DEPARTMENT OF MECHATRONICS AND ROBOTICS

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Comprehensive review of Sustainability in Offshore Wind power

Sustainable Development Assignment

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1 Introduction

Human began to utilize the fossil resources thousands years ago, and the booming of large scale use could be traced to the first industrial revolution. However, due to concerns of the exhaustion of fossil, the researchers in Europe started evaluating the potential of wind power as an alternative in the 1980s [1]. Eleven years later, the first 220 KW offshore wind turbine equipment came to its birth in Danmark, marking the advent offshore wind power era [1]. After the millennium, offshore wind industry has been booming and advancing in an unbelievable speed ranging from business to manufacture till now [1]. After the facing of Sustainable Development Goals (SDGs), the requirement and examination of one technology becomes more dimensional and stricter. Despite its parallel with the most goals of SDGs, offshore wind power can damage the environment as well. This paper will first present the introduction, then the basic overview of such technology, next different views from society, after that the evaluation of its life cycle, and finally provides my suggestions in the end. All these sections will go through offshore wind power through different requirements of Sustainable Development Goals (SDGs).

Fig.1. Sustainable Development Goals.

2 Outline of the scope of wind power

Offshore wind power is a technology mainly constituting of offshore wind farm, transmission lines, motor, and terrestrial grid. Originated from Europe, around 90% of the offshore wind farms in the world are installed in Northen Europe [2]. In recent years, the wind farms in Asia have developed rapidly. With the longest coastline stretching over 18 thousand kilometers, China is one of the most abundant regions for offshore wind energy.

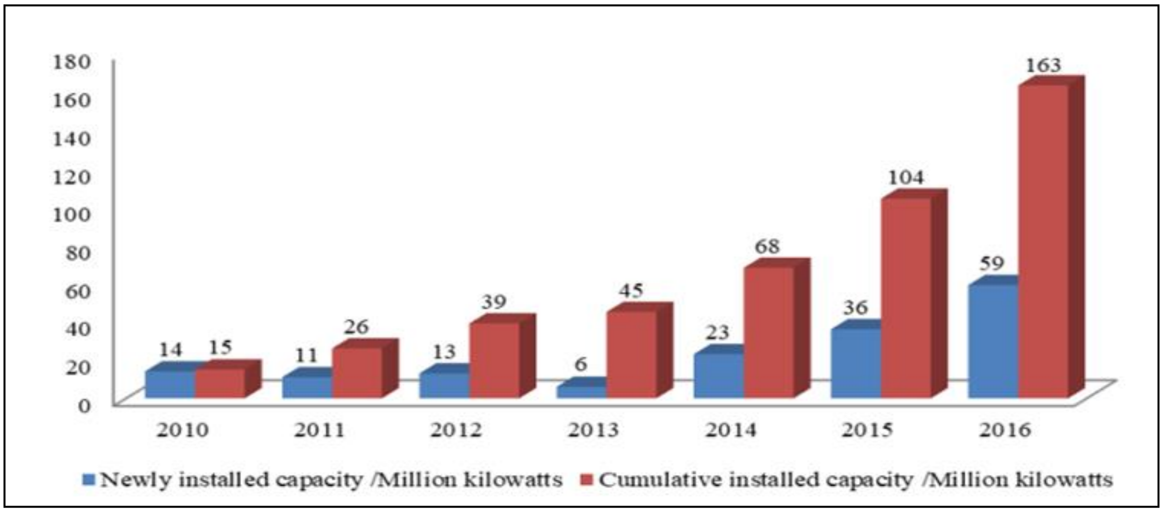


Fig.2. Development of offshore wind power in China until 2016 [1]

The past seven years have witnessed almost 11 times larger of the wind farm capacity in China, which is stunning and promising [1].

Moreover, offshore wind power includes its benefit of sustainability. Firstly, referring to the 7th goal of SDGs, it utilizes wind energy and does not depend on the consumption of non-renewable energy like fossil, reducing carbon emission which contributes to the soothing of global warming [3]. Secondly, based on 13th SDGs, offshore wind energy provides more stable cost in contrast of volatile price of fossil which depends on global market [3].

On the other hand, offshore wind power contains its own set of direct deficiencies. It brings about noise, which posing a threat to the living of marine animals. Then, Mangi [4] reported that the number of grey seals in the regenerating regions decreases because of noise. In addition, offshore wind power can lead to the death of marine birds.

Aside from these direct consequences, there exists some indirect influences brought by offshore wind power. The existence of wind farm increases the risk of ship collision. Sometimes, ships may transport chemicals or hazardous goods. If these materials leak into the ocean due to collisions with wind farms, the environmental consequence may be severe [5].

