solar Thermal Energy System (Sarbu & Sebarchievici, 2017)

Thermal Energy System	**Capacity (kWh/t)**	**Power (M.W.)**	**Efficiency (%)**	**Storage Period**	**Cost (€/kWh)**
Sensible (hot water)	10-50	0.001-10	50-90	Days/ months	0.1-10
PCM	50-150	0.001-1	75-90	Hours/ months	10-50
Chemical Reactions	120-250	0.01-1	75-100	Hours/ days	8-100

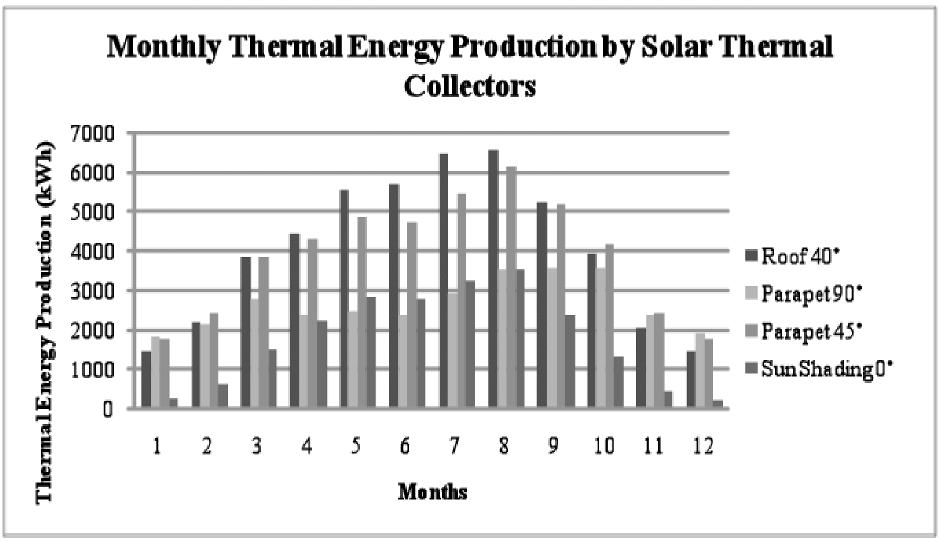

Figure 1: Monthly thermal energy production by solar thermal energy (Furundzic et al., 2020)

The year-long solar energy harvesting (from figure 1) indicates that solar thermal energy is fully capable of producing enough energy to run an offshore platform. As a proven, cost-effective technology, solar panels can be used for 20-25 years without routine operating costs. Even adding extra cells to solar panels will not create any negative effects except for the installation cost.

Building solar plants is a considerable issue. Floating solar plants is not a novel concept, and many countries are using them. Currently, China has the largest floating solar plant. It will be easier and feasible to connect offshore rigs with floating solar plant. Even if the plant is onshore, subsea cables can connect the offshore plant to the solar plant. Subsea cable is an environment-friendly technology to supply power from land to the marine environment. It reduces weight and makes the work environment safer, and it is easier to maintain than a generator or any other technology. Norway is the first country to use renewable energy in powering offshore rigs. They are using mostly wind turbine plants with subsea cable. The same process with a solar thermal power plant may be reasonable too, and it may become a feasible option in the future. A company may use more than one renewable energy source option to continue operating rigs to get more cost-effective results. Currently, solar thermal energy has been used in some Oil & Gas industry sites, such as the Mckittrick Oil Field and the Coalinga Oil Field in the United States, and the Amal Oil Field in Oman (Choi et al., 2017).

Photovoltaic Energy System

The photovoltaic (P.V.) system comprises solar panels joined with an inverter and other electrical and mechanical equipment that use energy from the sun to produce power. It generates electricity in a photovoltaic cell when it is exposed to sunlight. The photovoltaic system directly converts sunlight to electricity, and this tool is made of a semiconductor.

USA is running one of the biggest oil fields named Midway-Sunset Oil Field by this P.V. system. They built a 500KW P.V. system, and it supplies only 0.4% of total demand. 500KW is such a small amount of production. (U.S. energy information, 2020). Table 2 highlights some of the statistics of P.V. in the energy industry.

