WIND POWER DEVELOPMENT IN VIETNAM: SOLUTIONS TO REDUCE GENERATION COST

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Summary

Vietnam is estimated to have an advantageous position to develop wind energy. However, the current status of Vietnam's wind energy industry has yet met such great expectation, due to the uncompetitiveness of the cost of wind power generation. There have been few solutions to this problem, while the government's policies have not been supportive enough. This paper will present the lessons from the countries around the world and also from the wind power projects that have been developed in Vietnam in order to propose practical solutions for reducing generation cost of wind energy. The paper also uses these solutions to examine the factors that influence the generation costs of a wind power project in Vietnam (Hoa Thang Wind Power Project). The research finds that the generation cost varies from 7.01 to 9.14¢/kWh, depending on different measures (compared with 12.26¢/kWh in the reference case). However, beside optimistic scenarios which are hard to happen in the near future, wind generation costs in other cases are all higher than 7.8¢/kWh - the tariff set by the Government for wind power. If the Government does not increase the tariff, wind power projects in Vietnam will face huge challenges in attracting commercial investors.

Key words: *Wind energy, wind power project in Vietnam, generation cost.*

1. Introduction

Vietnam has favourable natural conditions to develop wind power. Besides the World Bank's estimate of nearly 512,000MW [1], another report [2] also calculates the theoretical wind energy potential of Vietnam at 80m height to be up to 430,000MW. The areas which have an average wind speed of at least 6m/s exceed 2,676km^2 and the respective capacity can be installed is estimated at approximately 26,760MW. Although nearly 50 wind power projects have been registered to be constructed in Vietnam with a total capacity of almost 5,000MW, only 3 projects have been built and put into operation (Tuy Phong project, Phu Quy project and Bac Lieu project) by 2014. One of the main reasons for the slow development of those projects is their high production cost which makes it difficult for them to compete with the traditional power plants. There are suggestions that the current electricity purchase price of 7.8¢/kWh according to the Government's regulations for wind projects is not really cost-effective for investors.

Meanwhile, the global statistical data shows that in the 1980 - 2003 period, wind power production cost of the world was reduced by 3 times; from 15¢/kWh to only 5¢/kWh, thanks to a series of cost reduction solutions applied. Therefore, while waiting for the Government to issue new regulations on electricity purchase price that is more attractive for investors, it is necessary to conduct researches to actively reduce the production cost of wind power. This article will focus on analysing the experience of the world and some lessons learned from the wind power projects which have been implemented in the country in order to propose a number of solutions for reducing the costs of wind power in Vietnam.

2. Overview of wind power generation cost

2.1. Global wind power market

The technical potential of wind energy in the world has been assessed at nearly 94 - 95TW (with the regions having an average wind speed of 5m/s at height of 10m above ground level) and concentrates in North America (11TW), EU and Russia (73.5TW), while the rest of the world just has limited potential (10.4TW) [3].

The share of renewable energy is 22.1% of total world energy consumption by the end of 2013, showing a strong growth in comparison with 8% in 2011 and 19% in 2012. In particular, wind power accounts for 2.9% of total world energy consumption [4].

The installed capacity share of wind power is approximately 57% of the total power capacity of renewable energy in 2013. The average growth of wind power capacity during the period 2005 - 2014 reached 23%. By the end of 2014, the total capacity of wind power is 369.6 GW and the new installed capacity is about 37GW. The share of wind power market has shifted from the Eurozone to Asia during the period 2001 - 2014; while the market share of Europe has decreased by nearly half from 71% in 2001 to 36.25% in 2014, that in Asia has increased almost 5 times from 8% in 2001 to 38% in 2014 [3, 5, 6].

Europe had an annual growth rate of new installations of 9.8% in the period from 2000 to 2014 and its total installed capacity was approximately 134GW (8,045GW offshore wind power) by 2014, concentrating mainly in the EU-28 with 96.1%. Asia has 6 years in a row leading the world in new installed capacity, which reached 141.96GW in 2014, mainly in China and India (accounting for 96.6%). North America has a total capacity of 78.1GW by 2014, with growth rates of about 30%/year over the period from 2001 to 2012, then decreased significantly in 2013 and 2014. The United States is leading the region with 84.3% of the capacity. The share of the remaining areas is only about 4.2% of the total wind power capacity in the world [6].