3 Framing of Product or System in a Sustainable Development Context

- Brief view

The construction of offshore wind farm has drawn the attention of different social classes, ranging from the government to the consumer. The pursuit of sustainable development of it is under consideration and evaluation by everyone.

- National policy

Regarding Chinese government, "13th Five-Year Plan for wind Power Development" proposed that promoting offshore wind power practice is indispensable, and emphasize on the development of offshore wind power in Jiangsu province with the construction scale will reach 10 million kilowatts [6]. Though the overall policy is ambitious, the large cost caused by operation and maintenance makes it susceptible for deficits, challenging the 9^{th} SDGs and becomes a bottleneck of the advancement of offshore wind power in China.

- Groups and individual investors

For enterprises and investors, on account of the high cost mentioned in the preceding paragraph, the constant passion of investing requires the government to subsidize for them [6]. Without continuous high allowance, it is hard for enterprises and investors to support the enhancement of such technology in China in the long term, impacting the 8th SDGs.

- Innovation orientation

It is true that the geographical trait of China possessing the long coastline provides huge potential holds vast potential for offshore wind power. Yet, this technology is not so complete in China. For example, variance of weather can lead to the delay of operation on sea [7]. According to Fu et al. [3] discovered that the large capacity AC electricity transmission will make the capacitor generator much more reactive power, diminishing the effective transmission efficiency. It is essential to break out the hinder of this technology, also better supporting 7th SDGs by optimizing energy consumption for higher efficiency.

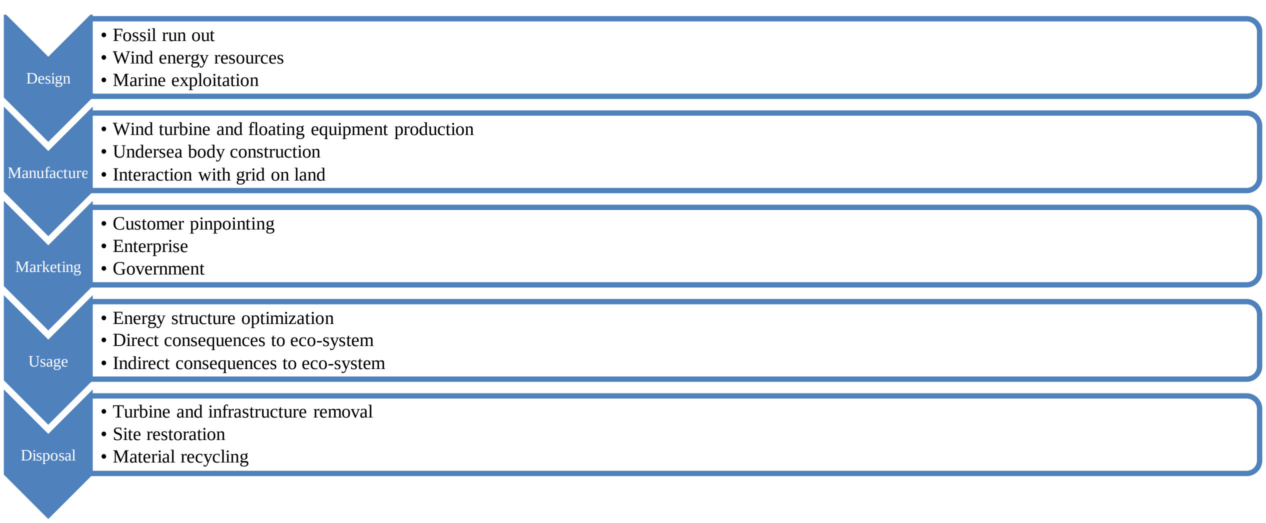
- Consumer perception

From the perspective of consumers, they are more optimistic about this technology. They think offshore wind power is conducive to reduce energy costs and promote the stability of power supply. As a renewable energy, it decreases the carbon emission, and echoes the eco-friendly vision of consumers, gaining continuous support from more and more consumers. Thus, for consumers, 13th SDGs can be fulfilled due to offshore wind power.

- Section summary

In summary, the offshore wind power is at a corner point where continued investment, innovation, and consumer support are crucial for its sustainable development. To better ensure the sustainability, it is suggested to take the life cycle of it into consideration, which illustrates which process of it will raise problems.