Table 2: Summary of the P.V. system in Oil and Gas field (Choi et al., 2017).

Site	**Midway-Sunset Oil Field**	**Kern River Oil Field**	**Louisiana Bayou Oil Field**
Country	USA	USA	USA
Peak capacity	500 kW	750 kW	17.85 kW
Operator	Chevron Texaco	Chevron Texaco	Kyocera Solar

The photovoltaic energy system has a growing market value. For industrial usage, it is beneficial due to no tax cost. But if there is an existing solar thermal energy system, then the photovoltaic system is not needed. Many researchers marked solar energy as a much better option than P.V. (Choi et al, 2017).

Geothermal Energy

A geothermal energy source is needed to operate a geothermal power plant. Geothermal energy being a source of thermal energy is not a new concept, but its feasibility as a power source for industrial scale is not known to many people. But, now environmental awareness and the new wave of support for renewable energy have largely changed the existing norms. In 2015, geo-energy was generating around 12.8 GW of power worldwide. If a cost-benefit analysis is done, it makes a huge prospect with a 10% benefit. Many countries, such as the U.S., El Salvador, Kenya, the Philippines, Iceland, New Zealand, and Costa Rica, use this energy source to generate electricity. Using the earth's thermal power can surely be benefited from the environmental point of view and reduce overall offshore plant operating costs. However, a key challenge to use this energy source is the location of the offshore plant itself. If such an active geothermal site is not present near the offshore platforms, then this technology may not be directly useful to the plant itself. However, still, it may power up the nearest industrial complexes.

Geothermal power has a tremendous potential to give moderate, clean energy that reduces the emanation of ozone-depleting substances, for example, carbon dioxide (CO_2). One of the most developed offshore rigs for deep subsurface wells is the Super 116E (Enhanced) Class lifting versatile offshore drilling platform. This platform uses geothermal energy and is designed to work in water depths of up to 106 m (350 ft), with a capacity of drilling up to 10,000 m (30,000 ft). (Offshore-mag, 2018). At Iceland, Deep Drilling Project (IDDP) on the country's Reykjanes Peninsula completed drilling at an estimated depth of 4,659 m (15,285 ft), with the possibility of opening up new areas for geothermal energy utilization (Offshore-Mag., 2018). So, geothermal energy is being used for offshore platforms as well.

Tidal Energy

Tidal energy is also known as tidal power. It is a form of hydropower. Tidal energy is not used widely, but it can be an ace for future electricity generation because tides are generally more predictable than other renewable sources, such as sun and wind. Tidal energy can be the most efficient renewable energy source and easy to use for an industrial operation like offshore platforms. Solar and wind energy depends on the weather. It may not be possible to gain energy constantly from these two sources. But tides are a daily event for the ocean. This occurs due to the earth-moon attraction force, and it takes place twice a day. Electricity can be produced from tidal force throughout the year, and it does not drastically pollute the marine environment.

Connecting the tidal barrage with offshore rigs can supply a sufficient amount of energy. Figure 2 displays an illustration of the tidal barrage system, and Figure 3 highlights the key locations around the world that have the potential for such kind of technology. It needs a high installation cost, which ranges from the U.S. $1.3 to $1.8 million.

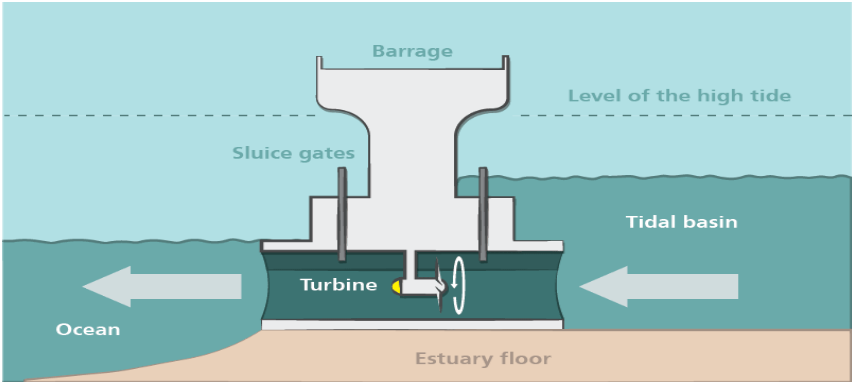

Figure 2: Illustration of a tidal barrage system (Renewable energy: Hydroelectricity, 2020)

