ANALYSIS OF ECONOMIC FEASIBILITY OF OFFSHORE WIND POWER

-FOCUSING ON CHINA AND SOUTH KOREA-

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Abstract

This paper utilizes benefit/cost analysis to explore the economic effects of offshore wind power in China and South Korea. In 2010, China accounted for the largest share (over 20%) of the total wind capacity worldwide, followed by Korea. Since large-scale wind turbines and offshore wind energy resources are plentiful in China, the development of its offshore wind power has accelerated, and the first offshore wind farm in Asia is already finished in Shanghai. In the case of Korea, the feed-in tariff, which was too low to support wind power development, was recently replaced by a Renewable Portfolio Standard (RPS) that will become effective in 2012. Following a new regulatory policy, the Korean government has announced a strategy to promote investment in offshore wind farms with a total capacity of 2.5 GW over the next eight years, an initiative that is expected to change costs and benefits. After providing an overview of the status of offshore wind power in China and Korea, this paper examines the strategic approaches of these countries, inquiring into such questions as the scale of investment, the ratio of government investment, and official policy. The practical analysis focuses on the operating and planned projects of China and Korea by 2025. The experience of these two countries can be of use to those who are planning to establish offshore wind power facilities in other countries.

1. Introduction

Europe leads the world in renewable energy. According to the Kyoto Protocol, by 2012, EU members must arrive at an 8% reduction of greenhouse gas emissions of the 1990 level. Accordingly, the proportion of renewable energy in the total energy consumption of EU countries is gradually increasing. Compared to Europe, South Korea is in the immature stage, but it plans to carry out investments that will lead to an 11% increase in renewable energy by 2030. The considerable growth of the Chinese wind energy industry has been driven by its national renewable energy policy. According to the rules of the first Renewable Energy Law implemented in 2007, non-hydro renewable energy must equal 1% of the total electricity mix by 2010 and 3% by 2020. The Third National Wind Energy Resources Census indicates that China’s total capacity for both inland and offshore wind energy is around 700–1200 GW.

The generation cost of offshore wind power is high—50 to 80 euro per unit per 1 MW—because of higher initial installation costs than those of onshore wind installations. On the other hand, offshore wind farms produce at a high level and are large so that their market share is expected to grow gradually. Offshore and onshore wind power differs in certain respects. To begin with, the output of the former is higher the farther the turbines are located from the shore, and the higher the wind speeds, the more the power that is generated. Compared to the onshore variant, offshore wind power has grown from between 30 and 50 percent of the total output. In addition, the life expectancy of offshore wind power installations is about 25 to 30 years, since the more stable energy density at sea reduces output fluctuations and mechanical fatigue. Finally, offshore wind turbines do not create disturbing noise.

However, offshore wind facilities have many disadvantages, such as very high initial construction costs and high maintenance costs. Initial costs are high, since turbine foundations are considerably more expensive than those of offshore turbines. Wind farm facilities, such as wind turbines, foundations, and electric cables, make up 79 percent of the total wind-farm construction costs. Furthermore, the costs of transformer stations and sea transmission cables are significant. Connections between turbines and a centrally located transformer station, and from there to the coast, generate additional charges. At the Horns Rev and Nysted wind farms in Denmark, the average cost share of the transformer station and sea transmission cables is about 21%. In addition, operational and maintenance costs are considerable. Despite these shortcomings, offshore wind power has a high market appeal; thus, it is spreading rapidly in Europe, the United States, and China.

In the case of China, the industry is quickly growing with massive government support. This rapid development has encouraged the domestic production of wind turbines and components in China. The Chinese manufacturing of these products has become increasingly mature, and the country is now the world’s largest producer of wind energy equipment. Components made in China are now satisfying both domestic and international demand. In recent times, China’s attention has gradually shifted from onshore to offshore wind power development. As can be seen from Figure 1, China is the Asian leader in wind power.