Although the wind energy industry has seen great development in the past decades, the turbines are still supplied by a limited number of manufacturers. Among the top 10 wind turbine manufacturers in the world, there are 5 from Europe (Vestas - 13.2%, Enercon - 10.1%, Siemens - 8%, Gamesa - 4.6% and Nordex - 3.4%) and 3 from China (Goldwind - 10.3%, United Power - 3.9%, Ming Yang - 3.7%), and the others are GE from US (4.9%) and Sulzon Group from India (6.3%) [7].

2.2. Wind power generation cost

For wind power, levelised cost of energy (LCOE) is often used to examine the cost of producing a kWh or MWh of electricity from wind. LCOE of a wind power project is proportional to the investment cost, capital cost, operating and maintenance cost (O&M) and inversely proportional to the power factor/performance (based on wind speed and turbines), turbine life-time. LCOE is calculated using the following formula:

$$LCOE = \frac{R_E \times C_0 + \sum_{t=1}^{T} \frac{(1-Tax) \times VC_t - Tax \times (I_t + Dep_t)}{(1+d)^t}}{\sum_{t=1}^{T} \frac{Q_t(1-Tax)}{(1+d)^t}}$$

Where:

LCOE is levelised cost of energy (cent/kWh);

R_E is percentage of equity (%);

C_o is total fixed cost (cent);

Tax is corporate income tax (%);

VC_t is variable cost in year t (cent);

I_t is cost of borrowing in year t (cent);

Dep_t is depreciation in year t (cent);

Q_t is production in year t (kWh);

d is discount rate (%).

According to data collected from the 2014 projects of IRENA [8] and IEA [9], the investment cost for onshore projects ranged from USD 1.28 million to USD 2.29 million/MW (USD 2.7 million - USD 5.07 million/MW for offshore projects). Operation and maintenance (O&M) cost is about USD 12 - USD 32/MWh (USD 21 - USD 28/MWh for offshore projects). LCOE of onshore wind power is in the range of 6¢/kWh to 12¢/kWh depending on the cost of investment and operation, longevity and wind energy turbines. For offshore wind power, LCOE is higher than that for onshore since the costs of installation, operation and maintenance are higher and in the range of 10¢/kWh to 21¢/kWh. The main factors affecting the cost of wind power are as follows:

2.2.1. Fixed costs

Fixed costs are the total cost of initial investment before the plant goes into operation. Fixed costs of wind power projects include the cost of the wind turbine, the cost of building infrastructure, grid connection cost and other fixed costs. Fixed costs account for 64 - 84% of the total cost of the project life [5, 10].

Turbine prices fell continuously during the period 1980 - 2000 due to improved technologies and the expansion of production from pilot projects to commercial scale. The price downs to the lowest around USD 700/kW in 2002 [5]. However, the turbine price in the next period increased due to the soaring in demand and the limitations of the supply chain of wind power equipment [10]. Price turbine orders increased from USD 1,130/kW in 2004 to USD 1,730/kW in 2009. By 2014, turbine prices fell by 30 - 35% compared with

the peak in 2009 when the producers scaled up to meet the new demands from the US and China. In addition, the base metal prices also fell, contributing to pulling turbine prices down to around USD 931 - USD 1,174/kW in the US and USD 676/kW in China in 2014 [8].

Construction costs include the cost of building the foundation, internal roads, as well as the cost to build a system of lines, sub-stations, and other ancillary works. The foundation of onshore wind projects is mainly made of concrete, so most of its costs depend only on the price of construction materials such as cement, steel, sand, and stone, etc., and cost of transporting these materials to the construction site. The average construction cost for onshore wind power projects is 4 - 10% of the total fixed costs, and for offshore wind projects is 15 - 25% [8].

Grid connection cost depends on the distance and type of grid (high or low voltage) that the wind farm will connect to, so this cost will vary between projects in different countries. The average cost of grid connection in Spain in 2006 was EUR 115.24/kW and increased to EUR 131.18/kW in 2008 [10]. IRENA [8] used average data for the countries and estimated that the average cost of connection for onshore wind projects ranges from 9 - 14% of the total fixed cost, and for offshore wind projects from 15 - 30%.

2.2.2. Variable costs

One of the most advantages of wind power as well as other forms of renewable energy is zero fuel costs. Thus the variable cost of wind power accounted for only 10 - 20% of the total cost compared to 40 - 60% in gas-fired power projects. Data from Germany from 1997 - 2001 showed that O&M costs ranged from 0.39 - 0.52¢/kWh (for projects under 2 years) to about 0.78 - 0.91¢/kWh for onshore projects. On average, O&M accounts for 26% of the variable cost of the projects in Germany. However, the variable cost of wind power has also changed a lot over time and varies widely between countries and regions as well as between locations around the world. For example, data from the US showed that O&M expenses decreased from 2.4¢/kWh for projects in 2013 to 1¢/kWh for projects since 2014 [8, 10, 11].