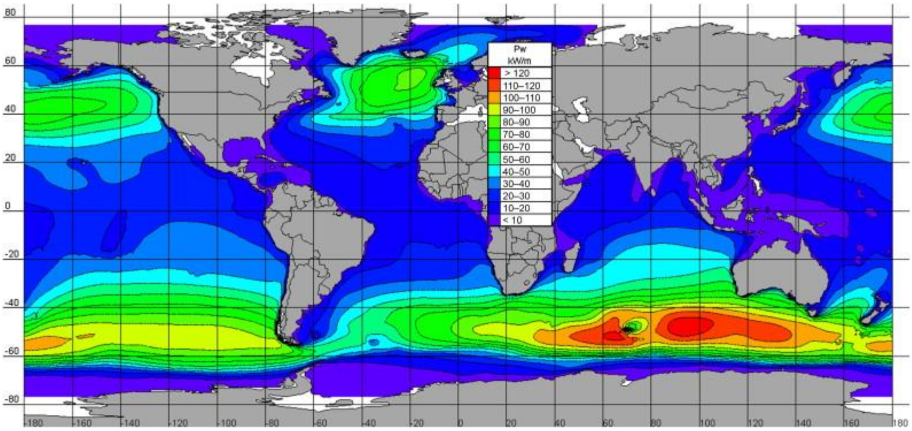

Figure 3: Tidal energy prospect across the world (Alcorn, 2014)

Because of the offshore platform's location in the sea and the constant battering of waves it would face, there is a possibility of harnessing green energy from the tidal waves. The harvested energy will, after a while, offset the initial investments made and generate revenue. Currently, South Korea uses tidal energy the most. Sihwa Lake Tidal Power Station in South Korea is the largest tidal power plant in the world; it can produce 254 Megawatt electricity per year. La Rance Tidal Power Plant of France and Swansea Bay tidal power plant of the UK are jointly the second largest tidal power plant with 240 Megawatt capacity. (Power-technology, 2020). The United Kingdom is performing research constantly to make this technology more efficient for general use. Already they are producing a large quantity of energy with this technology. Therefore, it is practical to use it to power up an oil-gas rig with this technology through subsea cable.

Scientists are thinking one step further and trying to build a hybrid marine power plant, which is a combination of wave and tidal power. Researchers from the University of South Carolina are working on this too (Tidal Energy, n.d.).

Wave Power Energy

Many scientists are working on the wave power development process. Over 50 types of devices are working in wave energy progress, including oscillating buoys, floating ducks, flaps, and enclosed chambers. Engineers are working on approaches to expand power yield, improve proficiency, diminish the natural effect, upgrade material hardness and stiffness, cost-effectiveness, repetitive expenses, and guarantee of survivability and sustainability.

Hypothetical expectations of the energy produced by wave energy converters are being approved through lab-scale physical model investigations and field tests. Instances of the most recent wave research facility offices incorporate the round wave tank, FloWave, Edinburgh, and the rectangular wave bowls at Shanghai, Plymouth, Cork, Trondheim, and Ghent, etc. Besides, field tests of wave energy converters can be found at WaveHub and EMEC in the U.K. (Lewis et al., 2012).