(Source: Global Wind Energy Council)

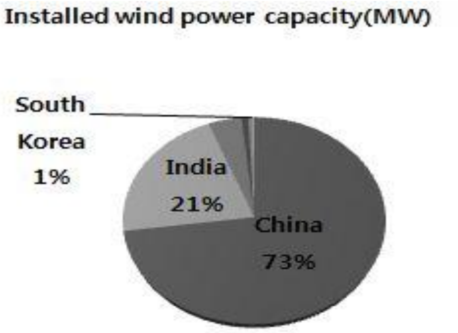

Figure 1. Installed wind power capacity in Asia in 2010

In the case of South Korea, although the market is in its initial stages, a 100 MW demonstration complex will be built by 2013; by 2019, the nation plans to build a 2.5 GW large-scale offshore wind farm. This study assesses the feasibility of offshore wind power in China, the Asian industry leader, and in South Korea, a newcomer to the field, by considering policy, technology, and the offshore wind energy market. The economics of the projects planned by the two nations in the next 15 years are evaluated using a cost-benefit analysis, based on the expected generation of offshore wind power.

Many economic studies on this industry have been conducted both in Korea and abroad. Calculating levelized generation cost, Jaegon Kim (2009) studies the feasibility of offshore wind power in South Korea. He demonstrates that maintenance costs are an important factor in offshore wind power because of the difficulty in accessing power generators; it is thus necessary to have an online monitoring system. Once introduced, the benefits of this system are realized after eight years. Dohyeoung Kim (2011) investigates the viability of domestic wind resources. According to his results, Korea has a capacity of approximately 11 GW in sea depths of up to 30 m. In addition, compared to countries more advanced in this field, the gap in its technology is not large; consequently, Korea’s offshore wind market will become sufficiently competitive with the application of the right policies. Unlike other scholars, James (2011) argues that the offshore wind power in China is not economical because of a lack of technology and high maintenance costs; he bases his conclusions on the internal rate of return of the Dongdakiahoh project in 2008. Furthermore, he indicates that the high installation costs caused by technical defects make the industry unprofitable.

2. Method

To analyze the economics of renewable energy, it is necessary (1) to compare total costs and benefits of renewable energy with alternative energy produced by fossil fuels and (2) calculate the cost of energy production using renewable energy equipment. When calculating energy costs, the total cost of the quantified present price during equipment operation divided by total production amount is used. The production cost of renewable energy differs with the discount rate, capital expenditure, equipment, operating costs, and especially the energy produced by changes in the equipment utilization rate. The calculation of levelized generation cost 1is being used in Europe and USA.

Cost-Benefit Analysis

Cost-benefit analysis measures the net present value (NPV) by estimating social benefits and costs rather than the perspectives of individual operators. In other words, cost-benefit analysis measures and compares the social benefits understood as the sum of the willingness to pay each consumer and the social opportunity cost understood as the benefits lost by not selecting the alternative use of the utilized resource. This method can be employed to economically evaluate large-scale infrastructure constructions, such as wind power generation farms. The feasibility of generation farm construction can be estimated by comparing the construction and operating costs and the operating benefits of the farms in a period. The indicators are the internal rate of return (IRR), the net present value (NPV), the breakeven point (BEP), the return on investment (ROI), the benefit cost ratio (BCR), and the payback period (PB). Among them, the net present value (NPV), which contains all cash flows (including initial cash flows, such as the cost of purchasing an asset), is used in this study. In this analysis, a discount rate is used to adjust for risk and time value, and it can be expressed by the following equation:

$$\text{NPV} = \mathrm{CF}_0 + \mathrm{CF}_1 \frac{\mathrm{CF}_1}{(1+\mathrm{r})} + \frac{\mathrm{CF}_2}{(1+\mathrm{r})^2} + \frac{\mathrm{CF}_3}{(1+\mathrm{r})^3}$$

CF_1 : The cash flow the investor receives in the first year; r : the discount rate

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[1] $\mathrm{p}^* = \mathrm{CRF} \times \sum_{\mathrm{t}=1}^{\mathrm{n}} \frac{\mathrm{C_t}/\mathrm{Q_t}}{(1+\mathrm{d})^{\mathrm{t}}}$; Levelized generation cost

The table 1 includes the factors and equations for each cost and benefit. Since other cost value is not that significant relatively, and the computation of effect of reducing the greenhouse gas emissions is such a complex process, these were ignored in this study.

