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RISKS AND OPPORTUNITIES FOR DEVELOPING THE OFFSHORE FLOATING WIND POWER IN CHIA

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Abstract

The motivation for carrying out this project is based on China missed its 5GW target for offshore installations by the end of 2015 and the government has slowed the offshore wind turbine installations in the 13th Five-Year Plan due to the bottleneck of low output of electric production and high overall costs of offshore wind turbine led to the economic effect is not good. Then, the problem of proper time on developing the emerging technology offshore floating wind turbine in China need be solved.

The problem is solved according to market analysis and decision making analysis. By the Five-Force as micro environment analysis to give the strengths and weaknesses for the floating wind turbine, using the PEST to see the macro environment about opportunity and threat, then the summary with an overview of SWOT. Combine with MCDA and expected value analysis to get the advantages of floating wind turbine compare to onshore wind turbine and near offshore conventional wind turbine.

The outcome of MCDA and expected value analysis is that the optimal type option of wind turbines is the floating wind turbine, since it can get more benefits than others, especially in economic effect. However, there is one big technology risk for it, thus, now is not the proper time to develop it in China.

Preface

This report, titled "Risks and opportunities for developing the offshore floating wind turbine in China", has written by the group RISK 4- 1 as the M.Sc thesis of 30 ECTS points on the 10th semester at the Faculty of Engineering and Science, Risk and Safety Management, Aalborg University, Campus Esbjerg. The report has been composed in the period between 1st of February 2016 and 9th of June 2016.

This project is aimed at analysing if it is a proper time to develop the floating wind turbine in China now for solving the bottlenecks of wind power industry. This report contains relevant market analysis and decision making analysis. It is divided into five parts.

The report has used some sources that are mentioned in the Harvard reference style and listed in the bibliography part at the end of the report. The in-text references consist of quoting sources by the surname of the author followed by the year in which they were published, in brackets, at the end of each paragraph where they are used or quoted. Moreover, this report contains a list of acronyms, and their coinciding meaning relevant to the project at the beginning. Further, all tables and figures are numbered according to the order in which they appear in the text.

Aalborg University Esbjerg, 09 June, 2016

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Acronym

CRI	Commercial Readiness Index
GW	Gigawatt
IEA	International Energy Agency
MCDA	Multiple-criteria decision analysis
MW	Megawatt
ORE	Offshore Renewable Energy
R&D	Research and Development
TRL	Technology Readiness Level

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Part 1 Introduction

1.1The Renewable Energy Development Is Trend

With the warming of the climate and the changes of air quality make the world more and more attention to the protection of the environment. Thereby, renewable energy development has become an important trend. Until 2013 the renewable energy has accounted for almost 22% of global electricity generation, moreover, renewable sources share was foreseen that would be increased at least 26% in 2020 by the IEA's Medium-Term Renewable Energy Report 2015. The whole world all focus on the potential of renewable energy and is committed to develop it, China is no exception (IEA, 2016).

As China's economy will continue to grow over the next 20 to 30 years, the energy demand also keeps increasing for a long time. How to maintain enough energy to supply such economic growth is a problem that China needs to face. Although China has abundant energy resources, the high-quality resources are limited, such as oil, natural gas. Moreover resource distribution is not even so that is difficult to develop. China has abundant coal that dominates current energy system. However, this fossil energy has caused serious air pollution and the situation has appeared in recent years, for instance, the fog and haze. To this end, China must low the use of coal and other fossil fuels to improve environment and develop a more sustainable clean energy supply strategy—low-carbon energy strategy. Actually Chinese government has concerned the problem of environment protection. In 2011, the 12th Five-Year Plan has indicated that China will promote the low-carbon energy strategy, develop diversified clean energy on a large scale and adopt relevant measures to encourage changes in energy production and use. These clean energies include wind power, hydropower, nuclear power and other non-fossil. The government proposed the target for non-fossil energy sources that can contribute 15% in total primary energy consumption in 2020. All of these appear that the energy strategy in China will focus on diversified development and environment protection (IEA, 2011)

1.2 Wind Energy Industry in China

Due to the cost effectiveness and low environmental impact, wind energy industry is better choice to be developed as large-scale commercialization in China. There is nothing is limited by resources and lower environmental constraint for developing and utilising wind energy source. The growth of Chinese wind power is rapid, at the end of 2010, the wind turbine installed capacity have been reached more than 40 GW and the grid connected operation capacity was more than 30 GW. However, the contribution of wind power is very small compare to other conventional power generation technologies in China (IEA, 2011).

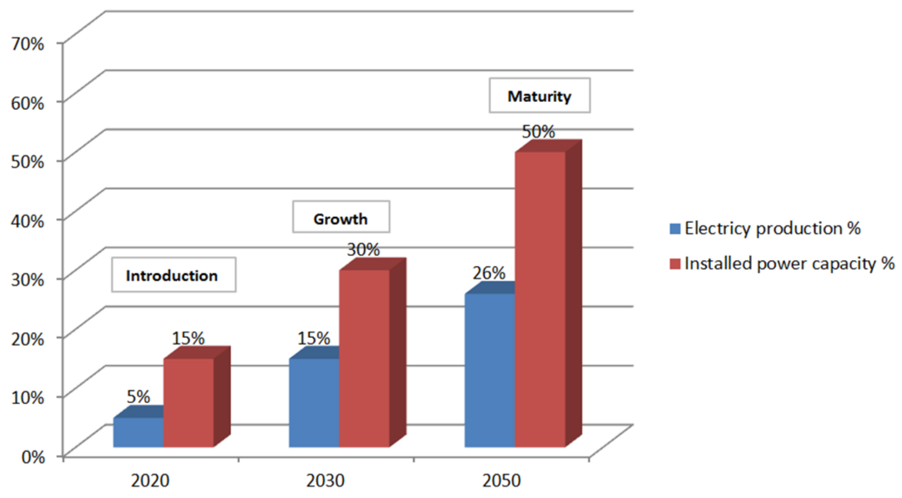
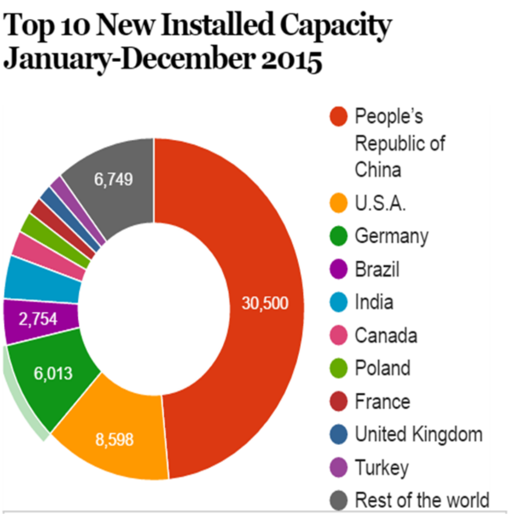


Figure 1: Vision of China's wind power industry (Data sources: IEA, 2011)

Figure 1 indicates the vision of China's wind power industry. Corresponding to the industry life cycle, China's wind energy industry is still in the introduction stage now. As the report of IEA that achieving the stage of maturity will be expected in 2050. By 2050, Chinese wind power could meet 50% of total installed power capacity, 26% of total electric power capacity and 17% of national electricity consumption. In the future, under the low carbon energy strategy, wind energy technology will continue to occupy the main position in the sustainable energy and should play an important role in the electricity supply field (IEA, 2011).

Up to now, China has become the biggest producer of wind power in the world. As Global Wind Energy Council's report, the installed capacity of China has met totals 145.1 GW, exceeding the Europe's 141.6 GW in 2015. This effort was driven under the support of Chinese government's clean energy strategy.