2.2.3. Production output

While fixed costs and variable costs decide the total cost of the project, wind power production output is the most important part of the decision on the cost per unit of energy produced. This is also a factor explaining the difference of the cost of wind power among countries and projects. Wind power output depends on the project location, farm design and the nominal capacity of the turbine. Data about the number of maximum operating hours among the different regions not only demonstrates the potential of wind, but also reflects the nominal capacity of turbine used. The number of maximum operating hours of North America is considered the world's largest, ranging from 2,628 to 3,942 hours (corresponding to the power factor of 30 - 45%), Europe 2,190 - 3,066 hours (corresponding to the power factor of 25 - 35%), China and Korea 1,752 - 2,628 (corresponding to the power factor of 20 - 30%). The average level for an onshore project is usually from 1,700 - 3,000 hours/year (Spain: 2,342 hours, Denmark: 2,300 hours, and England: 2,600 hours) [5, 8, 10].

2.3. Lessons learned from reducing costs of wind power

2.3.1. Technical improvements

- Turbine technology improvement

Improvements in technology such as design, materials used, operating procedures and logistics, enable the development of larger size turbines with lower costs. The average capacity of turbines in the United States increased from 0.7MW to 1.5MW in 5 years from 1999 to 2005, then stabilised at 1.5 - 2MW and currently up to 7MW. In addition, the height of tower increases from 55m in 1999 to more than 80m, the rotor diameter is also raised from 50m to more than 90m during this period. Similarly, in Germany wind power projects are also using more and more large-scale turbines. The capacity of the new turbines installed continuously increased from less than 0.5MW in the period from 1990 to 1992 up to 2 - 3MW turbines since 2006. Turbines bigger than 3MW also began to appear in 2003 and accounted for nearly 20% of newly installed turbines in 2011. Meanwhile in China, the biggest change in turbine technology is the average capacity, which has been continuously increased over the years, from 850kW in 2005 to more than 1.5MW in 2011. Larger capacity turbines will significantly reduce the number of towers, the area of used land and the costs of infrastructure construction such as road construction, tower foundation, or the cost of cables, leading to reduction of initially fixed costs [12 - 15].

With the characteristics of Vietnam's wind energy, the interviews with experts show that the suitable model for

turbine can be the 1.5MW. This is also the popular model for many manufacturers, and therefore easy to purchase, repair and replace. However, when selecting the turbine, it is also important to consider the simulation and detailed information based on project inputs. In general, the selection of 2MW turbine for Phu Quy project, 1.5MW turbine for Tuy Phong project and 1.6MW turbine for Bac Lieu project has proved suitable for the wind conditions of each project. It should also be noted that equipment selection must take into account all other factors such as climate and geographical condition, transportation, O&M costs, etc.

- Localisation

For countries like the US and China, localisation of wind turbine manufacture also significantly reduces the cost. The proportion of imported equipment in the total investment of wind power projects in the US fell considerably, from more than 64% in 2005 - 2006 to around 33% in 2011 [13]. The greater domestic production capacity helps to reduce costs of transportation of imported equipment from Europe. In addition, local firms can also provide better warranty service, maintenance and replacement of equipment, which help to save time and costs in the operation of wind farms.

The fast growth rate of installed capacity helped the rapid development in wind power equipment manufacture industry in China. So far, China has basically been producing parts of the wind turbine. When the wind power projects have to ensure the provisions of the localisation rate of 70%, foreign firms opened production facilities in China. Policies supporting local businesses allow local firms to rapidly scale up, utilise local resources and increase their market share in the wind power equipment market. Using the domestically manufactured devices is the most important economic solution for wind power projects in China to reduce costs. Among the benefits are lower turbine price, cheaper shipping cost, and avoidance of import taxes. Particularly, the price of domestically manufactured turbines is estimated to be 20 - 30% lower than that of imported turbines [16 - 19].

