Journal of Fundamentals of Renewable Energy and Applications

Nguyen, J Fundam Renewable Energy Appl 2014, 4:1
DOI: 10.4172/2090-4541.1000132

Review Article Open Access

A Brief Overview on Assessments of Wind Energy Resource Potential in Vietnam

Duc Luong Nguyen*

Department of Environmental Technology and Management, National University of Civil Engineering, 55 Giai Phong Road, Hai Ba Trung District, Hanoi, Vietnam

Abstract

With a coastline of more than 3,000 km and its location in the monsoonal climate zone, Vietnam is expected to have good potential for wind energy resource. In the recent years, several preliminary studies on assessment of potential of wind energy resource in Vietnam have been carried out. The objective of this paper is to draw an updated overall picture on wind energy potential and the current application as well as development of wind energy in Vietnam on the basis of data collected from various sources. The reviewing results showed that Vietnam has better wind energy resource than many other Asian countries. The highest potential areas of wind resource in Vietnam are the south central coast, central highlands, and south coast. However, the development of wind energy is just in the early stage and the application of wind energy is still negligible at present. This paper also identifies the major challenges need to be addressed for the future development of wind energy in Vietnam including those related to lack of the wind measurement and assessment of wind resource, lack of human resource, lack of comprehensive wind energy development planning, and lack of financial supportive mechanism. In order to promote the development and application of wind energy, much more effort need to be put forward in the coming years to overcome these existing challenges.

Keywords: Wind energy resource; Wind measurement; Wind energy application; Wind energy policy; Vietnam

Introduction

Likes the other developing countries in Southeast Asia, Vietnam is experiencing the high economic growth with the average Gross Domestic Product (GDP) annual growth rate of 7.2% during the period of 2001-2010. As a result, the country's energy demand has continuously increased at the rate of 15% per year during the last decade. It is estimated that the energy use comparative to GDP growth in Vietnam is twice bigger than that of developed countries. It is expected that the energy demand in the coming years will keep increasing at the significant rate of 11-16% due to the rapid economic development, urbanization, industrialization, and population growth. It is estimated that Vietnam's energy demand would be more than triple by 2020. Such situation would raise a number of questions concerning the availability of energy resources and environmental degradation [1].

According to Phan et al., the total installed capacity of all power producers in Vietnam in 2010 was 21,542 MW, of which the Electricity of Vietnam (EVN) accounted for 11,848 MW (55%) and the others, including the companies that the EVN has equity, accounted for 9,694 MW (45%). Among the current energy sources, hydropower represents the largest share (38%) in the total installed capacity, followed by gas turbines (32%) and coal-fired power (18%) [2]. Renewable energy sources currently just account for the smallest share, about 2%.

In order to meet the rapidly increasing energy demand, the Government of Vietnam has decided to increase its reliance on renewable energy sources. Following the Prime Minister's Decision No. 1855/QD-TTg dated 27 Dec 2007 approving the "National energy development strategy up to 2020, with a vision to 2050", the specific targets of increasing the renewable energy proportion has been set at 5% and 11% of the total primary energy consumption by 2020 and 2050, respectively [3]. Compared to the other Southeast Asian countries, Vietnam has a huge basin of renewable energy sources, including hydropower, wind, solar, biomass, geothermal, and wave and tide – all capable of supplying a large part of the country's energy requirements. Except hydropower which currently accounting for 38% of the country's total installed capacity, however, uses of the other renewable energy sources, especially wind resource, as alternatives to conventional energy sources have not been well promoted in Vietnam at present. Among the renewable energy sources (except hydropower), wind energy represents one of the strongest growth opportunities in Vietnam. With a coastline of more than 3,000 km and its location in the monsoonal climate zone, Vietnam is expected to have good potential for wind energy. Therefore, exploitation and application of wind energy in the future have an important meaning in terms of economic development, energy security, emission reduction, environment protection, and contribution to the sustainable development of human society in Vietnam. However, as is the case in many other developing countries, the assessment of wind energy potential in Vietnam remains incomplete. In the recent years, several preliminary studies on assessment of potential of wind energy resource in Vietnam have been carried out. The objective of this paper is to draw an updated overall picture on wind energy potential and the current application as well as development of wind energy on the basis of data collected from various sources as well as identify the major challenges need to be addressed for the future development of wind energy in Vietnam.