Country	MW	% Share
People's Republic of China*	30,500	48.4
U.S.A.	8,598	13.6
Germany	6,013	9.5
Brazil	2,754	4.4
India	2,623	4.2
Canada	1,506	2.4
Poland	1,266	2.0
France	1,073	1.7
United Kingdom	975	1.5
Turkey	956	1.1
Rest of the world	6,749	10.7
Total TOP 10	56,264	89
World Total	*63,013*	*100*

*Figures for the People's Republic of China are provisional.
Source: Global Wind Energy Council

Figure 2: Global new installed capacity in 2015 (Sources: ChinaFile, 2016)

The figure 2 shows that the global top 10 new installed capacity of wind power in 2015. Clearly, Chinese installation of new capacity accounts for almost 50% of the global total as 30.5 GW. In spite of this, coal power generation is still dominant. The main reason is grid connection problem that makes the potential of wind energy cannot be fully used (ChinaFile, 2016).

At present, China's wind energy development mainly focus on land-based wind turbines, since its technology is relatively mature and construction costs are lower than offshore wind turbines. Most of land-based wind farms were built in north and west of China according to the wind resource distribution.

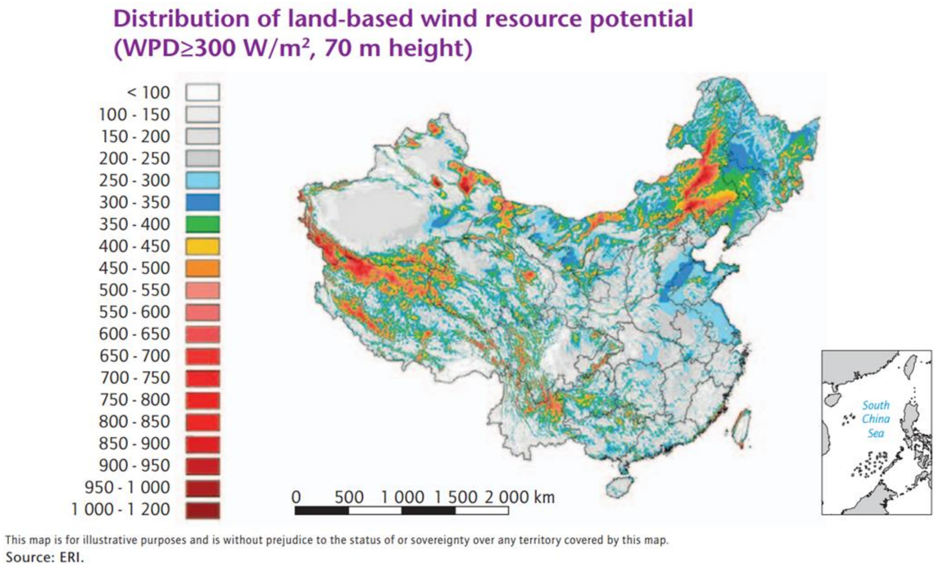


Figure 3: Distribution of Chinese land-based wind resource (Sources: IEA, 2011)

Figure 3 shows the distribution of land-based wind resource potential in China, that abundant wind resource concentrate in northern and west regions. But current economic development mostly is distributed in the areas of south and east in China; electric power demand in these areas is increasing rapidly, especially in east area. Thus electricity transmission from north and west to south and east is main grid connection structure. However, the two coastal economic boom regions, offshore wind power should be a good choice to support high electric power consumption.

1.3 Status Quo of Chinese Offshore Wind Power

China has rich wind resources around the south and east areas, particularly near Fujian, southern Zhejiang, Guangdong and Guangxi that are almost WPD≥500 W/m^2, see the data in figure 4. Therefore, in addition to northern Europe, China is also one of the few countries to develop offshore wind power.

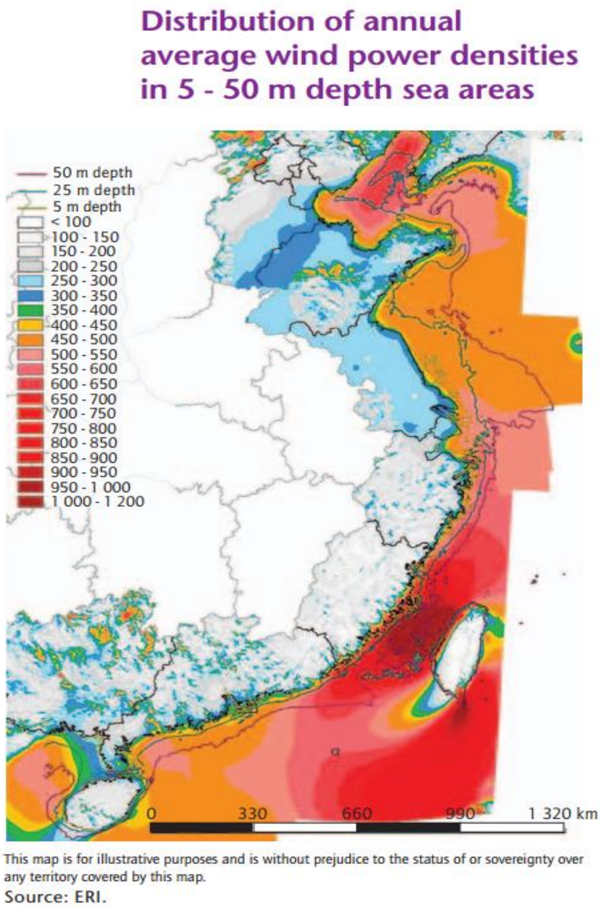


Figure 4: Distribution of Chinese offshore wind resource (Sources: IEA, 2011)

At present, China's offshore wind turbines were mainly built in the near offshore, such as intertidal area, the water depth in these areas generally is 5 meters to 25 meters; because of the wind turbine technology is relatively mature in the water depth. Such, the offshore wind resources cannot fully exert its potential (IEA, 2011).

In 2014, China had a rapid growth in offshore wind power industry. But the country missed its 5GW target for offshore installations by the end of 2015. Besides, Chinese government has planned to slow the offshore wind turbines installation in the upcoming 13th Five-Year Plan. The main reason for slowdown of wind turbines installation is the economic effect is not good. The investors have little chances of making profit due to the higher costs. Generally the overall cost of an offshore wind turbine project is to be twice that of an onshore one. As described above, yet a majority of wind power projects were built in Chinese coastal shallow waters, the wind is weak in there, so the output of electric power production is not enough to achieve the economic effect for investors. To get strong winds, the wind turbines have to be constructed in the offshore areas with deeper water, where the water depth is 40 meters or above. Actually China owns most deep-water areas, such as the Yellow Sea, the East China Sea and the South China Sea. The average depth of them is more than 40 meters. Besides, the seabed of China is mostly soft soil foundation which makes it more difficult for fixing generator foundation. Thus, the plan of the floating wind turbine system introduction and development perhaps is one ideal way to Chinese offshore wind power industry (Yang, 2015).

Part 2 Problem Formulation

2.1 Problem Definition

According to above introduction, it is brought an issue that offshore wind power development has not achieved the expected effect in China so far. The government has been aware of this issue and has lowered the speed of wind turbine installation in the near offshore. Then, now China needs to consider accelerating the development of offshore wind turbine on the deep sea or to expand on the onshore wind power, or as soon as possible to resolve the bottleneck of near offshore wind turbine.

Actually in 2011, China has concerned to start the wind farms in deep-water (50m – 200m) with floating turbines from 2020. But now the plan seems that maybe need to be planned ahead of time. This project will be studied for potential market opportunities and relevant risks of developing floating wind turbine in China aim to current issue mentioned above. That includes the situation of global development of floating wind turbines, market opportunities in Chinese wind power industry and the possibility of application of floating wind turbines (IEA, 2011).

Thereby, the main problem is formulated as:

Is the time to develop offshore floating wind turbine in China?