At present, Vietnam does not have enough capacity and funding for localisation of key equipment (turbines and propellers). Therefore, the only way is to choose equipment supply that has reasonable cost. Wind turbines can be divided into two groups based on their country of origin: from countries outside the G7 (China) and from G7 (Table 1). Accordingly, if using Chinese equipment, the price will be cheaper. However, the quality is lower (Table 1). Currently, there is a number of domestic enterprises in Vietnam that have sufficient capacity to produce towers such as UBI Tower, Vina Halla, and CS Wind, etc. The price is about USD 200,000/MW and may continue to fall after negotiations. However, using local towers is only really economically effective in case the investment size is large enough.

- Project location

Investors prefer looking for locations with good wind potential, and placement of wind farms that make the best use of the advantages of terrain and geology. The place which has the best wind resources in the US may have a power factor of over 40% [13]. In China, wind farms are concentrated in three regions in the North, namely Xinjiang, Gansu and Inner Mongolia, where the potential of wind resources is high. However, these areas are quite far from areas having large demand for electricity such as Liaoning, Shanghai and Guangdong in the eastern coast. Hence, the requirements for transmission lines are really big. A new direction in China today is to invest in the South, where the wind speed is low but the area is near the power consumers. The solution is to use the height tower and large blade turbine (up to 108m). Greater costs due to the use of this turbine will be offset by lower costs of investment in the power line and all production will be consumed.

The wind farm location also has a great impact on the effectiveness of the project and wind power generation cost in Vietnam. Tuy Phong project is one of the most successful projects, since it has one of the best locations

Table 1. *Comparison of wind turbines*

	Turbines from G7 countries	**Turbines from China**
Manufacturers	Vestas (Denmark), Enercon, Siemens, Repower (Germany), Gamesa (Spain), etc.	Sinovel, Dongfang, Sany, Goldwind
Characteristics	Tested for quality, reliability. High performance	Quality is lower. Operating time that has proven is short
Price	USD 1,100 - 1,400/MW	USD 900 - 1,000/MW
Time to supply	More than 6 months	4 - 6 months

with great wind energy potential, favourable terrain characteristics, proximity to the grid (1.5km) as well as to other key transportation infrastructures such as ports, and a far distance from the community. On the other hand, Phu Quy project was set up on the island with the purpose of supplying power for the local communities amid difficulties in connecting to the national grid. The project also faces challenges in equipment transportation, construction, and unfavourable weather conditions. Meanwhile, Bac Lieu project was selected to site at a coastal area. Despite great wind potential, the unique terrain characteristics make the project construction cost go up sharply and exceed the initial estimates.

2.3.2. Economic and management factors

- Economy of scale

Besides the use of larger size turbines, wind power projects in the world are also growing in scale to take advantage of the economy of scale. Increasing in size combined with increasing in turbine capacity can reduce the area of used land and the cost of renting. In addition, Lewis & Wiser [20] estimated the turbine price can be reduced about 5 - 10% when purchased in bulk. Qiu & Anadon [21] estimated production cost can be reduced from 6 - 8.9% if the project size is doubled.

Selecting the scale of investment is a solution to the rational use of resources, avoid unnecessary costs and thereby reduce costs incurred for wind power projects. However, the choice of scale depends on many factors. From the practical experiences in Vietnam, the experts (from REVN, Bac Lieu and Phu Quy projects) have estimated that for an onshore project in Vietnam, investors should give priority to large-scale projects and the lowest threshold to be considered for investment is 30MW.

- Learning experience

Another factor that can help the wind power company to increase efficiency and reduce costs is learning through the production process (learning-by-doing and learning-by-searching). Expanding production brings experience in production management and organisation, and therefore reduce the cost of manpower and time. Cost is reduced when manufacturers learn from each other, and the cost can be cut from 1.1 - 5.06% depending on the size of the manufacturer [21]. The lessons from some implemented projects in Vietnam (Phu Quy, Tuy Phong and Bac Lieu projects) show that good management of wind power projects may help save 15 - 20% of investment cost. The process of good governance for a wind power project needs to co-ordinate the work contemporaneously, to select the suitable and qualified contractors and ensure the progress of construction and installation of turbines, etc.