Global Status and Trend of Wind Energy Development and Application

During the period of 1996-2013, the global cumulative installed wind power capacity has continuously increased Figure 1. By the end of

***Corresponding author:** Nguyen DL, Department of Environmental Technology and Management, National University of Civil Engineering (NUCE), 55 Giai Phong Road, Hai Ba Trung District, Hanoi, Vietnam, Tel: +84-9-86071182; Fax: +84-4-38693714; E-mail: luongnd1@nuce.edu.vn.

Received June 06, 2014; **Accepted** August 09, 2014; **Published** August 20, 2014

Citation: Nguyen DL (2014) A Brief Overview on Assessments of Wind Energy Resource Potential in Vietnam. J Fundam Renewable Energy Appl 4: 132. doi: 10.4172/2090-4541.1000132

2013, the global cumulative installed wind power capacity was almost 318 GW. It was another record year for wind power, which again added more capacity than any other renewable technology [4,5].

The cumulative installed wind power capacities of top 10 countries and rest of the world by the end of 2013 are shown in Figure 2. For the first time since 2009, the majority of new capacity was installed in the Organization for Economic Cooperation and Development (OECD) countries, mostly in USA. Developing and emerging countries were moving firmly into the mainstream, however [4]. Currently, China is the leading country in wind energy development. The Chinese government's commitment to wind power has been reinforced once again by raising the official target for 2020 to 200 GW. The China, alone represented about 28.7% of the total global capacity, which a little bit higher than those of EU (28.1%) and American countries in 2013. The USA and China together accounted for nearly 48% of the total global capacity in 2013, followed distantly by Germany (10.8%), Spain (7.2%), India (6.3%), and the United Kingdom (3.3%). Others in the top 10 countries for capacity added were Italy (2.7%), France (2.6%), Canada (2.5%), and Denmark (1.5%). The top 10 countries accounted for nearly 85% of global capacity by the end of 2013 [5].

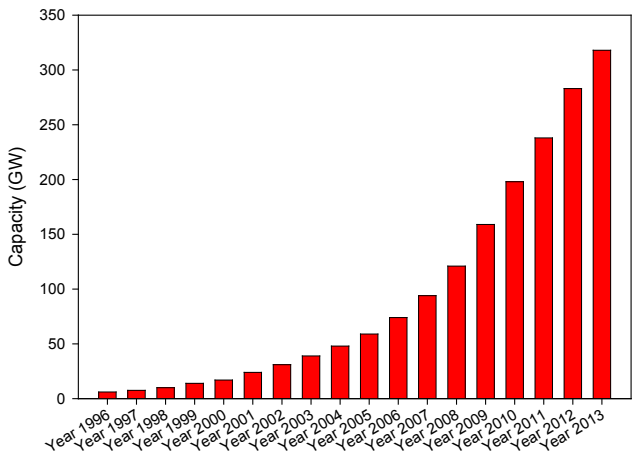

Figure 1: Global cumulative installed wind power capacity during the period 1996-2013.

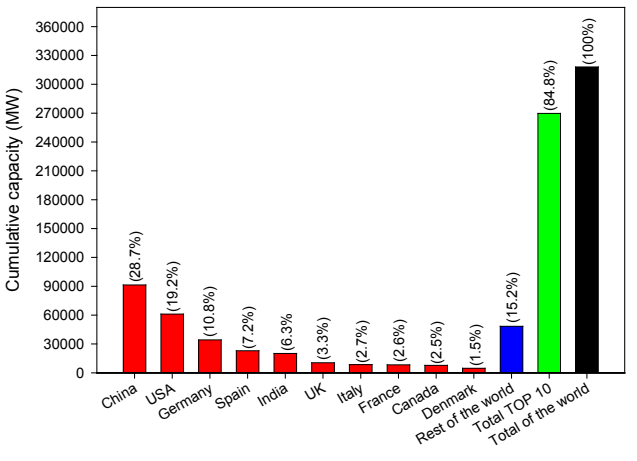

Figure 2: Cumulative installed wind power capacity and its corresponding share in total global cumulative installed capacity of top 10 countries and rest of the world by the end of 2013.