In order to answer this main problem, following three sub-questions should be solved:

1) How about current market development of offshore floating wind turbine?
2) Which advantages the offshore floating wind turbine has compared to onshore and near offshore conventional wind turbine?
3) Which risks China will meet if advance the development of the offshore floating wind turbine now?

2.2 Delimitation

This report is to see if it is the proper time to China to develop the floating wind turbine now and is limited to the business view. Thus, the project will not look at other sections, such as detail technology description, marine information etc., neither will it look at worker safety operation side. Furthermore, the market analysis is only focus on the wind turbines industry of China, will not involve other types of renewable energy such as solar, nuclear.

Additionally, during the report composed period, the 13th Five-Year Plan of China has not been formally introduced, therefore, the view and strategy description all based on 12th Five-Year Plan which was conducted from 2011.

2.3 Outline

This report is divided into five parts. It starts with the introduction about the wind energy industry. Firstly to see the renewable energy is the trend in the world, next the wind energy industry of China is introduced, followed by the offshore wind power description.

In the second part, the main problem is formulated that is the time to develop the floating wind turbine in China based on part 1 and three sub-questions followed for solve. Another, main methodologies of this report are made to carry the project are described as well.

The solution part is initiated from the marketing analysis that carried out in part 3. It includes micro and macro environment analysis and an overview of SWOT for summary. Following the marketing analysis, one MCDA tool is used to analyse the comparison among the onshore wind turbine, near offshore conventional wind turbine and the emerging floating wind turbine. Moreover, the expected value analysis is applied to verify the result of MCDA.

The last one part 5 is conclusion where the main problem and its sub-questions are answered in it.

2.4 Methodology

There are two parts are designed to solve the main problem about if it is the proper time for China to develop the floating wind turbine now, the marketing analysis and decision making analysis.

In the marketing analysis, starts with the micro environment analysis by the Porter's Five Forces of competitive position analysis. This is a simple framework and includes five forces which are supplier power, buyer power, competitive rivalry, threat of substitution and threat of new entry. This method is used to assess and evaluate the strengths and weaknesses for the floating wind turbine in the wind energy industry to see if it has attractiveness. Other words, it helps to see if the new technology floating wind turbine is potentially profitable (CGMA, 2013).

After Five Forces, one macro environment analysis is carried out by PEST that includes four elements which are political, economic, social and technology. This analysis can help to find out the opportunity for the floating wind turbine. Then the common tool SWOT is used to summarize and understand how to exploit the new technology's strengths to match market opportunity, and neutralise its weaknesses (CGMA, 2013).

For the decision making part, MCDA is mainly carried to measure three alternative types of wind turbine for finding the optimal type. MCDA is both an approach and a set of techniques, it can provide an overall ordering of all options, from the most preferred of stakeholders to the least one. There are five steps will be described, it is important to identify the stakeholders in the first step, since the stakeholder can influence and is influenced for the achievement of goal. The second step is to identify the preferences of stakeholders, followed by relevant criteria for assessing. Then the fourth step to evaluate the performance of criteria. The last step is about proposition of the preferred option (Communities & Local Government, 2009).

Part 3 Marketing Analysis

In order to overcome some key technological challenges in deep-water faced by offshore wind power, the floating wind turbine concept has been developed in Europe. This concept firstly occurred in the early 1970s, and it didn't start to research until the mid-1990s. In 2009, Hywind, the world's first large scale grid connected floating wind turbine with a 2.3 MW was installed by Statoil in Norway. After two years, WindFloat, the second large scale floating wind system with 2 MW wind turbine was developed and installed off the Portuguese's coast by Principle Power. Subsequently USA and Japan also have great interest in the floating wind sector (EWEA, 2013).

This emerging offshore floating wind sector needs to go through different stages of technological development before shaping commercialization. Commonly, the floating wind moves along one globally accepted benchmarking tool, Technology Readiness Level (TRL) index, for tracking progress and supporting development of a specific technology from basic research (TRL 1) to system launch and operation (TRL 9).With a great deal of research and development, the majority of technology risk can be eliminated while the technology moves through TRL 1 to 9. At the same time, some significant commercial uncertainties and risks can appear and remain in the demonstration and deployment phases. Commercial Readiness Index (CRI) as a tool was developed by Australian Renewable Energy Agency that used to measure the emerging renewable energy solutions (ORE, 2015). The figure 5 and 6 show how the TRL relates to CRI and along the technology development chain.

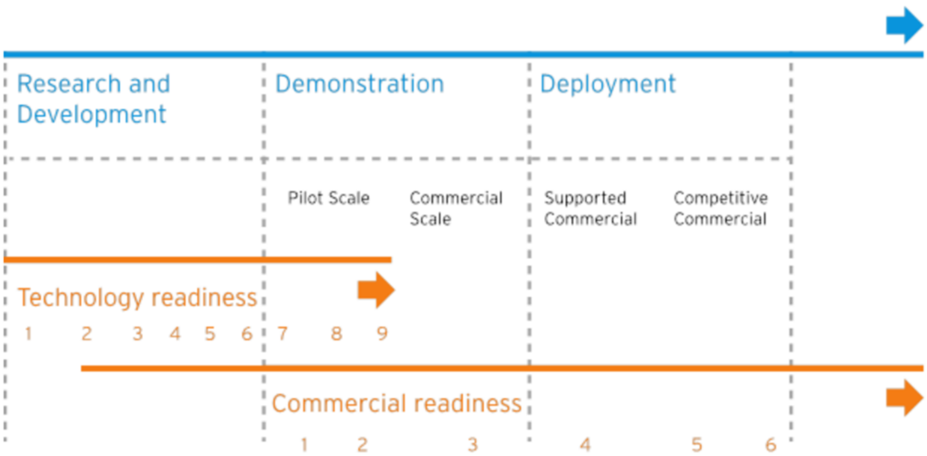


Figure 5: TRL and CRI mapped on the Technology Development Chain (Sources: ARENA, 2014)

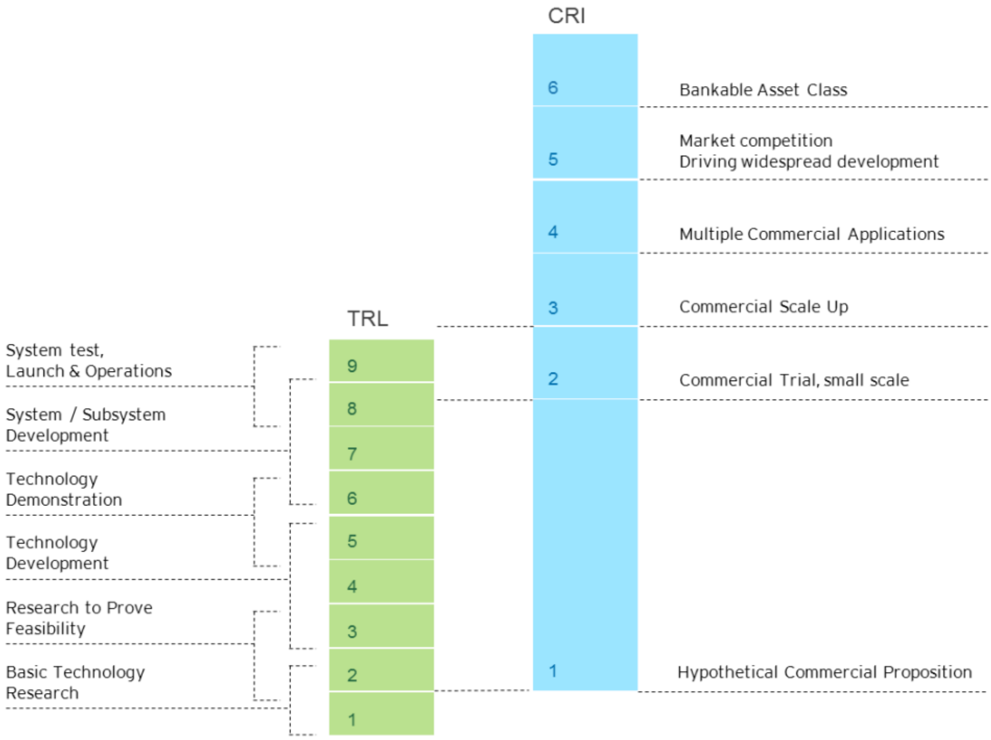


Figure 6: Relationship between TRL and CRI (Sources: ARENA, 2014)

As the ORE (Offshore Renewable Energy) Catapult's conclusion that current status level of global floating wind is CRI 2 - "Commercial Trial, small scale", and has potential to promote to CRI 3 "Commercial Scale Up". That means offshore floating wind technology has been recognized and can ready to go to the commercial market (ORE, 2015).