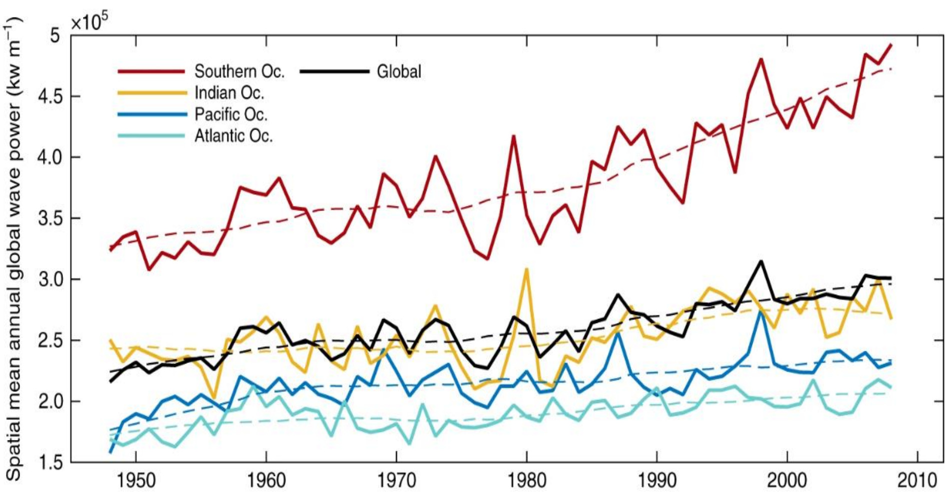

Figure 4: Increase in global wave power as a consequence of oceanic warming (Reguero et al., 2019)

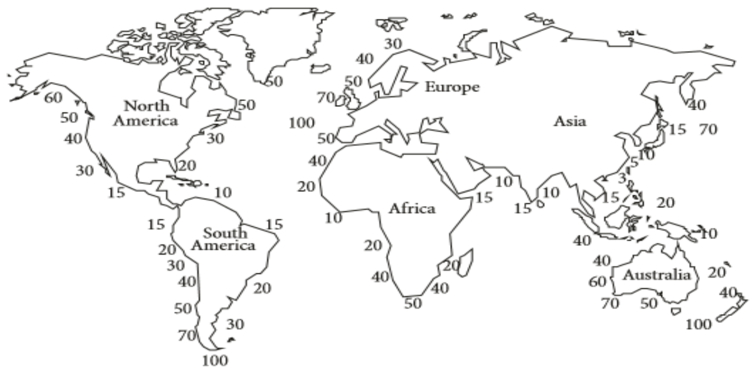

Figure 5: Approximate global distribution of annual mean wave energy density (kW/m) (Chen et al., 2013)

Figure 4 points out the increase in the possible wave power as a function of increasing sea temperature. Figure 5 shows the most suitable locations around the world for cultivating the maximum amount of wave energy. The advantage of the offshore wave energy extraction system is the wave vitality and monetary advantages can be obtained through a high energy density in deep water.

However, offshore wave energy extraction systems' construction and maintenance are expensive and difficult due to the unpredictable ocean condition. The system might depend upon a solid wave hasty burden (e.g., storm or typhoon) and thereby damage by peak pressures. Since 95% of the fresh wave energy is between the water surface and 7 meters under the water surface, this energy can generate power for the offshore structures (Barstow et al., 1997).

Wind Power Energy

Offshore wind-turbines were innovated like coastal wind turbines, which developed from windmills utilized for power creation. Offshore wind turbines commonly comprise of three sharp edges that turn about a center point and are like land-based wind turbines. Inland and offshore wind innovation are quickly developing, with the largest being SeaTitanTM having a capacity of 10 MW wind turbine of American Superconductor (AMSC) with a center point tallness of 125 m, rotor distance across of 190 m, the rotational speed of 10 rpm, and edge tip speed near 100 ms^{-1}. It seems achievable to upscale individual breeze turbines to 20 MW with 250 m rotors (Fichaux et al., 2011). For example, Principle Power has introduced a 2 MW offshore wind turbine on a drifting stage off Portugal, with a drawn-out point of accomplishing an ultimate absolute limit of 150 M (Salvacao et al.,2013)

Norway is the leading way to use wind farms for powering offshore structures. It needs 16 terawatt-hours a year to power up offshore rigs all over the world. This vast amount of energy can be managed by using wind power. Wind power is the second most popular renewable energy on this planet. So a large group of industries is working to make this cheaper and feasible. Moreover, it will reduce thousands of tonnes of CO_2 per year. Many international companies are making models to use wind energy as an energy supplier of offshore rigs. Table 3 shows the wind power systems that have been used in oil fields in different countries around the world.

