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Article

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Determining the Offshore Wind Power Potential in the Mix-electric Power of Vietnam: The Role of Feed-in Tariff Policy

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ABSTRACT

The purpose of the research is to examine the offshore wind power potential in the mix-electric power of Vietnam. By using net present value method, the paper also aims to explore how economic factors influence the offshore wind power feasibility in the conditions that the technical factors are ensured. The result indicates that offshore wind power will have a low proportion in the mix-electric power of Vietnam before 2030 and may be accelerated in the period 2035-2040. Electricity supply from offshore wind is not economically viable without improvements in investment, operating costs, and capacity factor. In particular, the Feed-in-Tariff (FIT) policy designed to support the development of renewable energy sources by providing a guaranteed, above-market price for producers, will be a decisive factor in developing offshore wind power of Vietnam. Additionally, the differences between characteristics of site's condition leading to the disparities in capital and operational expenditure and capacity factor. Thus, the electricity price and the subsidies for bottom-fixed sites and floating sites should be disparate and the location of offshore wind farms should be considered to ensure the harmonization of the profits derived from different types of offshore wind farms.

Keywords: Offshore Wind Power Development, FIT Policy, Capacity Factor, Power Development Plan 8
JEL Classifications: D4, Q21, Q28, Q41, Q43, Q48

1. INTRODUCTION

Currently, Vietnam is accelerating the development of electricity from renewable resources to meet the country's increasing electricity demand and diversify mix-electric power that ensures energy security. However, the most important characteristic of renewable energy is the intermittent in supply, thus, the power system must have a suffering backup source leading to the increases in the production cost of electricity. Over the last 3 years, the proportion of renewable energy has increased too quickly with a capacity exceeding the planning, while low electricity consumption demand during covid-19 period and the overloaded local grid has led to an excess of that source. According to National Load Dispatch Center (NLDC, 2021), over 3000 MW capacity of renewable energy was cut off on December 27, 2020, and the situation of reducing renewable power capacity is still happens regularly in the first half of 2021. Hence, the development of renewable energy in the following phase needs more careful study.

Offshore wind power is another renewable energy source, which has great technical potential in Vietnam. In addition, offshore wind farms have some advantages in comparison with onshore wind farms including high power rating, high yield energy, high offshore wind and unlimited space which make the installation of bigger offshore wind turbines possible etc. According to offshore wind road map for Vietnam launched by the World Bank Group (Tran, 2021), this energy source could play a significant role in sustainably meeting Vietnam's rapidly growing electricity demand and has the potential to supply 12% of Vietnam's electricity by 2035. To stimulate the growth of offshore wind energy, many policies which might include energy payment, international treaties, legislation, and incentives for investment are proposed. According to the government's Decision No. 39/2018/QD-TTg enacted by The Vietnamese Prime Minister (2018), EVN will buy wind power from investors at a tariff of 9.8 Us cents/kWh for offshore wind power projects commissioned before November 01, 2021. Recently, the new FIT policy with the proposed tariff of 8.47 US cents/kWh for offshore wind applied to commissioned projects will be put into commercial operation from November 2021 to December 2022 and the rates of 8.21 US cents/kWh for projects commissioned in 2023 and after 2023, FIT will be replaced with an auction system which is being mulled over (Phan and Doan, 2020). Changing in FIT policy or the emerge of the auction mechanism will affect the feasibility of offshore wind projects if there is no innovation in technology to reduce costs for offshore wind power projects.

Until now, there has been currently no research focusing on the economic potential of offshore wind in Vietnam. The economic potential can change over time along with the development of technology, thereby leading a reduction in investing cost, operating cost, and policy shift. The purpose of the research is to determine the economic potential of the different regions of Vietnam that has been assessed as having technical potential and its fluctuation when the economic factors such as investment cost, operating cost, FIT policy, and capacity factor change. Aside from determining the potential, we also compare it against the required capacity in PDP 8 (Table 1) for evaluation and policy recommendation.

The structure of this study is as follow: after introducing the background, the first part starts traditionally with a literature review of assessing offshore wind potential and then identifying the data and methodology that will be used in this paper to estimate the wind power potential in Vietnam, before showing a result of the research. Finally, it comes to conclusion and policy suggestions.