Currently, there are three main leading device concepts for deep offshore foundations are now progressing towards potential deployment:

- Hywind-- Spar Buoy: developed by Statoil -- at TRL 8
- WindFloat-- Semi-submersible: developed by Principle Power Inc -- at TRL 8
- PelaStar-- Tension Leg Platform: developed by Glosten Associates -- at TRL 4-5

An overview of offshore wind foundations is displayed in figure 7 as below:

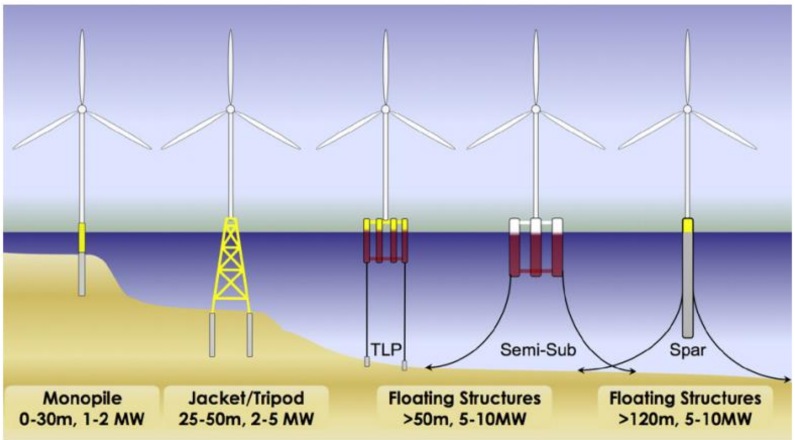


Figure7: Offshore Wind Foundations (Sources: Principle Power, 2015)

Then floating wind turbine as a business unit is an attractive industry? The following sections will study micro and macro environment analysis of the offshore floating wind market. Through these analysis to know which strengths and weaknesses exist in it as well as to find out the potential threats and opportunities.

3.1 Micro-Environment Analysis

The Five-force model is applied to analyse the micro-environment of offshore floating wind turbine in order to understand its competitors. Thereby, relevant weaknesses and strengths can be found out. Because the main problem of the project is about Chinese market, thus following analysis will be focused on China.

- **Industry competitors (Rivalry)**

The offshore floating wind turbine as a business unit, it will face two rivalries in Chinese wind energy industry, onshore wind turbine and near offshore wind turbine which have been operated now. The developers and government must understand the pros and cons of the three sectors, then consider if the floating wind sector is a better and attractive investment or not.

At present, onshore wind turbine occupies the dominant position of wind energy market, and the technology is relatively mature compares with offshore wind turbine. The offshore wind turbine is confronted with a lot of problems, for instance, inadequate technical standards are barriers for project planning, design and execution. Another, most offshore equipment are import, so the cost is expensive. Besides, higher installation and maintenance costs are also major factors in the impact of offshore wind efforts; not only in China, but also the leading of offshore wind power Denmark is aware of the cost problem (Yang, 2015).

Although there is a high rivalry in wind energy industry for offshore wind turbine, the emerging offshore floating wind technology may improve the weakness of costs gradually. The floating wind sector owns two key advantages, reduction of overall cost of wind turbine and less environment impacts. This technology can make developers to construct wind turbines in depth waters where previously inaccessible waters. These maritime spaces have stronger yet less turbulent winds. It actually is not necessary to build foundation for floating wind turbines. Moreover, the floating platforms can be commissioned and assembled at quayside that more flexible and safety for maintenance and operation works (Mellino, 2015).

- **Potential Entrants**

Barriers for enter into this energy industry are high regardless of which sectors. Each sector including floating wind all requires high investment in terms of both technology R&D and turbines construction. Besides, special technical innovation is required too for this kind of sectors. Now it seems that there is no new technology can exceed the advantages of floating wind turbine in the deep-water.

- **Power of Suppliers**

Almost all companies in this energy industry need to collaborate with each other. As developers of floating wind power are highly dependent on its suppliers, meanwhile, some key suppliers are also competitors for them in wind energy market and other renewable energy market. Suppliers in this industry are relatively monopoly, since they have the core and unique technology resources, such as Siemens and Vestas. It is also difficult for changing suppliers. For example, the suppliers might stop production of some components due to unprofitable, after all, offshore floating wind is an emerging sector, and it is trying to get the way of commercial benefits.

- **Bargaining power of Consumers**

The bargaining power is low for end electric consumers. As previously described, the process of industrialisation and urbanisation in China will continue over the next 20 years based on current Chinese economic development trends. Thereby the electricity demand will grow rapidly in the future, especially in eastern and southern areas of China. These important economic development areas are coastal cities and are very suitable for applying offshore floating wind power generation (IEA, 2011).

- **Substitutes**

In this high-end industry, technical development is key factor. It needs an endless stream of new technologies and innovations. Moreover, most of these technologies have patent, it is not easy to replicate. Thus, it is lower substitute risk for floating wind.

From above micro-environment analysis, we can know the offshore floating wind would become one new member of wind energy market in the near future. This technology can solve the issues that China has been met in the offshore wind sector, particularly in the costs. Moreover, it can lower the environment impact, such as land use, noise. However, at present phase, due to the lack of experience in floating wind turbine operation, thus the risks and costs are higher than onshore wind turbine.

3.2 Macro-Environment Analysis

The PEST analysis is a useful tool to analyse the opportunities for the floating wind power. It can scan the business and market circumstances to get the realization in which operations have been run in China and which will intends to enter.

- **Political**

Chinese government has always supported the development of offshore wind power, though the wording has been changed in the 13th Five-Year plan that from “actively push forward” to “steadily develop”. However, the development direction will not be changed. China needs a new strategy or technology to solve current bottleneck which came from near offshore projects. Besides, government also offers subsidies to clean energy in order to improve environment protection (IEA, 2011).

- **Economic**

As mentioned before, the stable Chinese economic development will continue in the future. The demand of energy market and electric consumption market will keep increased trend. Therefore, the current economic environment is good basis for developing new renewable energy technology, such as floating wind turbine.

- **Social**

With the climate warms, the popularity of environmental protection perception, China is more and more attention to renewable energy. People are more likely to support clean energy development. Floating wind turbines are built in the deep-water where is far away from residential areas. It further reduces the impact on the living environment of people. Hence it could get more rate of social support if China wants to start the floating wind projects now.

- **Technological**

In terms of technology in China is relatively passive. In addition to many technologies of offshore winds power are immature, such as wind turbines, installation, operation and maintenance; some devices have to be imported. There are only three types of deep-water offshore foundation for floating wind power in the world which have been verified. Therefore, if China wants to introduce floating wind technology now, then it is necessary to cooperate and learn with leading countries, technology research and development company (Bureau Veritas, 2016).

From above, the factors of government policies, economic circumstances and social impact all appear potential opportunity to floating wind power sector. But technology issue will be the main risk for investors and developers. Because of technology can influence overall costs and operations of project.