- Government policies

In the US, common policy applied to wind power projects is the Renewable Portfolio Standard - RPS. In California, the company was forced to increase its power generation from renewable energy by 1%/year and this had to reach 20% in 2010, with adjustments later in 2010 to 25% for the period 2011 - 2013 [5]. The Production Tax Credit (PTC) policy has the greatest impact on the development of wind power in the US in the 2000s. PTC began in 1992 under the provisions of the Energy Policy Act and has been extended six times. PTC reduces the corporate income tax component, thereby reduces the cost of wind power in the United States a lot. In addition, a revenue-based PTC thus promotes wind power plants to maximise annual production [5]. Modified Accelerated Cost Recovery System (MACRS) allows devices such as turbines, electrical systems, and transmission devices to enjoy 200% accelerated depreciation over 5 years. With the rules, tax and accounting methods in the United States, accelerated depreciation helps reduce and optimise the taxation part of the first year, increase taxes to pay part of the project the following year, thus reducing total taxes and thereby reducing production costs.

In Germany, the Renewable Energy Act (EEG), which came into force in 2000 and was amended in 2004, 2008, and 2012, is the most important policy to support the development of wind power in Germany. Accordingly, wind power projects in the first 5 years will receive higher premium tariff, which was about 11.93¢/kWh from 2012. Actual production after 5 years will be measured and if it is lower than the reference site, the time to enjoy high prices will be extended. Then lower basic tariff will be applied for the remaining years. Furthermore, projects which started before 2015 and meet the requirements of the System Service Regulation will receive a bonus of 0.63¢/kWh, while the repowering wind farm projects will receive 0.65¢/kWh [22].

In China, the development policy for renewable energies started in the period 1986 - 1993, but after 2003 it saw incredible growth of the market with the introduction of national wind power procurement programme. With this programme, the government chooses the locations

Table 2. *Incentives for the development of wind power market in Vietnam*

	Scope	Content
1	Power buyer	- EVN or authorised body is responsible to buy electricity - Legal responsibility under power purchase contract
2	Incentives	- Waiver of import tax - Waiver or reduction of corporate income tax (10% in the first 15 years, able to extend to 30 years; tax waiver in the first 4 years, 50% reduction in the next 9 years) - Waiver or reduction of land fee
3	Tariff (for grid-connected)	- Tariff at connection hub is VND 1,614/kWh (7.8US¢/kWh, excluding VAT) - Tariff adjusted according to exchange rate of VND/USD. The government subsidise VND 207/kWh (1US¢/kWh) from the environment protection fund

which have good wind potential and organises bidding to select investors with the lowest prices. The Renewable Energy Law in 2005 continued to concretise the priority development of renewable energy in a number of key measures. The first is mandatory that electricity producers must have a minimum of 3% of electricity generated from renewable energy (other than hydropower) before 2010, and then this level will be raised to 8% in 2020. The Chinese government also requires the transmission company to provide connectivity line and buy all electricity production from renewable energy. Feed-in-tariff is also applied to four different areas, ranging from 7.7¢/kWh in regions with high wind energy potential as Inner Mongolia and up to 9.2¢/kWh for areas with less potential for wind power development [19, 21, 23].

The tax incentives for imported equipment in China also reduce the cost of imports and the turbine domestic products. Specifically, since 2004 the import tax on turbines was reduced by 8% and that on equipment was reduced to 3% if they were used for domestic projects. Besides, in 2008 China adopted a policy of tax refund for turbines and related components with a capacity over 2.5MW in order to encourage technology transfer. For the domestic industry, the domestic wind power equipment only bear 50% of VAT. Corporate income tax for the wind power projects is also exempted for two years, and then exempted 50% for the next 3 years [16, 19, 24]. Also in 2008, to encourage the production of large turbines, each local firms (at least 51% stake) will receive USD 88,000/MW for the first 50 turbines with a capacity of 1MW [24]. This policy has helped firms such as Sinovel to catch up with major international brands such as Vestas and Enercon in the production of large-scale turbines.

To promote the development of wind power market in Vietnam, the role of the Government is very important. The energy prices in Vietnam are not very high, there are many incentives and preferential treatment offered by the Vietnamese Government to the wind power industry. Decision 37 dated 29/6/2011 offers incentives and preferential treatment in terms of funding, tax and fee to wind energy projects as shown in Table 2.

Under Decision 37, Electricity of Vietnam (EVN) has the responsibility for buying the whole electricity output from wind power projects with the electricity buying price at the point of electricity receipt being VND 1,614/kWh (excluding VAT, equivalent to 7.8US¢/kWh). This current subsidised tariff is too low in comparison with that in other ASEAN countries (19US¢/kWh in Thailand and 21.8US¢/kWh in the Philippines). The low power purchasing price is also a big barrier to wind energy projects.