2. LITERATURE REVIEW

Theoretical potential of offshore wind power is defined as pure potential in terms of energy which is estimated via analyzing statistics meteorological data (Du et al, 2020). The region has theoretical potential and is suitable for planning the construction of wind farms is supposed to be an area of technical potential. The region which has technical potential and wind farms in this area bring economic benefits to investors is considered as an economic potential area. In this paper, we focused on evaluating the economic potential of the areas having technical potential of offshore wind power.

Many economic studies on offshore wind potential have been conducted globally and the Levelized Cost of Energy (LCOE) and Net Present Value (NPV) are the two commonly used methods. There may be some different points in the calculation steps or the selection of the input factors among these papers, but the core method remained the same. Shin (2012) investigated the economic feasibility of offshore wind power in China and South Korea. This paper focused on the offshore wind power project which either has already constructed or being constructed. It was also an analysis of feasibility with NPV method conducted with the consideration of the status of technology, market and policy in Korea and China. Shin argued that NPV method can be employed to economically evaluate large-scale infrastructure constructions, such as wind power generation farms. This research demonstrated the policy's impact on the viability of wind power projects but showed the limitations in using the same discount rate of 7.5**%** for both Korea and China, which may lead to some non-objective judgments due to the distinct economic characteristics.

Table 1: Offshore wind power installed capacity in Draft PDP 8

	2020	2025	2030	2035	2040	2045
Offshore wind power Installed Capacity (GW)	0	0	0.5	6.4	14	19
Total Installed Capacity (GW)	69.2	97.3	132.8	183.8	227	270
Percentage	0	0	0.38	3.48	6.17	7.04

Source: IEVN (2020)

On the issue of estimating the operating cost of a unit production by the wind energy system, Diaf et al. (2013) used the LCOE method which is described as the ratio of the total annualized cost of the wind system to the annual electricity produced by this system. Because the economic viability of wind energy project depends on its ability to generate electricity at a low operating cost per unit energy, LCOE is an essential key to determine the economic potential of an individual site. The determination of the unit cost of energy involves two main steps: the first step is to calculate the present value of cost by taking into consideration the initial investment cost of the system and the present value of operation and maintenance cost throughout the lifetime-system, and the second step is to determine the unit cost of energy. Caglayan (2019) concerned on both economic aspect and sufficient detail. This research applied a high spatial resolution to the three aspects of offshore wind potential analysis including ocean suitability, the simulation of wind turbines and cost estimation. A set of constraints is determined, then turbine designs specific to each location are selected by identifying turbines with the cheapest LCOE, restricted to capacities, hub height and rotor diameters. Thus, LCOE is a powerful screening tool, and LCOE method demonstrates its strength in assessing the change of production costs when technology changes. However, according to EIA (2013), there are unaccounted factors that which need to be involved when analyzing systems. LCOE works best when combined with other methods to give a more accurate, encompassing comparison of generation systems.

To overcome this limitation, in the report conducted by Musial et al. (2016), LCOE and Levelized Avoided Cost of Energy (LACE) were computed to estimate the economic potential of offshore wind energy resources in Maine (United State). LACE is defined as a metric used to represent the electricity generation costs of a technology over its expected life cycle and is usually calculated per 1 MWh (Beiter et al., 2016). EIA (2013) considered LACE particularly useful in assessing the economic competitiveness of non-conventional energy sources such as wind and solar. LACE is determined based on the marginal cost of electricity generation and capacity value which are expressed as the average (avoidable) cost per MWh. The marginal power generation cost is determined by the production cost of the highest-cost power generating unit dispatched to meet the load demand.

The difference between the LCOE and the LACE in each region is defined as the "net value" of that area, and this net value is used to determine the economic potential on the principle that an area having technical potential with net worth greater than 0 is considered as an area with economic potential. This method evaluates the economic efficiency of wind power projects taking into account the power generation costs of other sources. However, this method still shows limitations in analyzing the impact of the electricity price policy on the viability of the project, for example, the profit change is not shown/indicated, and the amount of computation as well as the required data is also larger.