The trend towards increasing size of individual wind power projects has been continued, driven mainly by cost consideration. The largest EU onshore wind farm (600 MW) was connected to the grid in Romania, and the largest USA wind farm (845 MW), which began operating in Oregon, is expected to power 235,000 U.S. homes. Independent power producers and energy utilities are currently the most important clients in the market in terms of capacity installed, but interest in community-owned wind power projects is rising in Australia, Canada, Japan, USA, parts of EU, and elsewhere. For examples, community power represents the mainstream ownership model in Denmark and Germany. The use of small-scale turbines is also increasing to meet energy needs both on- and off-grid and is driven by the development of lower-cost grid-connected inverters; volatile or rising fossil fuel prices; and government incentives. Off-grid and mini-grid uses prevail, particularly in China and other developing countries. Applications are expanding and include rural electrification, water pumping, telecommunications, defense, and other remote uses. There are two distinct markets: models with rated capacity below 10 kW, and those in the 10–500 kW range. In general, the market is evolving towards 50 kW and larger turbines because they are easier to finance. Worldwide, at least 730,000 small-scale turbines were operating by the end of 2011, totaling 576 MW. In 2012, the total capacity of U.S. sales of small-scale turbines was 18.4 MW. With the exception of China, most interest is in North America and Europe, with slow progress in emerging wind markets [4].

The installed wind power capacity was increasingly able to meet the global electricity consumption. By the end of 2012, wind capacity was enough to cover 7% of the region's electricity consumption in a normal wind year in the EU. Several countries met higher shares of their electricity demand with wind. For examples, 59.6% of Spain's total power demand was supplied by wind power on 6 November 2011; 55% of all the electricity used by South Australians on 5 September 2012 was generated by wind power; and 30% of Denmark's electricity consumption was covered by wind energy by the end of 2012. The Danish government aims to get 50% of its electricity from wind by 2020 [6].

Studies on Assessment of Wind Energy Resource Potential in Vietnam

Similar to countries in most tropical and sub-tropical regions, the prevailing synoptic-scale winds in Vietnam are relatively weak. The dominant influences are the summer and winter monsoons, which are created by differences in temperature between the Asian land mass and the surrounding oceans – see breezes on a vast scale. The summer monsoon induces a counter-clockwise circulation around southern and eastern Asia, resulting in generally southerly and westerly winds in Vietnam. Whereas, the winter monsoon creates the opposite circulation, resulting in mainly northerly and easterly winds [7].

With respect to assessment of wind energy potential in Vietnam, several preliminary studies have been conducted during the last years. The World Bank (WB) carried out a study to prepare Wind Energy Resource Atlas for four Southeast Asian countries including Cambodia, Laos, Thailand and Vietnam for supporting the development of wind energy for the region [8,9]. Based on the Meso Map simulation model, this study provided a rough estimate of wind energy potential in Vietnam at 65 m above ground level which corresponding to the hub height of large turbines connected to the national grid. The study results showed that more than 39% of Vietnam's total land area was estimated to have annual average wind speeds of greater than 6 m/s at the height of 65 m above ground level – the wind speeds that suitable for operation

of large wind turbines. This developable land area is equivalent to a theoretical wind power potential capacity of 513,360 MW Table 1.

However, the theoretical wind power potential of Vietnam reported by True Wind Solutions might be overestimated since this study was mainly based on simulation modeling [9]. In 2007, an official study was conducted by Electricity of Vietnam (EVN) for assessing the wind resource for power generation [10]. This study carried out the measurements of wind speed at 65 m above ground level for a number of locations in different provinces of three regions of Vietnam. The measured data were compared to the modeled data which simulated for the same studying provinces/locations reported by TrueWind Solutions [9]. As shown in Table 2, the measured wind speeds were generally lower than the modeled wind speeds for most of studying provinces/locations. The measured wind speed data for the locations noted in Table 2 were used to extrapolate in estimating the regional wind with the inclusion of adjustments for surface roughness, shadow effects of buildings and other obstacles, and orographic effects. The regional wind data was then used to calculate wind speed data for other locations by applying similar procedures in reverse direction. Based on these results, the study identified land area suitable for wind energy generation with considering several factors such as distance to grid, land use, etc. which is equivalent to a technical wind power potential capacity of 1,785 MW as seen in Table 3 [8,10]). It is seen that the provinces of the centre region has the largest wind energy potential, followed by those of the south and north region. However, it should be noted that this potential estimate was not complete due to the scale of the study that just focused on several provinces/locations. It is possible that many other provinces/locations with good wind potential have not been identified, and therefore more provinces/locations would need to be included and evaluated before a complete picture of Vietnam's wind energy potential can be drawn.