3. Cost reduction of wind energy in Vietnam

3.1. Overview of wind power development in Vietnam

Up to date, only 3 projects are already operating[1] and around 42 wind power projects of 3,900MW are being implemented at various stages. The average size of projects is 95MW of capacity, with projects from 50 - 100MW being the most popular. About a third of the projects are developed by foreign investors. According to the Vietnamese Power Master Plan VII, Vietnam has set a target for wind power development at 1,000MW by 2020 that accounts for 0.7% in the power mix in 2020, and 6,200MW by 2030.

Wind power projects are approved by the Government in co-ordination with related Ministries, Departments and

[1] *In 2011, Tuy Phong project in Binh Thuan province was completed for phase 1 with a capacity of 30MW to be grid-connected by Vietnam Renewable Energy Joint Stock Company (REVN). In 2012, the wind-diesel system developed by Petrovietnam with a capacity of 6MW for Phu Quy island also in Binh Thuan province started operation. In 2013, Bac Lieu near-shore project completed its phase 1 with a capacity of 16MW. Phase 2 and Phase 3 of the project are also being implemented with the total capacity of 500MW to be achieved around 2016.*

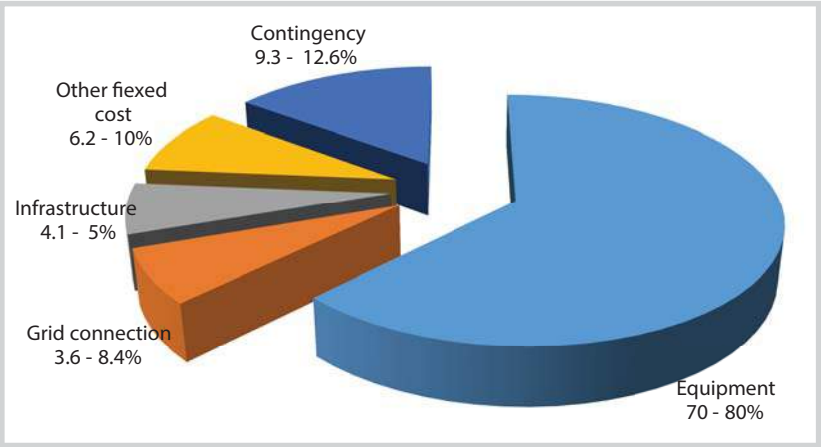

Figure 1. *Fixed cost components for wind projects in Vietnam*

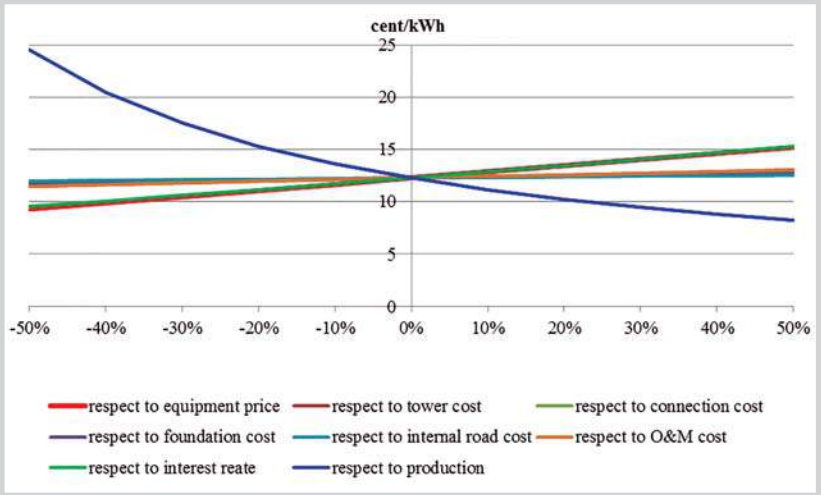

Figure 2. *Sensitivity analysis for factors affecting generation costs*

Agencies. Decision 37/2011/QD-TTg dated 29/6/2011 on the financial mechanism to support grid-connected wind power projects is the key legal document detailing the incentives. Besides, Circular 96/2012/TT-BTC dated 8/6/2012 provides more details for the developers and authorities in implementing and starting the operation of wind power projects. In particular, EVN will purchase electricity from wind power projects at the price of VND 1,614/kWh - equivalent to 7.8US¢/kWh, with the exchange rate to be adjusted to the rate set by the Government. Apart from being relatively low compared to the development cost of wind power, the actual procedures to receive the Government's support can be lengthy.