Table 3: Summary of wind power systems applied to oil fields. (Choi et al., 2017)

Site	Suizhong 36-1 Oil Field	Beatrice Oil Field	Utsira Nord Oil Field
Country	China	Scotland	Norway
Peak Capacity	1.5 MW	5 MW	6 MW
Operator	CNOOC	Scottish and Southern Energy, Talisman Energy	DNV GL of Norway

Hydro Power Energy

Initially, hydropower was used for mechanical processing, for example, grinding grains. Today, hydro plants produce power utilizing turbines and generators, where mechanical energy is generated when moving water turns rotors on a turbine. This turbine is associated with an electromagnetic generator, which produces power when the turbine spins.

Hydropower is being used for powering both offshore and onshore platforms. The installed overall hydropower limit is near 1000 GW, providing up to 3.5 TWh per year. Dams might be utilized for more than one century, and mechanical hardware might be refreshed following 50 years. The siltation of supplies might diminish the creation and adaptability of activity. Production may well rise from 3.5 TWh/year presently to 7 TWh/year by the mid-21st century and up to 9 TWh/year by the century's end. Five nations (China, Russia, Brazil, Canada, and Congo) have 40% of the world's potential (Nazir, 2014).

The expense per KWh might be in the range of 2 or 3 dollars for some future utilization with 1 or 2 cents for transport. For some plans, the cost will be in the scope of 5 cents during the first decades. An expense of 10 cents may be acceptable for such great quality that might be approved by the mid-21st century (Lempérière, 2011).

Biomass Power Energy

Most biopower plants use the combustion system. They consume biomass straightforwardly to deliver high-pressure steam that drives a turbine generator to make power. In some biomass industries, the separated or spent steam from the power plant is also utilized for manufacturing or heating purposes. These joined heat and power (CHP) system increases the efficiency of about 80%, from the standard biomass power with efficiencies of around 20%. Seasonal warming will affect CHP system effectiveness.

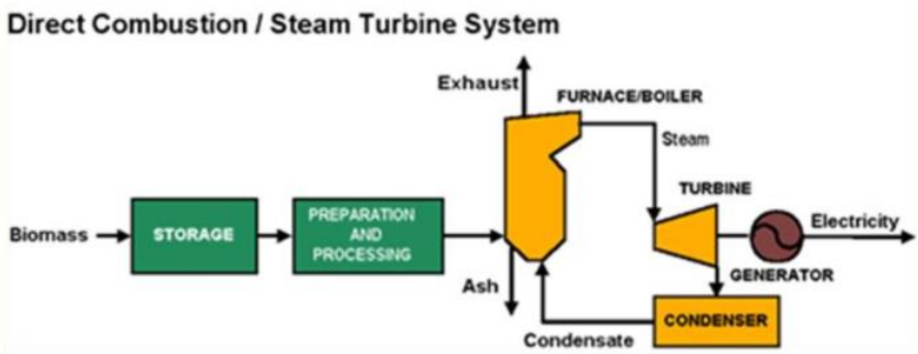

Figure 6: Biomass Power Generation Process. (U.S. Department of Energy, 2016)

The direct ignition system feeds a biomass feedstock into a combustor or heater, where the biomass is ignited with abundant air to warm water in a boiler to make steam. Rather than direct ignition, some technical methods gasify the biomass to deliver a burnable gas, and others produce pyrolysis oils that can be utilized to replace fluid fills. Boiler fuel can incorporate wood chips, pellets, sawdust, or bio-oil. Steam from the boiler is then extended through a steam turbine, which twists to run a generator and produce power (U.S. Energy Information, 2020). China Guangdong Nuclear Power Holding Corporation reported in November 2010 that it is contributing $65 million to construct a coordinated biomass power project by 2012. The undertaking involves a 19.8 MW biomass power plant fueled by wood and agricultural waste. And this power can be used in offshore platforms as well. (Hoong, N. W.,2012)

A study conducted in the Northern Arabian Sea using test panel exposure techniques for using biomass power energy in offshore platforms showed that around 100 species could be associated with fouling. Though in that study, the initial rates of bio-fouling were low because of soft body primary colonizers. With an expansion of exposure time, biomass development could worsen as calcareous living beings progressively got bountiful. At the Northern Arabian Sea, many offshore platforms have been built to produce and process oil and gas. A study was conducted on these structures to assess the impact of these structure's activities in the marine environment. After the study, it was suggested that biomass power could be used as an alternative for powering the offshore structures (Venugopalan et al., 1990).