4 Process Flow Diagram of Life Cycle (Cradle to Grave)



5 Matrix of Life Cycle Stages and Sustainable Development Impacts

Development impacts

Lifecycle stage ↓	Depletion resources	Cost	Energy Usage	Waste	Disturbance of animals
Raw materials	Mental && Composites	High initial costs due to the premium materials && technologies	Energy-intensive due to extraction && transportation of raw materials.		
Manufacture	Steel && rare earth metals for turbines	Short term ↑ Long term ↓	High energy consumption in making turbine && assembly.	metal offcuts && composite material remnants.	terrestrial √ during installation
Use		Operation ↓ Reparation ↑	Very efficient energy usage with high output and minimal operational input after installation.		Marine √ noise && vibration, during installation
Disposal	material recovery && recycling	↑		dismantling && landfill	temporarily Marine √ long-term Marine ×

6 Scoring Matrix of Sustainable Development Impacts

Lifecycle stage ↓	Depletion resources	Cost	Energy Usage	Waste	Disturbance of animals
Raw materials	Mental && Composites 3	High initial costs due to the premium materials && technologies 5	Energy-intensive due to extraction && transportation of raw materials. 4		
Manufacture	Steel && rare earth metals for turbines 4	Short term ↑ Long term ↓ -2	High energy consumption in making turbine && assembly. 5	metal offcuts && composite material remnants. 3	terrestrial √ during installation 2
Use		Operation ↓ Reparation ↑ 1	Very efficient energy usage with high output and minimal operational input after installation. -5		Marine √ noise && vibration, during installation 5
Disposal	material recovery && recycling 3	↑		dismantling && landfill 3	temporarily Marine √ long-term Marine × 1

7 Design Opportunities

- Begin with SDGs

Before the analysis of offshore wind power, it is necessary to evaluate such technology through SDGs. In the objectives issued by SDGs, they can be divided into three main categories which are environmental sustainability, economic sustainability, and social sustainability. This section will go through offshore wind power through these three classes first, and then analyze the deficiencies respectively, and finally present some general solutions as well.

- Environmental Sustainability

✧ SDG 7 (Affordable and Clean Energy)

The main issue regarding this criterion lies in the high cost of exploiting offshore wind power. Although there is no specific cost of utilizing wind energy, the large cost generates from the equipment. The total construction not only demands the undersea cable and boats for tackling with outrage, but also requires high investment on wind turbines. Li and Wang [2] found that the total cost of building an offshore wind farm requires two to three times of cost compared with 450 to 500 million Yuan of onshore wind farm.

✧ SDG 13 (Climate Action)

By reducing greenhouse gas emissions through clean energy production, offshore wind farms contribute to efforts against climate change. According to Li and Wang [5], offshore wind power will neither emit carbon dioxide to the atmosphere nor waste the water resources as a renewable energy.

✧ SDG 14 (Life Below Water)

The environmental impact on marine ecosystems must be carefully managed. Aside from the damage to marine mammal, this subtitle will provide a specific view into the impact of offshore wind power to benthic ecosystems. Mangi [4] found that the construction of offshore wind farm will bring about the increasing turbidity and the resuspension of sediment that can suffocate the benthonic organism, leading to the decrement of the water quality due to the release of organic by decomposition of benthos.