The cost for wind generation in Vietnam is decided by 3 major components: fixed cost, variable costs and electricity production. Fixed cost includes equipment, which varies from USD 1.5 to 1.7 million per MW and accounts for 70 - 80% of the total fixed cost. Other fixed cost items are grid connection, which ranges from USD 78,000 - 160,000/MW depending on the project's specific features; infrastructure costs which can be around 4 - 5% of the total fixed cost; and other items including contingency - about 9 to 12% of the total fixed cost (Figure 2). Variable costs in Vietnam comprise of O&M costs, which are around 2% of the fixed cost, equivalent to 0.8 - 1.21US¢/kWh. However, these figures can increase sharply due to both the climate characteristics in Vietnam and the expertise of local operators. Variable costs also include interest payments - which vary significantly from project to project, and corporate income tax, which is waived for the first 4 years with profit, and 50% of the standard rate (10%) for the next 9 years. For electricity production, the capacity factor in Vietnam is estimated to be from 34.2 - 37.5% (full load hour from 3,000 - 3,285 hours/year according to the FS of projects). But the figure again can change according to project location, for example Phu Quy project can achieve maximum capacity factor of 47.9% and 4,204 full load hours. All these cost estimates however only become more reliable when more and more projects are put into operation for a considerable period.

3.2. The cost of wind projects in Vietnam

3.2.1. Generation cost of wind energy

This section will deal with generation cost for onshore wind projects. The project selected for cost calculation is Hoa Thang wind power project invested by Petrovietnam. In terms of cost per kWh, estimate has been made for the reference scenario (base case), based on a number of assumptions as follows:

- The project is expected to be built on an area of about 734 hectares in Hoa Thang commune, Binh Thuan Province. The project uses equipment of Vestas manufacturer (Denmark), with a capacity of 49.5MW. The plant is connected to the national power system with 110kV voltage level. The distance to 110kV line is 5.5km from the 110kV transformer substation to the nearest transit of EVN;

- Annual energy output of each turbine is 3,715MWh, the wind farms

generate an output of 122,598.1GWh/year for 33 turbines, which is equivalent to full load hours of 2,477 (25% capacity factor);

- Total investment in the entire project (before taxes, not including interest) is USD 118 million (as estimated by the investor) and power project investment of about USD 2.39 million/MW. In which, the cost of equipment accounts for 64.4% of total fixed costs;

- O&M costs are assumed to be 2% of the total cost of equipment investment and construction, equivalent to 1.51¢/kWh;

- The lifetime of the turbine is set at 20 years;

- The debt/equity ratio is assumed to be 80% and 20% respectively, with interest rate of 8%/year, repayment period of 10 years and a grace period of 2 years. The discount rate is 10%.

Based on these assumptions, the generation cost of wind power production (LCOE) of Hoa Thang project is calculated at 12.26¢/kWh. 0 shows the impact caused by a 10% change of a number of key variables on wind power generation cost for Hoa Thang project, as compared with the base case. It can be seen that the generation cost of the project is mostly influenced by power output (for each 10% increase in output the price will reduce by nearly 10%), equipment cost and interest cost. The remaining factors such as the cost of wind towers, grid connection cost, O&M, etc. also affect the cost of wind power production but with lower level of impact.

3.2.2. Cost reduction senarios

The aim of this section is to propose a choice of measures that can contribute to reducing generation costs of wind energy in Vietnam. In general, the measures should concentrate on the variables or factors that most influence the cost of a wind energy investment. According to the solutions and sensitivity analysis mentioned above, these are as follows.

- Capacity factor or the output;

- Capital cost, which in turn driven by using equipment (Turbine, blade, sub-components etc.) from G7 or non-G7 equipment (China);

- O&M costs;

- Access to cheap capital finance.

According to the solutions proposed above, the reference scenario and cost reduction scenarios are summarised in Table 3. The difference of these scenarios is the selection of key equipment (turbines and its sub-components) from the manufacturer of the G7 countries or outside the G7 countries (China). For each option of the source device, there are two scenarios which are feasible scenario (likely scenario) and optimistic scenario (the most favourable conditions possible). According to the four proposed scenarios, the generation cost can be significantly reduced from 12.26¢/kWh to less than 9.14¢/kWh. However, except the optimistic scenarios (Scenario 2 and 4) which are difficult to prevail in the near future,

Table 3. *Scenarios to reduce wind power generation cost in comparison with base case*