Table 1. The factors and equations for cost and benefit

	Cost	Benefit
Factors	1. Initial investment cost(C0) 2. Operation and maintenance costs(OM(i)) (land rent, property taxes, insurance, maintenance, inspection costs, replacement parts costs, and labor costs, greenhouse gas monitoring) 3. Other (equal payments, periodic cost)	1. Revenue from the power generation(B(i)) ▪ Profit: The unit cost of power generation × total generation amount 2. Revenue from reducing the greenhouse gas emissions(GHG(i))
Equations	$\mathrm{PV(C)} = \sum_{\mathrm{i=0}}^{\mathrm{T}} \frac{\mathrm{UC} \times \mathrm{X_i}}{(1+\mathrm{d})^{\mathrm{i}}}$ *UC*: Unit Cost, X_i: the cumulative *d*: Discount rate	$\mathrm{PV(R)} = \sum_{\mathrm{i=0}}^{\mathrm{T}} \frac{\mathrm{P} \times \mathrm{TP_i}}{(1+\mathrm{d})^{\mathrm{i}}}$ P: Selling price per unit of generation $\mathrm{TP_i} = \text{Total capacity} \times 8760 \times \text{utilization}$
	$*\mathbf{Total\ NPV} = \sum \frac{\mathbf{B_i + GHG(i)}}{\mathbf{(1+r)^i}} - \left(\mathbf{C_0} + \sum \frac{\mathbf{OM_i}}{\mathbf{(1+r)^i}}\right)$	

* This equation was used for the analysis in this study.

3. Empirical Analysis

3.1 Data description

The data sources used in this study are constructed as described in Table 2. First, initial investment cost data in both Korea and China were transformed from those included in the Economics of Wind Energy of the European Wind Energy Association (2009). The initial investment cost was estimated at 2.25million KRW/kWh, Using the average investment cost of 10 projects in European countries and the average of exchange rate from 2001 to 2008(1323.04KRW/kWh). For China, the initial investment cost for Donghai Bridge 100MW offshore wind power demonstration project was used as an actual cost. Note that. The actual investment cost has used only for calculating NPV4. The generation capacity for Korea, is from the ministry of Knowledge economy and updating news. For China, the generation capacity came from the China wind power outlook (2010) and 4coffshore(website). Because the generation capacity data cannot cover the entire period of our analysis, we have used the method of interpolation

Table 2. data sources

	Korea	China
Initial investment cost	1) The Economics of Wind Energy by the European Wind Energy Association (2009) : set as a theoretical cost 2) Statistics for for Donghai Bridge 100MW offshore wind power demonstration project (4coffshore.com) : set as a actual cost for China	
[a] Capacity factor of constant	The Economics of Wind Energy (EWEA, 2009)	
Generation capacity	The roadmap of offshore wind power (2010, The Ministry of Knowledge Economy)	2010 China Wind Power Outlook
[b] Electricity Generation Cost	Korea Electric Power Corporation (2011)	China Electric Power Yearbook

[a] We calculated the capacity factor of the constant by using the average value of full load hours of 10 projects in the offshore wind power of European countries from 2001 to 2008.
[b] This includes Price of electricity, subsidy of Feed-in-tariff and unit cost of electricity generation.