Effiom et al. (2016) use an economic cost which was presented to evaluate the feasibility of offshore wind turbine farms in Nigeria. The methodology adopted in this study includes the cost breakdown structural approach and the simple LCOE method. The later was used in evaluating the Life Cycle Cost (LCC) of each phase of offshore wind turbine farm project. LCC is used to identify all the critical components of the project life cycle from pre-planning to decommissioning. LCC also takes into account the risks or expenses in different phases of the project and their impact on life cycle costs considering the value of money over time. Another study evaluated the economic potential of offshore wind energy in the Gulf of Bothnia which was analyzed using LCOE and LCC analysis by Lappalainen (2019). In both studies, life cycle phases are divided to Pre-development and Consenting (P&D), Production and Acquisition (P&A), Installation and Commissioning (I&C), Operation and Maintenance (O&M) and Decommissioning and Disposal (D&D). The combination of the LCOE and LCC method helps brings the more precise.

In short, LCOE focuses on the assessment of power production cost and output and while ignoring the calculation of revenue from electricity sales. The LCOE is a good indicator of the impact investment cost fluctuation caused by technological developments, and the final result is the change in production cost per unit of power. LCOE can be combined with other methods such as LCC to obtain more accurate outcome. However, LCOE is not suitable in comparing the feasibility of different projects with different types of technology, and LACE can be used in conjunction with LCOE to address this limitation. Nevertheless, even with such combination, LCOE is still not suitable in assessing the policy impact. NPV is used to calculate the project's net value in present value of currency, and the calculation using NPV requires both cost and revenue data. NPV is concerned with determining the trajectory of future market prices and the financial consequences of policies, and it is appropriate for studying policy impact. The limitation of this method is that it is difficult to determine the specific impact of each factor on the outcome in scenarios where many factors change.

3. METHODOLOGY AND DATA

The purpose of this study is to explore the impact of FIT policy, capital expenditure (CAPEX), operational expenditure (OPEX), and CF on the volatility of offshore wind power economic potential in Vietnam. FIT policy has always been a hot topic in Vietnam and the remaining factors are considered as the cost drivers in several previous studies (Ryan, 2016; IRENA, 2019). As the impact of FIT policy is accounted for in the assessment, NPV method is selected. Each area with technical potential is regarded a project. If the project's NPV is positive, the area has economic potential. The total national's economic potential is the sum of the capacity of all sites with positive NPV.

When calculating the economic potential, this paper focuses on the issue of determining the impact of economic factors, for example, investment costs and electricity price. Thus, we assume that the technical factors, such as the demand of power transmissions from the potential site to the onshore substations and the inter-regional power transmissions, are ensured. Therefore, the entire estimate power production from the potential farm is purchased. In addition, the average construction period of a wind power project usually takes 3-5 years, so this period is assumed 4 years.

This study is conducted in three main steps. The first step is to determine the Cash Flow After Tax (CFAT) in each project, which is divided into 2 phases. Cash outflows in the initial investment and financing phase are determined by the financing activity or fundraising to provide the main capital source, including funds from banks and investments. The investment activity concerning the use of mobilized capital, is invested mainly into capital expenditure (CAPEX). This phase is equal to the project construction time (4 years) and the first year of this phase is equivalent to a financial year of −3.

Cash inflows (benefits) during the long-term operational phase are characterized by the main cash inflows from revenues, determined by two main value drivers: price per unit or tariff per unit produced (in kWh) and the quantity sold, or output measured in kWh as annual energy production (AEP). There are two main types of cash outflows (Costs) in the operational phase: OPEX, especially operation and maintenance of wind turbine generator and cost of capital (COC), which mainly consists of debt service. To determine the CFAT in the operating phase, the interest payment is first calculated to determine taxable income. Until now, the equity in offshore wind power projects in Vietnam has usually accounted for 20-30% of total investment, the rest is either domestic or foreign loan. Since interest payments will be deducted from taxable income, investors usually set the highest possible loan. In this paper, the weightage of equity will be 20% so that the weightage of debt will reach 80% (the highest possible level), thus bringing the highest interest payment. Data on the grace period, repayment period and cost of debt are shown in Table 2.