3.3 SWOT

Based on micro and macro environment analysis, an overview picture of SWOT (Figure 8) is used to summarize which strengths and weaknesses have existed in floating wind sector, which potential opportunities and threats are for developing offshore floating wind power in China.

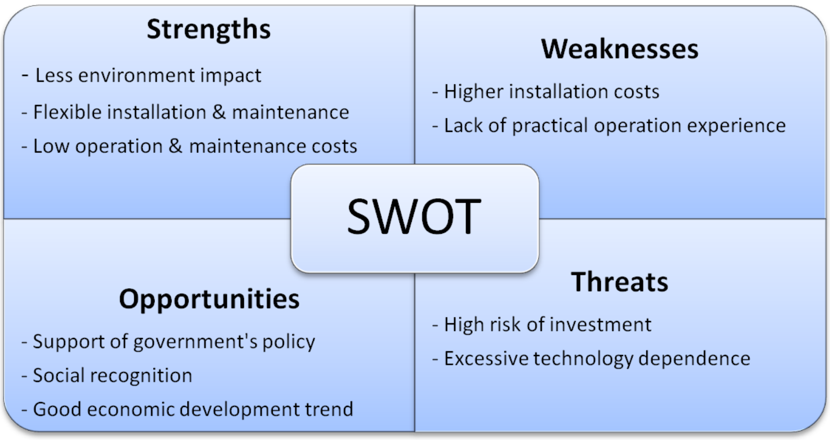


Figure 8: SWOT overview

Obviously, these strengths of floating wind power can match market opportunities. The advantages of less environmental impact will be supported and favored by Chinese government and public. In the long term, flexible and low-cost operation and maintenance way can bring better economic benefits. To learn the advanced technology with leading countries and cooperate with professional partners may reduce the risk of investment and overall costs. Besides, good cooperation can help to improve the weaknesses on lack of technological experience, avoid going the wrong way.

Part 4 Decision Making

Refer to current near offshore wind turbine development's bottleneck that high costs, low economic effects, China needs to consider whether the developing of the offshore wind turbines in the deep-water area should be ahead of schedule. The previous plan was open the floating wind turbine introduction in 2020 as described in part 2. There is no doubt that abundant wind resources make wind energy is an attractive industry. However, how to allocate the investment reasonably, utilize the resources effectively to obtain the maximum benefit is a selective problem that China is facing now. This optimization option is complex problem and is involved into monetary and non-monetary objectives.

Within Chinese wind energy industry, there are three sectors which are onshore wind, near offshore wind and further offshore wind. Each of the three sectors has its own advantages and disadvantages. Whether the emerging deep-water floating wind power is optimized and maximum benefit than others? Thus MCDA will be applied to analyse the problem in this part.

There are five main steps in the progress of MCDA will be described in the following sections (Communities & Local Government, 2009):

1. The aims of the MCDA setting, and identify stakeholders and relevant key players
2. Identify the options or preferences of stakeholders
3. Define the criteria for assessing the consequences of alternative options
4. Evaluate the performance of criteria follow step3
5. Propose the preferred options based on the evaluation outcomes

4.1 Step 1: Aims of MCDA and stakeholders identification

According to the previous description, the aim of use MCDA is to measure the effects of onshore conventional wind turbine, offshore conventional wind turbine and offshore floating wind turbine to find out the optimal type in this project.

Firstly key players should be chosen for the MCDA. Because of the key players are represent all the crucial perspectives in the analysis process. One important point, the stakeholders' values should be represented by key players who participate in the MCDA (Communities & Local Government, 2009).

In type options of wind turbine, the stakeholders certainly are government and developers. Their view of benefit and value is the main orientation for the decision making. Other key players should include electricity companies who provide power to users, suppliers who hold professional technology that could assist the decision analysis, investors who have capital and public users. See the figure 9 for the key players of wind farms as below:

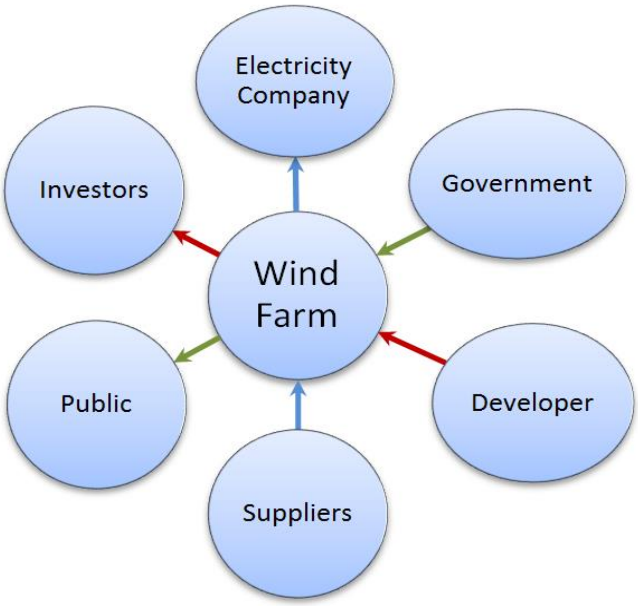


Figure9: Key players of wind farm

The vertical in the figure which connect by blue arrow lines is expressed players who within the supply chain of wind power operation. They bring the information about the expectation value of developer, the views of electric operators and suggestions of suppliers. The relevant suppliers include wind turbine manufacturers, various components producers; they can give some feasible suggestions about costs, equipment and technology. Electricity companies can give related advices and feed-in conditions are combined with the existing power grid and possible updated of power grid. For the green arrow lines indicate that government has liability to listen the voice from public, such as environment impact. The red arrow lines express the relationship between developers and investors what is the benefit. That means the developer has to concern the investors' interest.

Since these key players provide different kinds of information, so which are the more forceful to influence the decision making should be considered by the player's participation power in the analysis. Based on the important level of the key players and their impact level on the optimal type option of wind turbines, one key players' power analysis matrix was made as figure 10.

Key players' Power Analysis Matrix

Key players' name	Level of importance	Level of influence in the option	Total Score
Government	5	5	25
Developer	5	5	25
Electricity Company	3	4	12
Supplier	4	5	20
Investor	4	4	16
Public	3	3	9

Figure10: Key players' power analysis matrix

The matrix used Liker scale from 1 to 5; 1=No/Low, 2=Moderate, 3=High, 4=Very high, 5=Extremely high. Thus the result of high score, the power is higher.

Government is the decision maker of policy and use of sites; it will involve a number of relevant government departments, such as State Oceanic Administration, National Energy Administration and Ministry of Environmental Protection etc. Developer is the sponsor and main investor of wind power project, and is also the master of the whole project. Thus, the highest level of important and influence are both of government and developer that are marked 5 for each column. Secondly, supplier is the provider of advanced technology, high quality equipment and various components; the total power score is only next to government and developer. One major factor for wind power project is financial support. No funds project plan is just empty talk. Hence, the third position is investor whom has sufficient money. Electric company's information mainly influences the connection technology between wind turbines and grids, but the importance is not very high. The government generally listens to the views and attitudes of the public, especially in the living environment, health and safety and so on; the public is indirect effects on the option.

From the result of matrix score and at market stand, the type option of wind turbines has to be focus on the interests of government, developer and supplier. It may lead to three crucial factors which are the benefits of public, capacity of probability, and risk degree by the key players' power.

4.2 Step 2: Identification of the options of stakeholders

As described in previous part, China needs make an optimal option for solving current bottlenecks of wind power development that are high costs problem, low economic effects and electricity consumption. According to different shareholders' stand in the wind energy industry, there generated three options for the sustained and stable commercial development of wind energy.

1) The first option can be considered is still focus on the onshore wind turbine expanding, solving serious curtailment of wind power phenomenon and constructing cross regional power transmission channel as soon as possible to transport the wind power to power load centre in eastern China (Göß, 2016).