More recently, the Ministry of Industry and Trade (MOIT) conducted a study to assess wind resource at selected sites in Vietnam for updating the previous Wind Energy Resource Atlas of Southeast Asia by using the mesoscale-microscale modeling system verified by the latest wind measurements from 9 tall towers instrumented for wind energy assessment [7,9]. The results showed that in the south, the relatively good wind resource along exposed coastal points of south-central Vietnam, especially between Ho Chi Minh City and Khanh Hoa, including those in Ninh Thuan and Binh Thuan provinces Figure 3, is due mainly to deflection of the monsoon winds, especially in summer, around the Southeast Asian landmass, and secondarily to localized see breezes. The mean wind speeds at 80 m above ground level at these points have been predicted to reach 6.5-7.0 m/s. Farther south there is another area of better-than-average winds (5.0-6.0 m/s) along the coast near Can Tho Province. The third area of significant interest is the highlands west of Binh Dinh Province along the Dac Lac and Gia Lai provincial border, where channeling through a broad mountain gap is expected to result in the mean wind speeds of 6.0-6.5 m/s. Moving north, relatively windy areas are mainly confined to the coast, notably near Quang Binh Province and southeast of Ha Noi. These are due mainly to sea breezes. In addition, the forcing of winds over the mountains along the Laotian border in central Vietnam is predicted to produce relatively good winds along the ridgelines. Aside from these areas, most of the rest of Vietnam experiences relatively low wind speeds ranging from less than 3.0 m/s to 5.0 m/s at 80 m height. Based on the newly modeled and measured wind data, the wind resource potential of Vietnam has been reestimated. In this work, areas deemed unlikely to be developed for wind energy (such as areas with slopes exceeding 20%, internationally and nationally protected parks and nature preserves, wetlands, urban areas, and watercourses and water bodies) have been excluded. The developable areas within each wind speed threshold category has been estimated assuming a mean density of 10 MW per km^2. It should

	Average wind speed (m/s)					Total
	< 6	6-7	7-8	8-9	> 9	
Vietnam						
Estimated developable land area (km^2)	197,242	100,367	25,679	2,178	111	325,577
Percentage of developable land (%)	60.6	30.8	7.9	0.7	~ 0	100
Wind energy potential (MW)	NA	401,444	102,716	8,748	452	513,360
Wind energy potential of other Southeast Asian countries (MW)						
Thailand	NA	149,348	2,992	52	0	152,392
Laos	NA	155,148	24,280	2,684	140	182,252
Cambodia	NA	24,620	1,260	120	0	26,000

Table 1: Wind energy potential at 65 m above ground level of Vietnam in comparison to other Southeast Asian countries.

Region	Province	Location	Average wind speed (m/s)	
			WB (modeled data)	EVN (measured data)
North	Quang Ninh	Mong Cai	7.35	5.80
	Nam Dinh	Van Ly	6.39	6.88
	Thanh Hoa	Sam Son	6.61	5.82
Centre	Ha Tinh	Ky Anh	7.02	6.48
	Quang Binh	Quang Ninh	7.03	6.73
	Quang Tri	Gio Linh	6.52	6.53
	Binh Dinh	Phuong Mai	6.56	7.30
South	Khanh Hoa	Tu Bong	6.81	5.14
	Ninh Thuan	Phuoc Minh	8.03	7.22
	Lam Dong	Da Lat	7.57	6.88
	Binh Thuan	Tuy Phong	7.79	6.89
	Tra Vinh	Duyen Hai	7.24	6.47

Table 2: Comparison of average wind speeds at 65 m above ground level estimated for different provinces of Vietnam by WB and EVN.

No.	Region	Wind energy potential (MW)
1	North	50
2	Centre	880
3	South	855
4	Total	1,785

Table 3: Estimation of wind energy potential with average wind speeds ≥ 6 m/s at 65 m above ground level for three regions of Vietnam.