The interest payment of each project can be estimated from those data. After calculating the interest payment, the taxable income of the projects is established by Formula (1).

$$TI_t=CFBT_t\text{-}D_t\text{-}I_t \quad (1)$$

Where: TI_t is the taxable income at time t, $CFBT_t$ is the cash flow before tax at time t and $CFBT_t$ = $Revenue_t$ – $OPEX_t$, D_t is

Table 2: Cost of capital and yield expectation of investors

	Index	Remarks
Weightage of equity	20%	Common use
Weightage of debt	80%	Common use
Cost of equity	10%	Common use
Cost of debt	6%	State Bank of Vietnam (2021)
Grace period	4 years	Equal to the assumed construction time
Repayment period	10 years	Common use in feasibility studies of some projects. Starting from the first year of operational phase

Source: Elaborated by authors

the depreciation at time t (for the convenience of calculation, the straight-line depreciation method will be and the depreciation period is assumed to be 20 years which is equal to the operating period and has no salvage value), I_t is the interest payment at time t.

Income Tax (IT) can be calculated by multiplying TI by the tax rate. The tax rate is not fixed, and its determining principle is shown in Table 3.

Profit After Taxes (PAT) can then be determined and CFAT can be calculated by Formula (2).

$$CFAT_t = PAT_t + D_t - G_t \tag{2}$$

where: $CFAT_t$ is the cash flow after tax of investors at time t, PAT_t is the profit after taxes at time t, G_t is the principal payment at time t.

The second step is to calculate the NPV of each potential site, then calculating the total economic potential. The NPV of each project can be established by Formula (3).

$$NPV = \sum_{t=-3}^{T} \frac{CFAT_t}{(1+r)^t} \tag{3}$$

where: $CFAT_t$ is the cash flow after tax of investors at time t, r is the discount rate, T is the time period (in this case, it is the lifetime of the project and is assumed to be 20 years which is equal to the average lifetime of the current turbine).

The weighted average cost of capital (WACC) serves as the discount rate. Due to the difference in project's tax rate, each site will have its distinct discount rate. As shown below, the WACC formula is:

$$WACC = W_D * K_D * (1-TR) + W_E * K_E \tag{4}$$

where: W_E is the weightage of equity in total capital, W_D is the weightage of debt in total capital, K_E is the cost of equity, K_D is the cost of debt, TR is the tax rate of the project and its formula is $TR = \frac{t_5 + t_{10} + t_{20}}{T}$ where t_5, t_{10} and t_{20} are the total number of years when the tax rate is 5%, 10% and 20%, respectively.

In the last step, the analysis scenarios are proposed. The first scenario is the baseline scenario (BAU), presenting the impact

Table 3: Income tax rate for power projects in Vietnam

Tax rate	Index
Profitable first 4 years	0%
The next 9 years	5%
The next 2 years	10%
Other years	20%

Source: MOIT (2014)

OPEX, CAPEX, CF and FiT policy in 2020. Taking account of the recent announcement of the FIT application extension to the end of 2023, two alternate 1-changing-factor scenarios (SC2 and SC3) with lower FIT prices compared to the base scenario. These scenarios can be used to estimate the offshore wind power potential in Vietnam when FIT 2 and FIT 3 prices come into effect after November 01, 2021 and January 01, 2023 respectively.

The remaining (SC4 to SC12) are scenarios with four factors changed. In each phase, two types of scenarios are proposed, the normal scenario and the low scenario. The normal cases are based on the projections of the change of cost and CF. In the low cases, both FIT and CF costs will be lower than those in the ordinary ones. These scenarios are based on the forecast of the likely variation in costs and CFs of the offshore wind technology (IRENA, 2019), along with the adjustments to suit the situation in Vietnam (Brown and Vu, 2020; Authors). Since IRENA's forecast are made up to 2050, analysis scenarios to 2050 will be developed.