2) The second one is continue to research and develop the near offshore conventional wind turbine. To find out a solution to reduce high costs and improve low effects.

3) The third option is about the emerging floating wind sector. China will develop the wind turbine in the deep-water, introduce the floating wind turbine technology and start the plan of research and development.

4.3 Step 3: Identification of the criteria

For assessing the consequences of three options, some criteria need to be made as specific and measurable objectives. To make the criteria requires considering the core value what the floating wind turbine offers. Thereby the criteria can be identified for alternative options in terms of three crucial factors which described in step 1. The specification of criteria for the optimal type option of wind turbines as following:

- The level of maximizing **energy yield**
- The lower costs of **construction** and **O&M** (operation &maintenance)
- The level of **electricity consumption**
- Contributing to commercialized development with **standard mass production**
- The less of environmental impact (reduction of **land use**, low **noise disturbance**, less **visual impact**)
- The low risk degree that involved in **economy, technology and safety**

The more detail qualitative description for each option thinking about specific criteria is expressed on a performance matrix as table 1.

Performance Matrix

Options	Wind resources	Energy yield	Construction costs	O&M Costs	Electricity consumption	Potential of standard process & mass production	Land use	Noise disturbance	Visual impact	Economic risk	Technical risk	Safety risk
Conventional Onshore wind turbine	Moderate	Moderate	Low	Low	Low	Low	High	High	High	Low	Low	Low
Conventional near offshore wind turbine	Moderate	Low	High	High	High	Low	Low	High	High	Moderate	Moderate	High
deep water floating wind turbine	High	High	High	Low	High	High	Low	Low	Low	High	High	Moderate

Table 1: Performance Matrix for type options of wind turbine

All items are used high, moderate and low to represent the level of each criterion according to information introduction in Part 1 and market analysis of Part 3. These criteria are designed based on three crucial factors as described in step 1, capacity of probability, benefits of public and risk degree.

The criteria on the capacity of probability are designed based on a simple business chain as below:

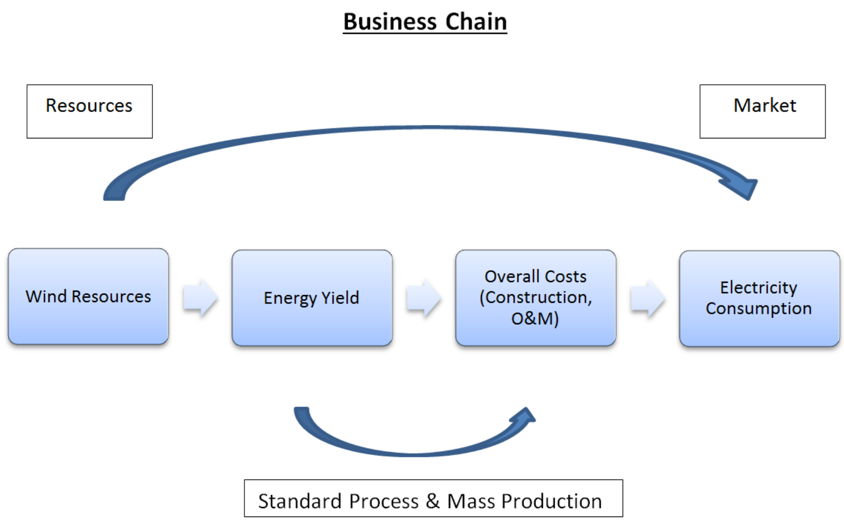


Figure11: Simple Business Chain of wind energy industry

To consider about how to earn profits from wind energy industry, the stakeholders have to see where the wind resources are rich, which type can bring high yields and low costs, and where can offer large market for electricity consumption. From figure 4 in Part 1.3, obviously offshore areas in eastern and south of China can get rich wind resources, especially in deep-water area, thus floating wind turbine is marked high. The floating wind turbine can be placed in the best wind resources areas since less location restricted ability, thereby its energy yield is higher than other two types. As introduced before, current overall costs of offshore wind turbine are twice onshore's, thus onshore type is marked low in both columns construction and O&M costs. However, as the floating wind technology continues to improve, it has the potential to reduce construction costs in the future. There is a foundation advantage for the floating wind turbine that is less dependent of variable factors, such as site specific, soil conditions, etc., therefore some same elements and equipment can be used almost anywhere. That means it is possible to actualize mass production and standard process for achieving the purpose of cost reduction. But other two conventional wind turbines are limited by variable factors, each element is custom made, it is difficult to perform mass production and standard process. China's rapid economic development regions are concentrated in coastal regions, so the electricity demand in these areas is higher than in the inland areas. The consumption space of offshore wind power is bigger than onshore wind power (Nilsson & Westin, 2014).

On the benefit of public is mainly focus on environment impact. The installation process of conventional wind turbine can generate the noise disturbance to the residential environment and marine mammals by many activities, particularly is the pile-driving process. But the foundation of floating wind turbine is relatively simple that it doesn't need piling, so it is less harmful for human and marine mammals. Besides, the sites of onshore wind turbine and near offshore wind turbine are closer to residential regions lead to the impact of visual sense (Ospar, 2008).

With regard to risk considerations, stakeholders can look at three aspects which are economy, technology and safety. These risks relate to the operation of the entire wind energy industry. Compare to the offshore wind turbine, the risk of onshore wind turbine is lower due to mature technology and experience. However, the floating wind turbine technology is a completely new field worldwide, thus it is the highest risk among the three type options.

4.4 Step 4: Evaluation of the performance of criteria

In order to achieve an overall evaluation on the optimal type option of wind turbines, the relative preference scales should be illustrated. The scales represent preferences for the consequences of options. Then weighting the scales for the relative importance and calculating weighted averages across the preference scales. In this thesis, a simply way is used as fix these scales at the two ends by the most and least preferred options on a criterion (Communities & Local Government, 2009). See the table 2 as below:

Scoring the options

Options	Wind resources	Energy yield	Construction costs	O&M Costs	Electricity consumption	Potential of standard process & mass production	Land use	Noise disturbance	Visual impact	Economic risk	Technical risk	Safety risk
Conventional Onshore wind turbine	50	50	100	100	0	0	0	0	0	100	100	100
Conventional near offshore wind turbine	50	0	0	0	100	0	100	0	0	50	50	0
deep water floating wind turbine	100	100	0	100	100	100	100	100	100	0	0	50

Table 2: Scoring the options for type options of wind turbine

The scoring is made by the most preferred option is assigned a score of 100, the least one is a score of 0 and moderate is given as 50. The different numbers represent the different strength of preference. In table 2, label preference scores are based on a high to low order for wind resources, energy yield, electricity consumption, potential of standard process & mass production. For example, the higher wind resources the better, and then the preference score is given is 100. The rest of criteria are to assign preference score from low to high. The means the criterion is marked as low, the score is 100; the marked high is allocated the preference score of 0. For example, the three risk criteria certainly are the lower the better, thus, which marked as low is assigned score of 100.

The units of preference should be equated as formally equivalent to judging the relative importance of the scales. Thus to use the right weighting procedure for making the judgements is meaningful. The method of 'swing weighting' is used for explaining weights for the criteria in this thesis. For the comparisons of differences on criteria should be allocated 100 points against the criteria as weights (Communities & Local Government, 2009).

To compare the differences between the most and least preferred for all criteria of optimal wind turbine type options, three directions economy, environment and risk are set based on the crucial factors which the key players care about.

As business view, any wind turbine project requires funds offers by developer and investors. No capital investment, the project can't open, this is basic factor. The most critical point to attract investors is the rate of return, which is the profitability of the wind turbine project. China didn't achieve its 5GW target for offshore wind turbine installations in 2015, the important reason is that the economic effects are bad, the investors can't earn profit as introduced in Part 1.3. Therefore, economy direction is assigned 55% as showed with green in table 3. Each item in economy direction is given 10 points, in addition to potential of standard process and mass production only is 5 points, because it is gradually improved along with the development of technology, which is a long-term strategy.