Table 3. cost related to electricity generation in Korea and China

(unit : KRW/kWh)

	Price of electricity	Feed-in tariff	Unit cost of electricity generation
Korea	SMP : 117.77	107.29	115
China	93.22.98.70,106.01,111.5	93.22,111.5	146.224

*1 CNY : 182.78 KRW, year average exchange rate in 2010

Since there is no electricity price for only wind power in Korea, we have used an average selling price of electricity in 2010. In the case of China, rates for wholesale electricity for wind power were used. The benchmark feed-in-tariffs for onshore wind farms were used for both Korea and China. The same reduction rates that are 2.5 percent of initial construction costs were applied as well. Note that. The unit costs of offshore windpower generation were 115KRW/kWh for Korea and 146.224KRW/kWh for China.

3.2 Empirical results

The indexes used in this study are constructed as described in Table 4. The original index is applied of the general electric power industry in Korea. For the convenience of the analysis, the indexes were based on Korea for both Korea and China. The discount rate was estimated from EWEA, the average of 5 percent to 10 percent. The initial investment cost and coefficient of utilization of facilities are estimated using the practical data during 2001 to 2008 in European counties. The initial investment cost in China, the data for Shanghai-Donghai offshore wind farm was applied for total capacity, including other projects in China.

Table 4. Transformed indicators calculated from the cost of domestic wind power generation

	Index	Revision	Remarks
Discount rate (%)	7	7.5	Average of discount rate 5%~10%
Initial investment cost (10,000 won/kW)	170	225	Set value
The rate of O&M (%)	2.5	*-	Application of the average national performance in Korea
Uprise rate of O&M cost (%)	2	*-	Estimated value
Coefficient of utilization of facilities (%)	23	38.64	Set value
Economic life expectancy (year)	15	25	Set value

＊Blanks were used as the existing value.
Source : original index (The guidelines on a standard price of Renewable energy electricity, The Ministry of Knowledge economy,2010)

1) Korea

- NPV 1 : No subsidy (Under RPS system)
- NPV 2 : When exist the subsidy from Feed-in-Tariff

2) China

- NPV 3 : The theoretical initial investment cost : 2.25KRW(mill)/kWh
- NPV 4 : The actual initial investment cost: 1.18KRW(mill)/kWh

The difference between NPV1 and 2 is from whether the subsidy exists. If Korea introduces RPS system to offshore wind power, there is no support from government. In this case, as seen NPV1 in the table, the NPV continuously decreased by 2015 because of high construction cost. Although NPV trend seemed to increase after that, it does not become the positive value in whole sections between year 2011 and 2025. In fact, the NPV applied the Korean present policy, is NPV 1 which means, with RPS system, the feasibility of the offshore wind power has not showed by the next 15 years. NPV 2 is calculated when assuming that the subsidies of Feed-in-tariff applied to the onshore wind power, introduces to offshore wind power. According to the guideline for standard price of Renewable energy electricity in 2010, the subsidies amount of Feed-in-tariff is about 107.29KRW/kWh. As a result of introducing this subsidy to offshore wind power, NPV start increasing from 2016 and it changed to positive value from 2019(Table 5).

Table 5. The result of NPVs in Korea and China

(Unit : 10billion,KRW)

	Korea		China	
year	NPV 1	NPV2	NPV 3	NPV 4
2011	-18.79	-15.40	-34.96	-11.25
2012	-62.97	-48.85	-56.67	-9.46
2013	-86.46	-57.45	-481.98	-145.34
2014	-119.43	-70.4	-488.39	-40.94
2015	-303.78	-212.21	-638.7	30.12
2016	-286.53	-152.96	-713.45	176.43
2017	-269.23	-94.51	-769.23	367.65
2018	-252.14	-37.16	-763.7	620.17
2019	-235.48	18.5875	-707.58	923.28
2020	-260.57	34.24	-610.55	1267.3
2021	-210.65	121.34	-481.13	1643.72
2022	-164.21	201.64	-260.83	2074.74
2023	-121.01	275.74	-97.80	2484.75
2024	-80.83	344.04	145.60	2938.87
2025	-43.45	407.04	321.33	3361.59

From the cases 1, 2 in Korea, in order to ensure the economic, a subsidy or intensive system from government is needed especially for the projects which need a high initial capital such as the offshore wind power. Roadmap of Green energy strategy(2009), Indeed, policies of subsidy to the offshore wind energy were implemented in many countries. In Canada, the Feed-in-tariff system has implemented since 2009 and the electricity price of selling is about C$0.135/kWh to C$0.19/kWh for 20 years. In Germany, the improved tariff was included so that government gives 15cents/kWh to operators for the next 15 years for the offshore wind power. For accelerating the development of offshore wind power, the government in England also gives 2ROCs(Renewable obligation certificates) per each turbine to investors.