The improvements in CAPEX and OPEX are based on the status that Vietnam is well-positioned to capture economic benefits from supply chain development. For industry players, in addition to the capacity in civil construction, the greater use of local sources will be the basis for reducing costs and increasing the competitiveness of offshore wind energy compared to other energy sources. Currently, Vietnam has one of CSWind's major facilities located in Phu My serving the global market with a capacity of more than 900 towers annually. Moreover, GE Vietnam supplied turbines for offshore wind projects in Vietnam such as Bac Lieu offshore wind power plant and Helukabel manufactures turbine cable components, including medium voltage applications. According to the DEA's statistics (DEA, 2020), Vietnam will have a production localization of 30% by 2030, 60% by 2040, and 100% by 2050. Moreover, in the feasibility analysis of some offshore wind projects in Vietnam, it is proposed to use turbines from such major turbine producers in the world as Vesta, GE Energy or Siemens. The expense for those turbines tends to decrease thanks to the development of technology, especially from 2020 to 2025. However, Vietnam is still in the early stages of development, so the capital and operation costs are likely to be set at a high point compared to the world average cost before 2030. The resolution passed at the congress sets the target that Vietnam will have become a high-income country by the year 2045, so we assume that Vietnam will catch up with other developed countries' cost reduction rate in the period 2040 - 2050. In addition, Vietnam has a good wind regime, so the CF will be set equal to the world's forecasted CF growth rate.

MOIT proposes to change the application route of the competitive wind auction mechanism and this route will be implemented after 2023. However, according to some assessments, Vietnam government should develop a new FIT tariff for offshore wind power that can support the auction mechanism in the early stages or can be applied in parallel with the auction mechanism (Stephenson, 2021; Li et al, 2021). Therefore, we assume FIT policy is still implemented after 2023 and the change in FIT can be suggested by the authors. The National Power Plan 8 reflects Vietnam's reticence in promoting offshore wind power development before 2030. In addition, FIT rates are often adjusted downward over time thanks to tariff degression to encourage technology cost reduction. Therefore, we assume that FIT price will continue to decline in the period before 2035. From 2040 to 2045, offshore wind power will develop rapidly according to the power plan. Furthermore, some areas with technical potential haven't been exploited due to significantly higher costs and complex terrain. To attract investment and ensure that the proposed capacity is met, we assume the FIT price in this period should be increased compared to that in the previous period. Scenarios are shown in Table 4 with the factors as the percentage change in comparison to the BAU scenario.

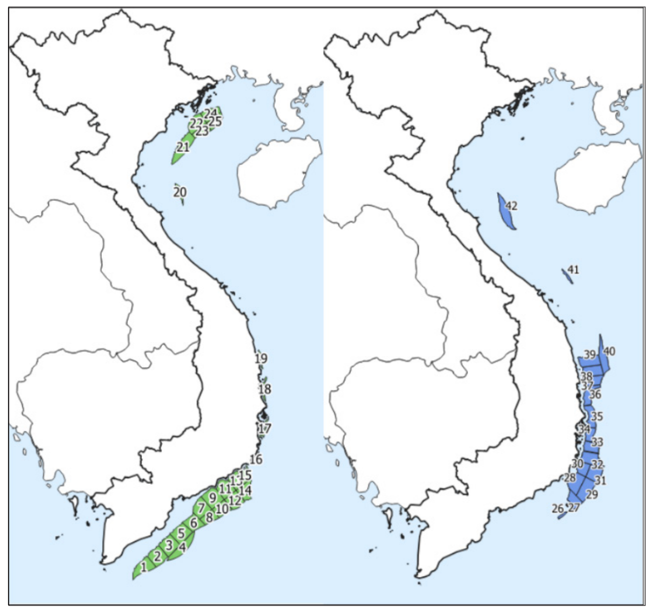
Regarding data collection, all secondary data on technical potential including park size, number of turbines, annual energy production (AEP), as well as CF and estimated costs data including CAPEX, and OPEX are based on the research conducted by the Danish Energy Agency (DEA, 2020). The CAPEX includes not only the development and construction costs of the offshore wind farms but also the expenses for the substations and cables from the wind farm sites to the shore. The DEA's research identified 25 potentially feasible sites for fixed bottom foundation projects (the left-hand side of Figure 1) and 17 sites for floating foundation projects (the right-hand side of Figure 1) – along the coast of Vietnam. Both fixed bottom and floating projects with 500MW nameplate capacity have been considered for each site. All the sites have a total area of about 37,400 km^2, are 5-100 km from the shore, and have wind speed of 6.5-9.5 m/s.