Power Buoy

A key challenge to offshore Oil and Gas operations is to supply power to devices used in operations and monitoring. The present Power Buoy configuration is a consequence of extensive numerical simulations and wave tank testing. Its field preliminaries include a long time trial while associated with the power work in Hawaii, shorter arrangements in Scotland and Spain, and a 3-month development off the coast of New Jersey, which endured Hurricane Irene. Ocean Power Technologies offer a few adaptations of the PowerBuoy, such as the PB40, appropriate for providing moderate force requests, and the Autonomous Power Buoy-350 reasonable to providing low force requests (Mekhiche & Edwards, 2014).

Opportunities for using renewable energy in offshore structures

Renewable power sources are playing an important job in giving sustainable and clean energy while alleviating environmental pollution. The key opportunities are:

1. **Global Impact:** The usage of renewable energy is increasing globally day by day. Organizations like Tesla has developed Solar City and has declared to help power the whole island of Ta'u in American Samoa. While this is a little island with around 600 occupants, this activity is a significant sign of the sustainable power source (Ospina, 2016). The following table represents the power obtained from renewable energy sources.

Table 4: Power Obtained from Renewable Energy Sources (Sommer & Nat, 2013)

Source	Available energy in Northern scenario (North Sea)	Available energy in Southern scenario (Mediterranean)	The energy available at the ideal condition
Sun	23 kW	45 kW	55 kW
Wind	48 kW	37 kW	67 kW
Waves	106 kW	18 kW	319 kW
Total	184 kW	100 kW	441 kW

2. **Social Impact:** Using renewable energy gives social advantages like progression in innovations, and open doors for new jobs. The social impact of various renewable energy sectors is shown below in table 5.

Table 5: Social Impact of Renewable Energy (Kumar & Majid, 2020)

Technology	Impact	Magnitude
Photovoltaic	Toxins	Minor-Major
	Visual	Minor
Wind	Bird strike	Minor
	Noise	Minor
	Visual	Minor
Hydro	Displacement	Minor-Major
	Agricultural	Minor-Major
	River Damage	Minor-Major
Geothermal	Seismic activity	Minor
	Odor	Minor
	Pollution	Minor-Major
	Noise	Minor

3. **Environmental Impact:** Nonrenewable energy sources used for power generation in the United States and China has enormous natural consequences. In 2007, 2.4 billion metric tons of carbon dioxide (CO_2) was emitted from power plants in the United States, representing around 40 percent of the nation's energy usage related ozone-depleting substance (GHG) emissions. Around the same time, power generation in China produced a little more than 2 billion metric tons of CO_2, representing around 33% of its energy-related GHG emission. The burning of fossil fuel is also responsible for reducing different gases, such as nitrogen oxides (NO_x) and sulfur oxides (SO_x). Using renewable energy can avoid these types of occurrences. Some environmental benefits of renewable energy are less global warming, inexhaustible energy, low emission of CO_2 and other greenhouse gases, reduced air pollution, reduced water pollution, and so on.