As the wind power itself is a renewable energy industry, the impact on the environment is less, thus the proportion of the environment direction is 15%, as yellow part in table 3 and each item is allocated 5 points.

Because stakeholders are in the pursuit of profits, meanwhile, also need to consider the degree of controllable risk. The effort of high profit and low risk is of course the perfect choice if possible. The value of risk is relatively subjective, mainly depends on risk attitude of stakeholders and investment tactics, which is risk averse or risk seeking. That's mean the decision makers are radical or conservative. If stakeholders' risk attitude is risk averse, then they more like to avoid risks, allocate high weight in risk part, they are conservative. Conversely, stakeholders are radical they believe that higher the risk, higher the returns. In this project, the stakeholders are assumed as radical, they are more concerned about profits than risks, and hence the risk direction is assigned 30% as shown red part in table 3. Every item of risk direction is given 10 points. However, this allocation point gap is not great (Kaplan, 2012).

When the all scores and weights are set, the calculation of overall weighted scores is needed to perform. The formulation is that multiplying a type option's score of one criterion by the importance weight of this criterion. Then calculate each criterion one by one. Finally sum the outcomes for the overall preference score for specific option (Communities & Local Government, 2009). The calculation of overall scores is exposed in the table 3 as below:

Calculating overall scores

Direction	Economy 55%						Environment 15%			Risk 30%			Total
Options	Wind resources	Energy yield	Construction costs	O&M Costs	Electricity consumption	Potential of standard process & mass production	Land use	Noise disturbance	Visual impact	Economic risk	Technical risk	Safety risk	
Conventional Onshore wind turbine	50	50	100	100	0	0	0	0	0	100	100	100	**60**
Conventional near offshore wind turbine	50	0	0	0	100	0	100	0	0	50	50	0	**30**
deep water floating wind turbine	100	100	0	100	100	100	100	100	100	0	0	50	**65**
Weights	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05	0.1	0.1	0.1	

Table 3: Calculating overall scores for type options of wind turbine

Through the calculation, the result shows that the winner is the deep-water floating wind turbine with the highest score is 65. That means the benefits from this type are better than other two wind turbines. However, the score gap between the winner type and onshore wind turbine is small, is only 5 points. Is this result firm for decision? Next step needs examine it to think about agree the way forward or any other recommendation.

4.5 Step 5: Propose the preferred option

In order to verify this result, an examination is worked out as showed in figure 12.

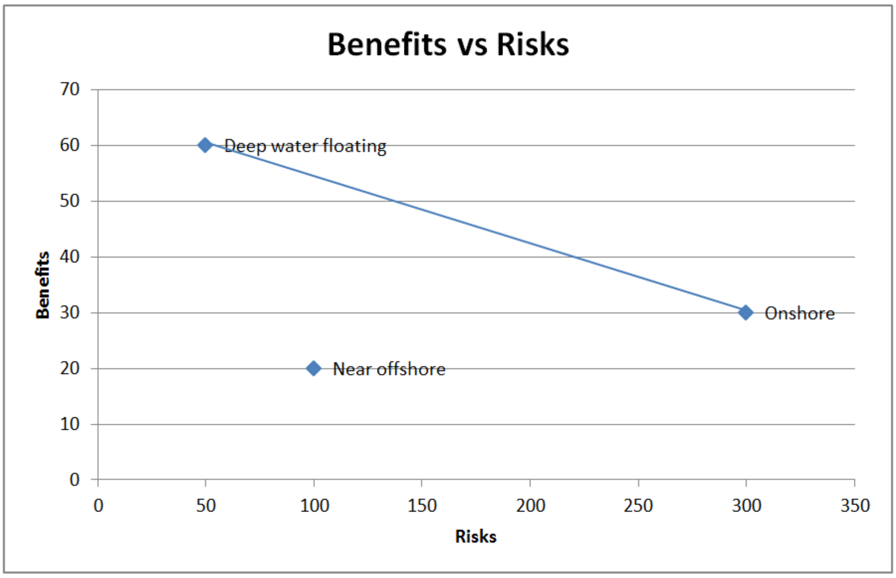


Figure12: Benefits vs. Risks for wind turbine options

This examination is made by a useful display of a two-dimensional plot to expose the crucial trade-offs, benefits and risks for wind turbine. Because of the two factors are the stakeholders the Chinese government and developers care about as mentioned in step 1. Moreover, refer to the different investment risk attitudes, the benefits and risks are key points for matching. Here the benefits include economic effects and less environment impact based on calculation of the table 3. It essentially expresses a relative value-for-risk. Then to set the weight on risk part to zero, recalculate the benefits, the result is found in figure 12 that deep-water floating wind turbine still is a winner, but at the same time it has also highest risk degree. Whereas, the onshore wind turbine can provide moderate benefit with little investment risk. That is to say, at current view, onshore wind turbine might be a more dovish project for business investment and development.

Next step, a sensitivity analysis is conducted to examine the robust extent of results that shown in figure 13. Since the reduction of overall costs is one of key issues in wind power industry, and is also most stakeholders more care about now. Thereby, the weight on construction costs and O&M costs is doubled from 0.1 to 0.2. That improves the overall benefits of onshore and floating wind turbines and the highest overall score still is deep-water floating wind turbine. But it can be seen in the new graph, the increased score of onshore wind turbine is more than floating wind type. According to this examination, the set of weights good reflects three crucial factors' value. Thus, based on previous assumed that developer and investors are radical, the optimal option is deep-water floating wind turbine as the result. However, it is a bit ambiguous.

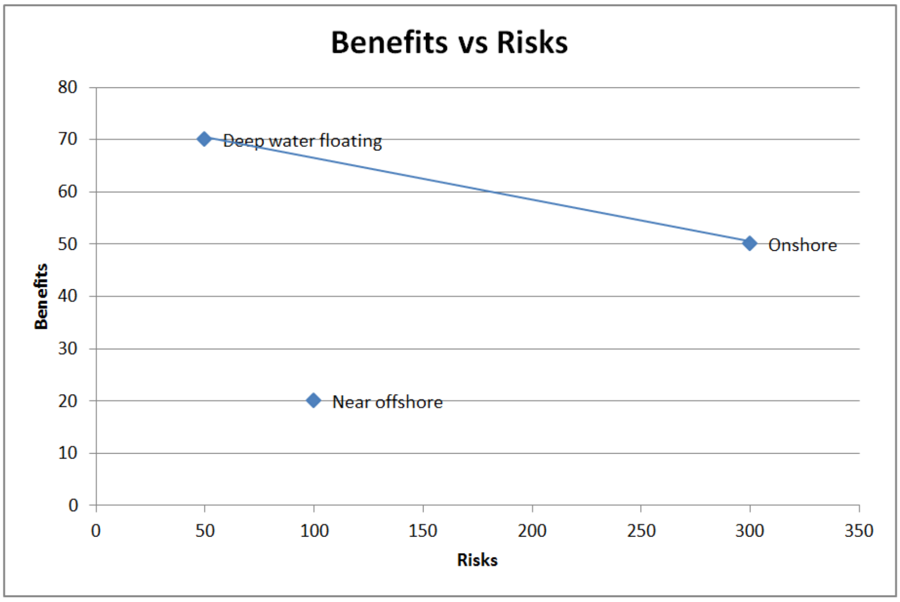


Figure13: Sensitivity analysis for Benefits vs. Risks for wind turbine options

4.6 Multiple-objective decision making

Although the floating wind turbine obtains the highest overall score through MCDA analysis, but it perhaps not be the optimal option due to the high degree of risk. Hence, this section will conduct an expected value analysis for multiple-objective decision making to further test the above analysis result. Due to the optimal option will be got between onshore and floating wind turbines, so only the two options will be analyzed.