The difference between NPV 3 and 4 is the initial investment cost. We had set the investment cost using the European data. NPV 3 calculated with using the assumed cost has decreased until 2017. This is because offshore wind farm needs a high cost for the construction at the beginning same as in Korea. NPV started to increase from 2018 and finally became a positive value in 2024. NPV 4 increased from 2014 and it changed to positive value from 2015. It means that under the practical investment in China, the offshore wind power is economically feasible.

As a result, NPV 1 and NPV 4 are reflective of the situation of policy in two countries. The offshore wind energy is China is economically feasible in the next few years, while the feasibility won’t have achieved in Korea for a period of analysis. (Figure 2)

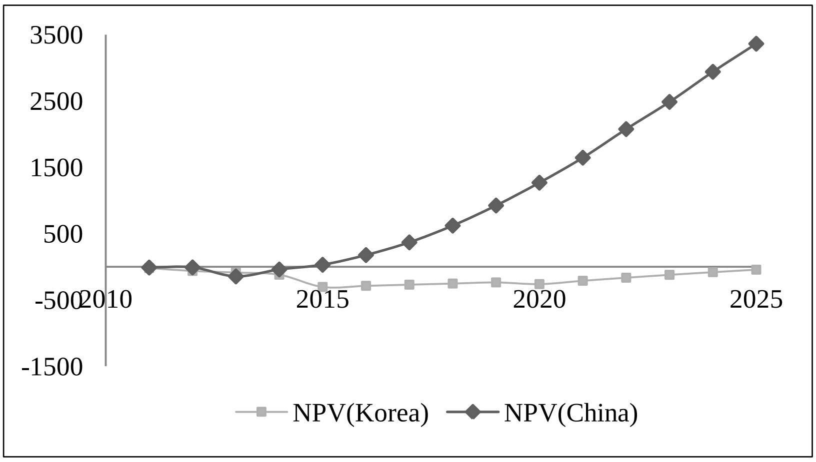

Figure 2. NPV in Korea and China

4. Discussion and Conclusion

Focusing on the offshore wind power projects which constructing or already constructed, an analysis of feasibility with NPV method was conducted with considering status of technology, market and policy in Korea and China. Although Korea is going to introduce RPS system from 2012, it seems that Korean government should stick to Feed-in-tariff policy partially in case of offshore wind power. Since offshore wind energy is expected to obtain economic, so that it helps the government plan to cover 11% of energy consumption to renewable energy by 2020. China has already had successful offshore wind farm in Shanghai. From this, we estimated the actual initial cost for China, KRW 1.18(mill), which is about a half of the theoretical cost set from European data. With actual initial cost, benefit occurs from 2015 which means offshore wind power in China would secure the economic in the near future.

To activate the offshore wind power projects, the government should create some new incentive structures for operators to develop the offshore wind power. Benchmarking a successful example in China, Korea as well as the other Asian countries should focus on the localization of wind power equipments with investment to research and development both government and private, in order to reduce the production cost. Since the NPV analysis is very sensitive to the discount rate, a small change in the discount rate causes a huge change in the NPV values. If the more adequate discount rates for the offshore wind farms are used, more accurate results are expected. Moreover, through including the indirect cost, such as the cost of ecosystem degradation, noise, shadows, interference, scenery, and fishing yields as well as the direct cost in the total cost, the economics analysis of offshore wind power would be more accurately evaluated.

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