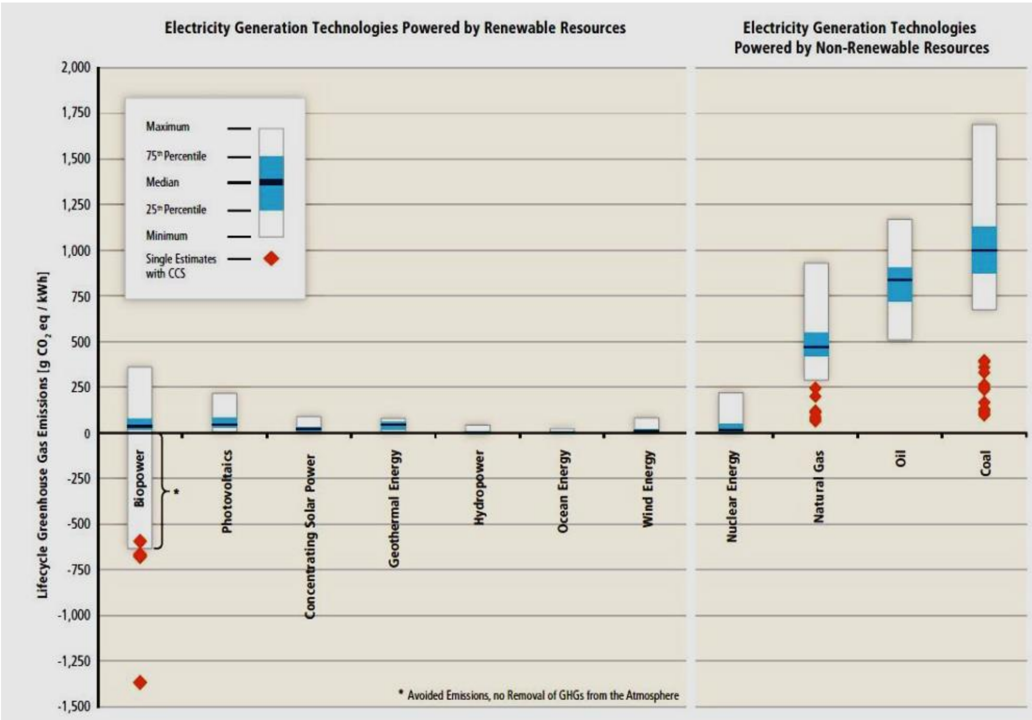

Figure 7: Electricity generation by Renewable and Nonrenewable energy sources (Union of Concerned Scientists, 2009)

4. **Business Impact:** Business insight is one of the major concerns behind this paper. Using fossil fuel may become a reason for financial losses, especially in offshore sites. Nowadays, it takes a huge cost to transport fuel oil for the offshore structures from onshore to the sites as transporting of oil does not occur at a low cost. And if an oil tanker is sunk in the sea, then maybe the offshore plant may go out of production, and the company may also have to bear environmental damage costs. Although this is the worst-case scenario, fossil fuel usage to the offshore sites will certainly result in Carbon-tax. Currently, $15 is charged for emitting 1 ton of carbon, and the U.S. earns $80 billion from this revenue (Carbon Tax Center). So using renewable energy will save billions in tax and will make a profit for the company as well as for employees. The money will be saved, energy will be cheaper, and all will get a sustainable world. Table 6 shows the global renewable energy scenario by 2040 from that the business impact could be understood.

Table 6: Global renewable energy scenario by 2040. (Demirbaş, 2006)

Total Consumption (million tons equivalent)	**2001**	**2010**	**2020**	**2030**	**2040**
	10,038	10,549	11,425	12,352	13,310
Biomass	1080	1313	1791	2483	3271
Large hydro	22.7	266	309	341	358
Geothermal	43.7	86	186	333	493
Small hydro	9.5	19	49	106	189
Wind	4.7	44	266	542	688
Solar thermal	4.1	15	66	244	480
Photovoltaic	0.1	2	24	221	784
Solar thermal electricity	0.1	0.4	3	16	68
Marine (tidal/wave/ocean)	0.05	0.1	0.4	3	20
Total RES	13,655	17,455	29,644	4289	6351
Renewable energy contribution source (%)	13.6	16.6	23.6	34.7	47.7

Challenges of using renewable energy in offshore structures

Renewable energy-based technologies do come with several challenges. Some of these challenges are:

1. **Availability of Power**: This is the biggest concern for renewable energy. Solar or wind energy depends on the weather. At night solar panels will not work, or in cloudy or rainy weather, people might not get enough energy during the daytime. Again if the wind speed is very low, then sufficient energy cannot be harvested. In terms of geothermal energy, it depends on the geological conditions. And if there are enough resources to produce geothermal energy, still steam volume may fluctuate sometimes. So producing a certain amount of power at a constant pace may not be guaranteed.