Based on data of table 3, the approach is used that a 100-point scale where the worst outcome is given 0 points and the best outcome is given 100 points. Corresponding table 3, here three items are set as economic effects, environment impact and risks. The probabilities are calculated by individual value of every wind turbine type option that accounts for the proportion of the total value of each item. For example, in table 3, the deep-water floating wind turbine is assigned 500 points, the total value is 600 points for the economy part, so the probability of this kind type is around 80% (500/600) (Clemen, 1996).

The table 4 shows the expected values for all three items.

Economic effects		Probabilities		Expected Value	
Category	Points	Onshore	Floating	Onshore	Floating
High	100	50%	80%	50	80
Low	0	50%	20%	0	0
Sum				50	80
Environment impact		Probabilities		Expected points	
Category	Points	Onshore	Floating	Onshore	Floating
High	100	0%	100%	0	100
Low	0	100%	0%	0	0
Sum				0	100
Risks		Probabilities		Expected points	
Category	Points	Onshore	Floating	Onshore	Floating
High	100	100%	17%	100	17
Low	0	0%	83%	0	0
Sum				100	17

Table 4: Expected value calculation for two type options of wind turbine

The objective is now to choose the type which gets the highest points, the weights are same as table 3 and the result is shown in table 5 as below:

Items	Weights	Onshore	Floating
Economic effects	0.55	50	80
Environment impact	0.15	0	100
Risks	0.3	100	17
Sum		57.5	64.1

Table 5: Result for optimal option of wind turbine type

The result same as previous MCDA's, the deep-water floating wind turbine is optimal option, though it has the highest risk degree, that overall benefits it can get the best.

In the same way, sensitivity analysis is used to see how sensitivity is the decision to choose the floating wind turbine with the attached weights. The weight may reflect the assessment of how severe such risk is compared to the other two items. Thus a graph is made as shown in figure 14.

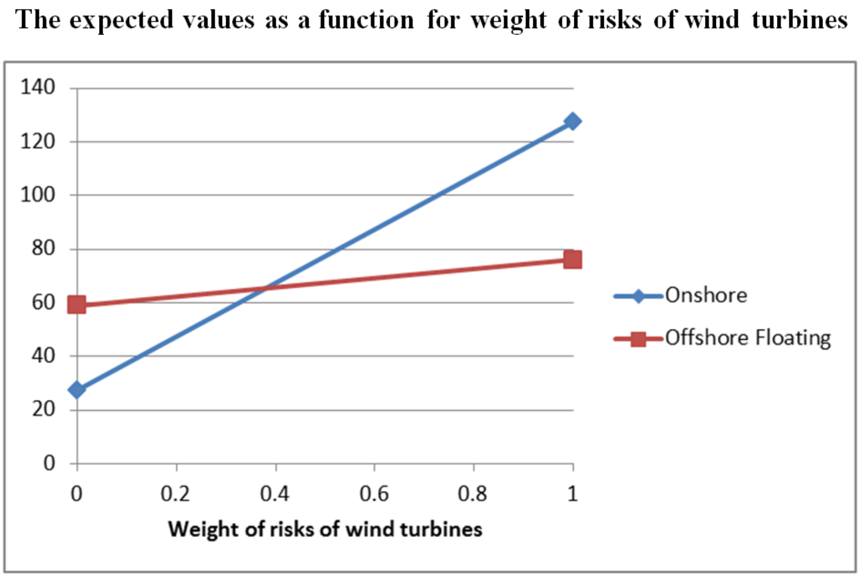


Figure14: Sensitivity analysis for result of wind turbine options

From figure 14, it is seen that the switch point is about 0.4. Therefore if the stakeholders assign sufficiently high weight on the risk item, then the onshore wind turbine type is optimal. For instance, if developer is conservative, the weights for risk item could be high, the result will choose continue to develop onshore wind turbine project.

According to MCDA and expected value analysis result, the deep-water floating wind turbine is the optimal option under the assumption that stakeholders are radical. However, the result is not very robust, just increase a bit weights for risk direction, the optimal option will be shifted to onshore wind turbine.

Obviously the floating wind turbine has high economic effects advantage, but because it is a new system, technology and practical operation have many uncertain factors. If China is to develop the system now, the biggest risk is that technology, and China has great dependence on it. Furthermore, technological risk can affect the economic risk; after all, the floating wind turbine still at CRI 2 phase that cannot perform mass production now, thus the construction cost is currently very high.

Part 5 Conclusion

Now the development of renewable energy has become an important role in many countries based on the mission of environment protection, China is one of them. Especially when China has faced one serious issue of air pollution where caused by the use of abundant coal dominates current energy system. Thus, the promotion of the low-carbon energy strategy has been indicated in Chinese 12th Five-Year Plan in 2011. The wind energy as renewable energy has nothing is limited by resources and lower environmental constraint for developing and utilizing, it is better choice for the development of large-scale commercialization in China. So far, wind energy industry in China is still at the introduction stage, it will be expected to achieve the mature stage in 2050 as IEA's report. Since onshore wind turbine's technology is relatively mature and construction costs are lower than offshore wind turbine, thus, wind energy development of China mainly focus on inland now. But the high electric consumption comes from the economic boom regions where mostly distributed in south and east of China, the coastal areas. Therefore the offshore wind power could be a better choice in there. Whereas, due to the technological factor, the most offshore wind turbines were built in the near offshore, such as intertidal areas, that cannot fully exert wind resources potential. This situation on the low energy output and high costs caused the bad economic effect to investors that they cannot get a good return from the offshore wind turbine project; though China has rich wind resources around the coastal areas. The bottleneck has let Chinese government to slow the offshore wind turbine installations in the upcoming 13th Five-Year Plan. The high output of electric production is based on the strong winds, then, the wind turbines have to be constructed in the deep-water where the water depth is 40 meters or above. However, if China wants to move the development of offshore wind power to the deep-water area, then, the emerging floating wind turbine technology will be needed to introduce. But this floating wind turbine has a big investment risk due to the uncertainties of technology and less experience. The project therefore discusses about if China should develop the offshore floating wind turbine now through by the analyses on the market of floating wind, comparison among three types of wind turbines and existing risks.

As the ORE Catapult's conclusion that the offshore floating wind technology has been recognized and can ready to go to the commercial market. From the micro environment to see, the floating wind sector has two key advantages which are the possibility on reduction of overall costs of wind turbine and less environment impacts. Thereby this technology can bring the solution for the issues that China has met in the offshore wind sector. But, due to the lack of experience in floating wind turbine operation, the risks and costs are higher than onshore wind turbine currently.

At the macro view, the government policies, economic circumstances and social impact all appear opportunities to floating wind power sector. But, again the technology issue will be the major risk for investors and developers. The technology however can influence overall costs and operation of project.

Based on the long term, flexible and low-cost operation and maintenance way of the floating wind turbine can bring better economic benefits. Another word, the emerging technology project could attract the eyes of developers and investors.

According to the result of MCDA and expected value analysis, the deep-water floating wind turbine is the optimal option under the assumption that Chinese government and developers are radical. Nevertheless, the result is not very robust. The optimal option is easy to be shifted to onshore wind turbine along with the different risk attitude.

All above, the advantage of floating wind turbine is the high economic return, but because it is a new system, technology and practical operation have many uncertain factors. Meanwhile, the gap of total score between floating wind turbine and onshore wind turbine is not obvious. If China will introduce and develop the system now, the biggest risk is technology, and China has great dependence on it. Furthermore, after all, the floating wind turbine still at CRI 2 phase that cannot perform mass production, thus the construction cost is currently very high. Based on the technological risk can affect the economic risk, it is not proper time to develop the floating wind turbine in China now, however, learning and researching can be started.

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