Criteria		Reference case	G7 equipment		Non-G7 equipment (China)	
			Feasible (Scenario 1)	***Optimistic (Scenario 2)***	***Feasible (Scenario 3)***	***Optimistic (Scenario 4)***
1	Equipment	G7 equipment	G7 equipment		Non-G7 equipment[b]	
2	Price discounts[a]	No discount	Discount 5%	Discount 10%	Discount 5%	Discount 10%
3	Wind tower	Imported tower	Vietnam-manufactured tower			
4	Grid connection to 110kV	Self-invested	Self-invested	EVN invested (saving VND 29.56 billion)	Self-invested	EVN invested (saving VND 29,56 billion)
5	Internal road costs	As in FS	Saving 50% cost due to reduction of internal roads			
6	O&M costs[b]	2% of equipment	2% of equipment	2% of equipment	5% of equipment	5% of equipment
7	Interest rate	8%/pa	5%/pa	3%/pa	5%/pa	3%/pa
8	Output (million kWh/year)[c]	122.59	122.59	128.73 (Reference case + 5%)	122.59	128.73 (Reference case + 5%)
9	Contingency (% of capex)[d]	13.4%	13.4%	10%	13.4%	10%
	Generation cost (cent/kWh)	12.26	9.14	7.01	8.99	7.14

[a] Price discount for buying equipment can be up to 2%, 5% or 10%, depending on negotiation; [b] O&M cost for G7 and non-G7 equipment are 2%/pa and 5%/pa of Capex.
[c] Output can be raised by 5% with above-mentioned technical solutions; [d] Contingency cost is 10% by Vietnamese laws for projects less than 1 year, 13.4% for projects above 2 years. If project management is well applied, the project can be finished within 1 year.

other scenarios can reduce the generation cost to a certain degree, but still the final figure is higher than 7.8¢/kWh, the level that the Government sets for EVN to buy power from wind power projects. Therefore, it is possible to reduce the cost of wind power in Vietnam by some extent, but it is not an easy task to get to the level as low as set out by the Government.

Besides, the results show that if the favourable conditions in 2 optimistic scenarios do happen, using the equipment from China for Hoa Thang project will not be as efficient as using those from G7 (as compared between Scenario 2 and 4). The reason is O&M cost for non-G7 turbines is about 5% of Capex cost, significantly higher than the 2% level of G7 wind turbines. This makes the lower Capex from non-G7 manufacturers not a huge advantage after taking into account considerable variable costs over the years.

4. Conclusions and Implications

This paper aims to analyse the generation costs and solutions to reduce this cost for wind power production in Vietnam and other countries. The results show that capex costs, full load hours, and financial costs are three main factors that have the most impacts on generation costs. Lessons to make wind energy more competitive in other countries as well as from projects developed in Vietnam reveal three main solutions. First is the technical solutions. These include improvements in location selection process, wind measurement, project design and appraisal, turbine's rated capacity, turbine manufacturers and related O&M issues. Second is the economic-financial and management solutions. These include solutions to access credit, improve project management, minimise construction delays and related cost escalation. Third is the policy solutions. These include the measures taken by the Government to support local wind industries, as well as solutions to support directly wind projects in terms of electricity price, taxes and other incentives.

These solutions have been analysed and applied for a case study in Vietnam (Hoa Thang project). The results show that the generation cost varies from 7.01¢/kWh to 9.14¢/kWh, depending on different measures (compared with 12.26¢/kWh in the reference case). However, beside the optimistic scenarios which are hard to happen in the near future, wind generation costs in other cases are all higher than 7.8¢/kWh - the tariff set by the Government for wind power. Therefore, with such low level for renewable, wind projects in Vietnam will face huge challenges to attract commercial investors.

In order to develop wind energy in Vietnam, the Government should have a long-term plan for localisation of the equipment as well as attracting more foreign manufacturers to the country. Besides, the financial costs of a wind project can be sharply reduced if the project can access the assistance from the Government in terms of official guarantee, including ODA funding or special interest rates from state-owned banks. Also, the Government can consider to raise the power price to ensure the minimum margin for wind investors. In practice, the wind energy investors in Vietnam still keep complaining about very low purchasing price while the current cost of electricity generated from wind power plants is still quite high due to large technical investment. Discussion with various experts and stakeholders in Vietnam as well as our research results reveal that a power price around 10 - 12¢/kWh might be needed to make the wind energy projects become more financially feasible. If the price of wind energy (Feed in Tariff) is not increased to region levels, it will be very difficult to attract foreign investors.

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