2. **Power Quality Issues**: To run an offshore structure for extracting energy requires consistently high-quality power to ensure the network's stability and efficiency. Current renewable energy sources cannot fulfill all the requirements of powering the structure for now.

3. **Installation Cost**: The installation cost for renewable energy is generally high. This initial investment may be significant for personal household/ transport sectors using existing technologies. For large-scale industries with an issue of tax due to carbon emission or environmental pollution, this high installation cost-based technology returns to profit in the long run by reducing carbon emission and pollution and reducing operational costs.

4. **Political Issue**: There remains a strong political lobby group for the continuation of traditional fossil fuel-based industries. However, fossil fuels are depleting at a rate higher than ever before. It is wise to plan for the future and invest and initiate renewable energy-based offshore platforms, and such early steps will put a country forward in the race to secure energy demands.

5. **Evaluation Process:** There are some challenges to the evaluation of the technologies as well. However, it requires several important factors to be considered. From Table 7, the evaluation of renewable energy technologies can be understood.

Table 7: Evaluation of renewable energy technologies. (Delyannis & Belessiotis, 1996)

Criterion	Solar thermal energy	Photovoltaic	Wind energy	Geothermal energy
Suitability for powering desalination plants	Well suited for desalination plants requiring thermal power	Well suited for desalination plants requiring electrical power	Well suited for desalination plants requiring thermal power	Well suited for desalination plants requiring thermal power
Site requirements and resources availability	Typically good match with a need for desalination	Typically good match with the need for desalination	Resources are location-dependent	Resources are limited to a certain location

Continuity of power output	The output is intermittent (energy storage required)	The output is intermittent (energy storage required)	The output is intermittent (energy storage required)	Continuous power output
Predictability of power output	The output is relatively unpredictable	The output is relatively unpredictable	Output is very unpredictable/ fluctuates	Output is predictable

Conclusion

This work offers a detailed review of the existing capability and limitations of using renewable energy for offshore structures. Offshore energy sources will become the key source of extracting energy for the foreseeable future. For extraction of energy, the offshore structures themselves require a large amount of power to operate. For example, each year, around 16 terawatt-hours of electricity are needed to globally power up the offshore oil and gas platforms, equivalent to Croatia's whole year's residential power utilization. Therefore, renewable energy technology is the ideal option for powering up this major industry while reducing environmental pollution. Many renewable technologies are currently available, each having its unique set of pros and cons. By selecting the right sets of technology discussed in this paper, a green and energy-efficient future may be implemented.

Recommendations

To overcome the addressed challenges and obtain the opportunities in powering offshore structure, the following recommendations are suggested for offshore structures' powering:

a) For powering the offshore structures, more than one renewable source can be used. For example, wave and wind energy can be used together.
b) There should be backup arrangements for power supplies powered by nonrenewable energy sources to be used for emergencies or when renewable sources are temporarily unavailable.
c) For renewable energy to be manageable and user-friendly, technical issues must be resolved. Unfriendly impacts must be distinguished, and relief estimates must be planned before renewable device deployment happens.
d) In offshore production, by using renewable energy, the production cost can be reduced. However, since the installation cost is usually very high, the initial phases of this modernization process may be initiated by steps.
e) Data science and artificial intelligence is an inevitable part of modern industrialization. Implementing data science and artificial intelligence in the offshore sector will help to make more efficient decisions to power the structures.

f) Time Series Forecasting is a popular method to forecast future demand and supply. Energy demand can be forecasted according to operations and can be compared with the production or energy supply. It will be much more comfortable and economical, managing the whole system.
g) For long-distance offshore platforms, a DC transmission system from onshore is a well-known backup plan. It will be helpful in critical moments. And there are many ways available to produce DC power supply using renewable energy sources described throughout this paper.
h) Some high energy demanding machinery or processes may not be available or may not work with a renewable energy source. Such equipment should be continued to be used with fossil fuel-based energy until renewable energy-based efficient machines are developed.

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