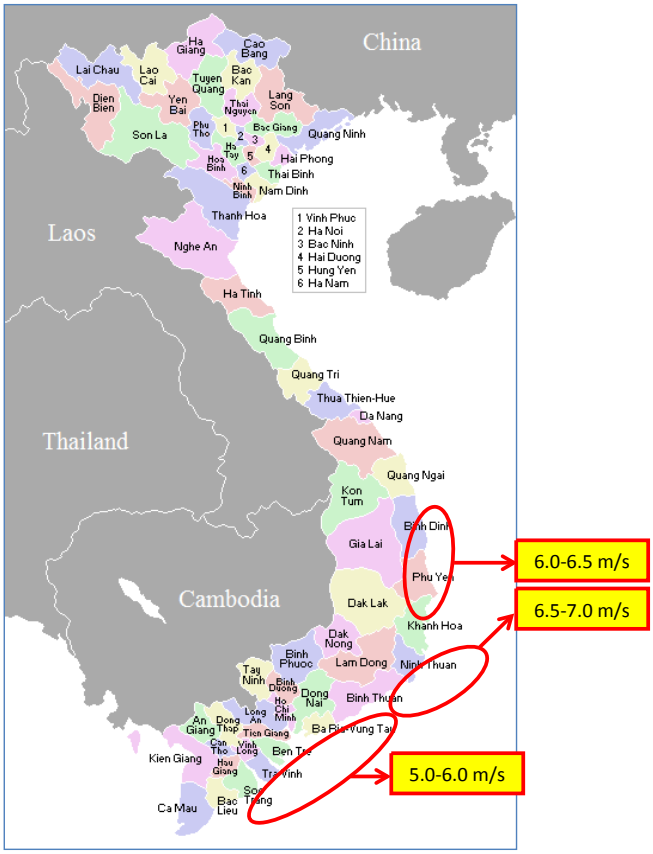

Figure 3: Map of Vietnam showing location of provinces with good wind potential at 80 m AGL.

be stressed that these values represent, at best, a very approximate, high-level estimate of the developable potential. However, the other factors such as economic viability, local siting constraints, community concerns, locations of transmission lines and transmission capacity, and the influence of topography on wind turbine density have not been considered. The estimated results are given in Table 4. Compared to the previous study TrueWind Solutions , AWS Truepower gave more moderate assessment results [7,9]. For example, for wind speeds of greater than 6 m/s that suitable for installing and operating large wind turbines, the technical wind power potential capacity of 26,763 MW estimated by AWS Truepower is about 19.2 times lower than that estimated by TrueWind Solutions [7,9]. However, it should be noted that this comparison has not considered the difference in the heights of wind data between two studies (65 m in TrueWind Solutions and 80 m in AWS Truepower) [7,9]. The study results of AWS Truepower [7] also support the earlier hypothesis that the Wind Energy Resource Atlas of Southeast Asia TrueWind Solutions overestimated the wind resources of Vietnam [7,9]. Through the above studies, it is seen that there is a significant difference in the estimated wind energy potentials in Vietnam provided by different agencies. Therefore, in order to give a complete and accurate picture of Vietnam's wind energy potential, more studies on wind measurements are clearly needed.

The wind energy potential of Vietnam estimated by AWS Truepower was compared with those of the other Asian countries as shown in Figure 4 [7].

It is seen that the wind energy potential of Vietnam is just lower than that of India, however, much higher than those of Pakistan, Iran, Cambodia, Taiwan, and Thailand [11-16]. This suggests that Vietnam remains an attractive region for wind energy development.

Wind Power Projects in Operation and Under Development

The application of wind energy in Vietnam is still in the early stage. By the end of 2013, there were only four projects are in operation with full or partial capacities as summarized in Table 5. For example, the wind energy project in Bac Lieu province Figure 3 has started generating electricity for the national grid on May 29, 2013. With a total capacity of 99 MW from 62 turbines, the wind mill is expected to generate 320 million kWh per year.

Compared to the other countries Figure 5, the cumulative installed capacity of wind energy in Vietnam was much lower than those in several countries belong to the top 10 countries in the world which have the largest installed capacity by the end of 2013 such as UK, Italy, France, Canada, and Denmark. The installed capacity of wind energy in Vietnam was also much lower than those in some Asian countries such as Japan, Taiwan, South Korea, and Thailand although the wind energy potential in Vietnam is higher than those in some of these countries as shown earlier. This implies that in order to exploit and utilize effectively the given wind energy potential, Vietnam needs to put much more effort in the coming years. However, by the end of 2013, the cumulative installed capacity of wind energy in Vietnam was higher than those of the other Asian developing countries including Pakistan, Iran, Sri Lanka, and Mongolia [17].