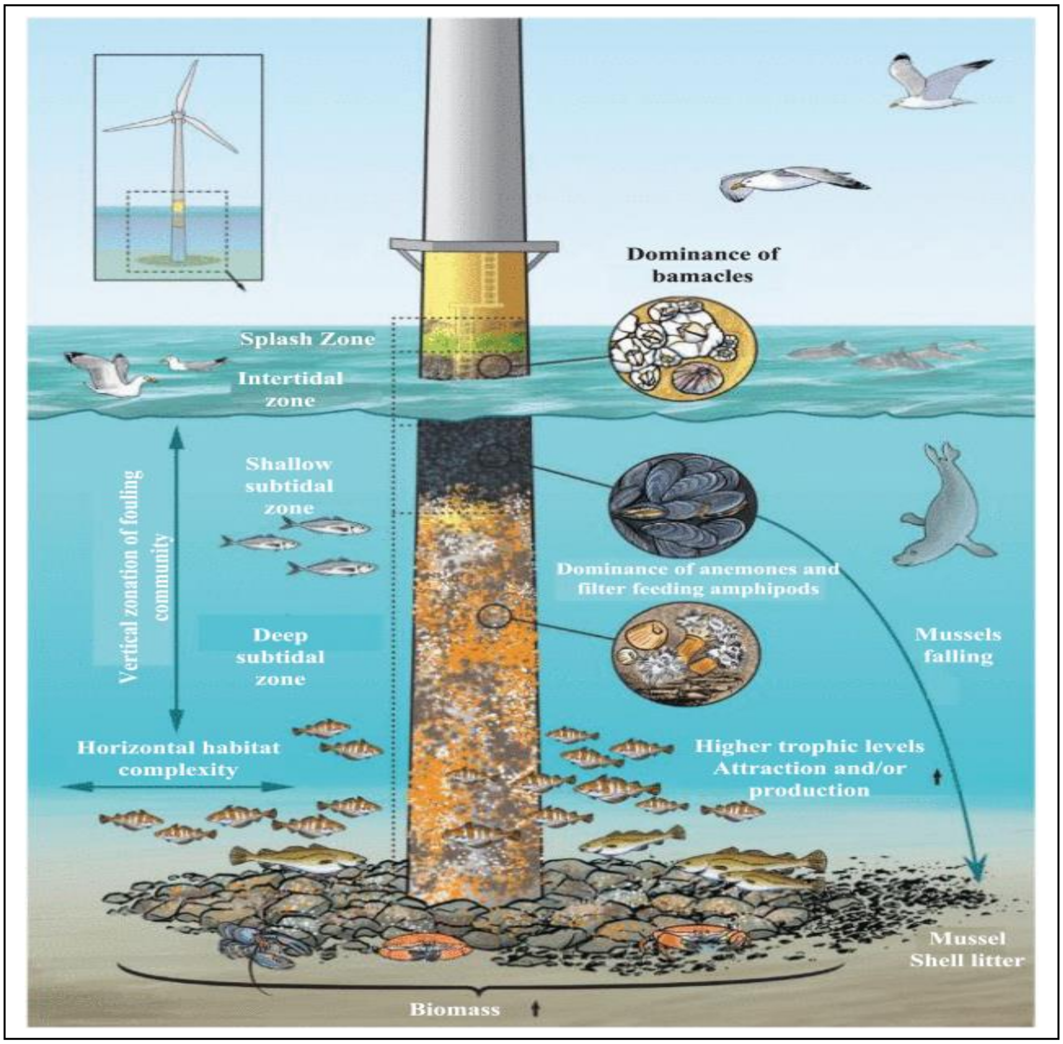


Fig.3. Damage of offshore wind power to marine ecosystem [8]

✧ SDG 15 (Life on Land)

While it is primarily relevant to marine ecosystems, it is true that the manufacture process is finished on the land and can contribute to some disturbance to terrestrial ecosystem. Considering its wind turbine components such as towers, blades, and nacelles, the manufacture of these facilities can consume significant amounts of land and resources, potentially impacting terrestrial ecosystems. Moreover, the location of these factories can lead to deforestation, habitat loss, or changes in land use patterns.

- Economical sustainability

✧ SDG 8 (Decent Work and Economic Growth)

Admittedly, offshore wind power can create job opportunities. During the construction, it involves site preparation, installation of turbines, and infrastructure of substations and transmission lines. Regarding operation and maintenance, it also requires a steady workforce to manage and maintain the wind farms. However, whether these jobs are stable and can last long are waiting to be evaluated. Also, considering the societal factors, whether offshore wind power can ensure fair working conditions, and adherence to labor laws which might boost economic growth are also unknown parameters.

✧ SDG 9 (Industry, Innovation, and Infrastructure)

The innovation of offshore wind power is urgently needed, particularly for China. The updating of equipment of offshore wind turbine is almost ground to a halt, and it is necessary to achieve the breakthrough by researching on deepwater offshore wind power [1]. According to Afridi et al. [8], the Floating offshore wind turbines (FOWTs) may be the solution on accounting of their ability to take advantage of stronger, less turbulent winds in deeper waters. However, the challenges of such technology lie in the instability in complex Marine environments such as pitch flap flutter and rotor shaft vortices [8].

✧ SDG 12 (Responsible Consumption and Production)

The end-of-life cycle of offshore wind power might be enough to evaluate such criterion. It is nearly impossible to decommission an offshore wind farm without posing any threat to sustainability. Firstly, dismantling the construction 必然会 lead to the disturbance of marine animal. Secondly, how to recycle or dispose the materials particularly those materials that are not so easy to decompose such as Glass fiber reinforced plastic (GRP) blades [9].

- Social sustainability

✧ SDG 11 (Sustainable Cities and Communities)

When discussing the influence of offshore wind power to SDG 11, the flexible DC transmission technology is the key part, which directly decides the stability of power transmission between offshore wind power and the city. Admittedly, such technology is viewed as the future of offshore wind power, it contains its own sets of deficiencies such as the complex control process and high unit cost [3].

✧ SDG 17 (Partnerships for the Goals)

Partnerships here mainly means the role of government. Due to the large percentage of offshore wind power to the whole structure of economy, and the fear of deficits if not managed well, the support for offshore wind power is not adequate for its booming compared with its promising future as it stands.

- End with solutions

  Considering the deficiencies analyzed above, here are some suggestions on environmental, economic, and social sustainability. Firstly, to minimize the impact of offshore wind power to the environment, it is suggested to optimize the construction method and material selection, thus reducing the waste emission and pollution during the construction. Secondly, the government ought to reduce the cost of offshore wind power by promoting technical innovation and achieving best cost performance by scale effect. Thirdly, it is necessary to promote relevant science popularization lectures to raise the awareness of people.

8 References

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