By the end of 2013, there were nearly 50 wind energy projects registered in the whole of Vietnam Table 6, concentrating in the central and southern provinces with the total registered capacity of ~ 5,000 MW, each having capacity in the range of 6-250 MW [2]. The average capacity of these projects is 95 MW, with 50-100 MW representing the biggest share (38%), followed by those of over 100 MW (26%). The investors include both local and foreign from Germany, Canada, Switzerland and Argentina [8]. These projects are currently in various stages of development, in which many of them are in the planning stage and are awaiting concrete support policies from the Government.

Major Challenges and Recommendations for Development of Wind Energy

Although there is a good potential for wind energy resource, the development of wind energy projects in Vietnam currently face several challenges.

Firstly, prospective investors may lack reliable and useful information about overall picture of Vietnam's wind energy potential when seeking investment opportunities since there is a lack of comprehensive assessments on the potential of wind resource in Vietnam due to inadequate wind measurements. The process of building the station anemometer (wind measuring station) to collect statistics and analyze comprehensive wind data is just being gradually

	Wind speed (m/s)							Total
	< 4	4-5	5-6	6-7	7-8	8-9	> 9	
Estimated developable land area (km^2)	95,916	70,868	40,473	2,435	220	20	1	209,933
Percentage of developable land (%)	45.70	33.80	19.30	1.20	0.10	0.01	0.00	100
Wind energy potential (MW)	959,161	708,678	404,732	24,351	2,202	200	10	2,099,333

Table 4: Wind energy potential with average wind speeds ≥ 6 m/s at 80 m above ground level of Vietnam.

Province/city	Location	Staring time for operation	Installed capacity (MW)	Type of wind farm	Investor
Hai Phong City	Bach Long Vy Island	October 2004	0,8	Onshore	Youth Union
Binh Thuan Province	Binh Thanh commune, Tuy Phong District	March 2011	30 (total capacity: 120 MW)	Onshore	Vietnam Renewable Energy JSC (REVN)
Binh Thuan Province	Phu Quy Island	August 2012	6	Onshore	PetroVietnam Power Renewable Energy Limited Company
Bac Lieu Province	Vinh Trach Dong commune	May 2013	99	Offshore	Cong Ly Construction-Trading-Tourism Company

Table 5: Grid-connected wind energy projects in operation by the end of 2013.

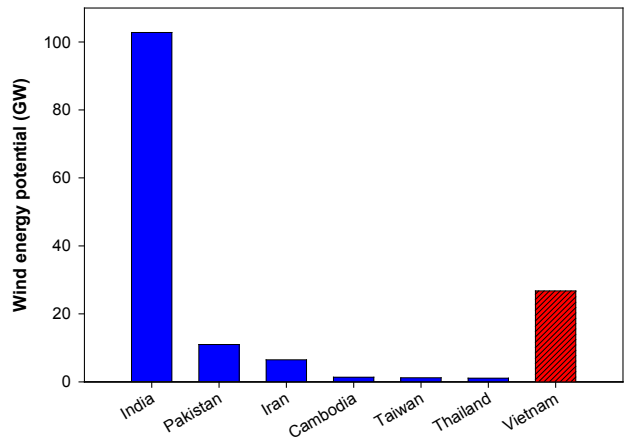

Figure 4: Comparison of wind energy potential between Vietnam and the other Asian countries.

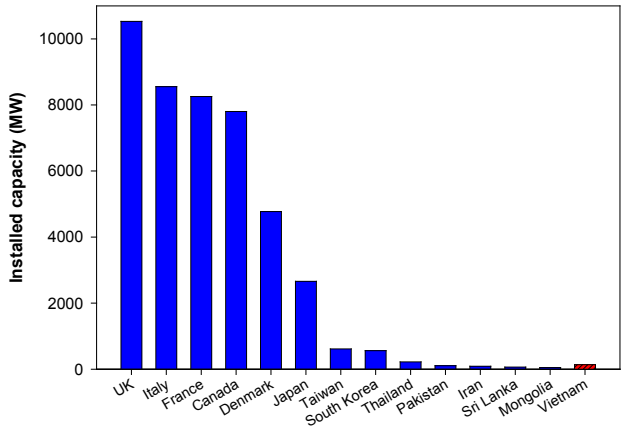

Figure 5: Comparison for cumulative installed capacity of wind energy between Vietnam and the other countries by the end of 2013.

Province/city	No. of investor	No. of project	Registered capacity (MW)	Status			
				IR	IP	TD	UC
Lang Son	1	1	200	1			
Binh Dinh	3	3	251	1	2		
Phu Yen	1	1	50	1			
Lam Dong	1	1	300				1
Ninh Thuan	9	13	1,068	5	6	1	1
Binh Thuan	13	14	1,597	10		2	2
Gia Lai	1	1	40.5	1			
Ba Ria – Vung Tau	2	3	118	1		2	
Tien Giang	1	1	100	1			
Ben Tre	2	2	280	2			
Tra Vinh	2	2	123	2			
Soc Trang	4	4	450	4			
Bac Lieu	1	1	99				1
Ca Mau	2	2	300	1			1
Total	43	49	4976.5	31	8	5	5

Note: IR = Investment Report; IP = Investment Project; TD = Technical Design; UC = Under Construction

Table 6: Grid-connected wind power projects under development.

implemented at present. In order to overcome this challenge, more comprehensive surveys and studies should be carried out in order to give a complete and accurate wind resource map in Vietnam. Wind measurements should be focused in potential areas of strategic importance for wind energy development, and especially in areas that have not been previously monitored. It is necessary to elaborate plans

and make adequate investment in conducting surveys and studies for obtaining additional data for planning and zoning areas for wind energy development and preparing investment and exploitation plans.

Secondly, lack of skilled personnel for carrying out a complete wind power projects (conducting wind resources assessments, preparing investment reports, etc.), basic technical and maintenance services, operation and management after installation of wind turbines is also the challenge for development of wind energy in Vietnam. Thus more efforts on development of human resource, both in quantity and quality, should be made. Training and raising professional qualifications for managers, technicians, and skilled workers for wind energy projects should be promoted.

Thirdly, lack of comprehensive wind energy development planning presents another challenge. The situation of 'first come, first served' is still common in the provinces where wind energy projects are planned to develop. In many cases, investors tend to reserve the land first, and develop their projects later. Therefore, new investors may find difficult to look for suitable sites. In addition, as land-use planning for wind energy development is not well-done, it might be risky for investors as the project sites might be reclaimed for other activities during the project evaluation process. In fact, such situation already occurred in Vietnam. With the perspective of growing number of wind energy development projects in the country and the increasing scarcity of suitable sites with adequate wind potential, the central and provincial governments should examine the current land-use policy for wind energy installations and formulate policies for land allocation on a "footprint" basis.

Finally and most importantly, Vietnam lacks effective and feasible supportive mechanism relating to the sale and purchase price of wind power – one of the most challenging issues for investors. Currently, the purchasing price of wind power, regulated by the Prime Minister's Decision No. 37/2011/QD-TTg on supporting mechanism for development of wind energy projects, is as low as 1,614 VND per kWh (equivalent to 7.8 US cents per kWh), although it is 310 VND per kWh higher than the average power price of 1,304 VND per kWh [18]. This price already includes 1.0 US cent subsidy from the state budget for a wind energy project's operational period of 20 years. This purchasing price, however, is much lower in comparison to those in other countries developing wind energy, thus not really attractive to foreign and private investors. For instances, the Government of Thailand has subsidy policy for power purchasing prices of 15.0 and 11.7 US cents per kWh for wind energy projects with installed capacities of ≤ 0.05 and >0.05 MW, respectively for a period of 10 years [19]. Meanwhile, the Government of Japan has set up the feed-in tariffs of up to 73.5 and 29.4 US cents per kWh for wind energy projects with installed capacities of ≤ 0.02 and >0.02 MW, respectively for a period of 20 years [20]. The Japan's tariffs are among the highest in the world. Therefore, to attract more potential investors and promote the development of wind energy which is now in the early stage, the Government should consider to increase the purchasing price of wind power to appropriate level with the consideration of key aspects such as the actual levelized cost of electricity generation, and the "value" of renewable energy generation, either to society or to the wind power purchasers (the avoided cost of purchasers). This process should be implemented with public consultation in a systematic and transparent manner in order to get the valuable feedbacks from all relevant stakeholders. On the other hand, the improving purchasing price of wind power should be distinguished by project cost, technology type, installed capacity, contracted capacity, time of installation, and project locations with different wind resource distributions and construction conditions (for examples, inland versus island, onshore versus offshore) as the experiences of many countries such as Denmark, India, Thailand, and China [11,19,21,22]. Furthermore, there is a lack of financial services for investors to borrow money from financial institutions or banks for the development of wind energy project. Actually, in 2012 some investors had to borrow short-term capital from domestic commercial banks at the really high interest rates of 20% per annum on average. This may make new investors shrink back and reconsider their intention to pour money into wind energy projects. Whereas, in other countries, investors can borrow huge sums of money at very low interest rates (in Denmark, for example, just 1.5% per annum). This is unfeasible in the Vietnam's current condition. On the other hand, domestic commercial banks are quite small and a single bank is unable to supply sufficient finance for a wind power project. In the context of the economic downturn, domestic banks are incapable enough to provide the huge amount of money in capital to wind power projects. In addition, most of domestic banks lack experiences in assessing and appraising renewable energy projects. To overcome the financial shortages for development of wind energy projects, the Government should establish the supportive mechanisms and financial services to enable the investors to borrow money from international financial institutions and banks that showing their increasing attention to and involvement in renewable energy market in Vietnam recently.

Conclusions

Compared to many other Asian countries, Vietnam has better wind energy resource as demonstrated by several preliminary studies during the last years. The highest potential areas of wind resource in Vietnam have been identified including the south central coast, central highlands, and south coast. However, the development of wind energy is just in the early stage and the application of wind energy is still negligible at present in Vietnam. In order to promote the development and application of wind energy, much more effort need to be put forward in the coming years in order to overcome the existing challenges related to the lack of the wind measurement and assessment of wind resource, lack of human resource, lack of comprehensive wind energy development planning, and lack of financial supportive mechanism. More importantly, the Government should develop comprehensive policies for supporting the development of wind energy based on the real on-going development situation and lessons learnt from international experiences. For the successful development of wind energy, a mixture of incentive policies/strategies such as increase of funding for R&D programs, grants towards investment costs, establishment of a premium purchasing price for wind power, etc. may be necessary.

References

1. Nguyen KQ (2007) Wind energy in Vietnam: Resource assessment, development status and future implications. Energ Policy 35: 1405–1413.
2. Phan TT, Vu CM, Wasielke A (2012) Status of wind power development and financing of these projects in Vietnam. Project study.
3. Prime Minister (2007) National energy development strategy up to 2020, with a vision to 2050. Decision No: 1855/QD-TTg.
4. REN21 Steering Comimittee (2013)Renewables 2013
5. Global Status. REN 21, UN.
6. Global Wind Energy Council (2014) Wind in numbers, 2013.
7. AWS Truepower (2011) Wind Resource Atlas of Vietnam.
8. GIZ/MoIT (2011) Information on wind energy in Vietnam..

9. TrueWind Solutions (2011) Wind Energy Resource Atlas of Southeast Asia. LLC, New York, USA.

10. EVN (2007) Annual Report.

11. Khare V, Nema S, Baredar P (2013) Status of solar wind renewable energy in India. Renew Sust Energ Rev 27: 1-10.

12. Muhammad KF, Kumar S (2013) An assessment of renewable energy potential for electricity generation in Pakistan. Renew Sust Energ Rev 20: 240-254.

13. Bahrami M, Abbaszadeh P (2013) An overview of renewable energies in Iran. Renew Sust Energ Rev 24: 198-208.

14. Sarraf M, Rismanchi B, Saidur R, Ping HW, Rahim NA (2013) Renewable energy policies for sustainable development in Cambodia. Renew Sust Energ Rev 22: 223-229.

15. Chen F, Lu SM, Tseng KT, Lee SC, Wang E (2010) Assessment of renewable energy reserves in Taiwan. Renew Sust Energ Rev 14: 2511-2528.

16. Chingulpitak S, Wongwises S (2014) Critical review of the current status of wind energy in Thailand. Renew Sust Energ Rev 31: 312-318.

17. http://en.wikipedia.org/wiki/Wind_power_by_country .

18. Prime Minister (2011) Mechanism Supporting the Development of Wind Power Project in Vietnam (In Vietnamese). Decision No: 37/2011/QD-TTg.

19. Tongsopit S, Greacen C (2013) An assessment of Thailand's feed-in tariff program. Renew Energ 60: 439-445.

20. http://www.renewableenergyworld.com/rea/news/article/2012/06/japan-approves-feed-in-tariffs .

21. Munksgaard J, Morthorst PE (2008) Wind power in the Danish liberalised power market—Policy measures, price impact and investor incentives. Energ Policy 36: 3940–3947.

22. Zhao ZY, Wu PH, Xia B, Skitmore M (2014) Development route of the wind power industry in China. Renew Sust Energ Rev 34: 1-7.