4. RESULTS AND DISCUSSIONS

If the points representing the economic potential of the scenarios are connected (Figure 2), an upward sloping curve is obtained. The association of the curve shows the difference in economic potential at different times or at the same time under different conditions. Intuitively, it can be seen that the potential before 2035 is relatively low and gradually increases over time. There will be a sharp increase in the potential from 2035 to 2040 and this increase will slow down after 2040.

In the BAU scenario, there are two fixed bottom projects having positive NPV, indicating an economic potential of 1000 MW for offshore wind power in Vietnam's mix-electricity. In case that the

Figure 1: Vietnam offshore wind technical potential map - site screened



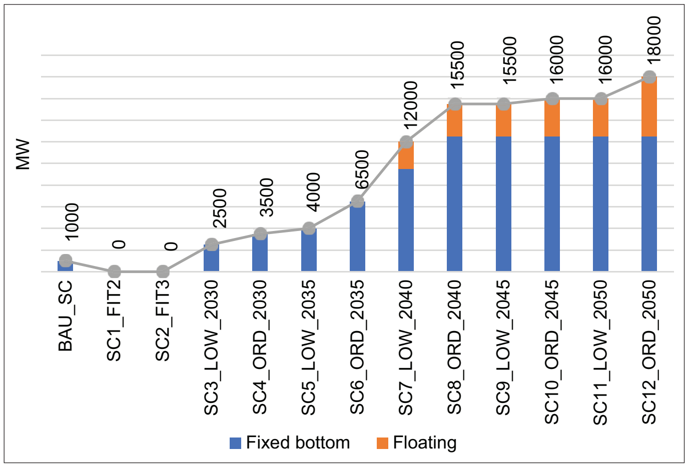
Source: DEA (2020)

Table 4: The offshore wind power development scenarios

	BAU_SC	SC1_FIT2	SC2_FIT3	SC3_LOW_2030		SC4_ORD_2030		SC5_LOW_2035	
				Fixed	Floating	Fixed	Floating	Fixed	Floating
CAPEX (real 2020)	Set value	0%	0%	-15%	-15%	-20%	-20%	-25%	-25%
OPEX (real 2020)	Set value	0%	0%	-10%	-10%	-15%	-15%	-20%	-20%
FiT (Uscent/kWh)	9.8	-13%	-16%	-20%	-20%	-20%	-20%	-22%	-22%
CF (%)	Set value	0%	0%	15%	17%	15%	17%	16%	18%
	BAU_SC	SC6_ORD_2035		SC7_LOW_2040		SC8_ORD_2040		SC9_LOW_2045	
		Fixed	Floating	Fixed	Floating	Fixed	Floating	Fixed	Floating
CAPEX (real 2020)	Set value	-30%	-30%	-35%	-35%	-40%	-40%	-40%	-45%
OPEX (real 2020)	Set value	-25%	-25%	-25%	-25%	-30%	-30%	-30%	-35%
FiT (Uscent/kWh)	9.8	-22%	-22%	-16%	-16%	-16%	-16%	-12%	-12%
CF (%)	Set value	16%	18%	17%	19%	17%	19%	20%	22%
	BAU_SC	SC10_ORD_2045		SC11_LOW_2050		SC12_ORD_2050			
		Fixed	Floating	Fixed	Floating	Fixed	Floating		
CAPEX (real 2020)		-45%	-50%	-45%	-50%	-50%	-55%		
OPEX (real 2020)	Set value	-35%	-40%	-35%	-40%	-40%	-45%		
FiT (Uscent/kWh)	Set value	-12%	-12%	-8%	-8%	-8%	-8%		
CF (%)	9.8	20%	22%	22%	23%	22%	23%		

Source: Elaborated by authors

Figure 2: Economic potential of offshore wind power in Vietnam in 13 scenarios



Source: Results of this study

Table 5: The NPV of potential sites in the BAU scenario and the 2030 scenario

	Site number	Capacity (MW)	NPV (USD)	Total economic potential (MW)
BAU_SC	Site 14	500	63,770,076	1000
	Site 15	500	65,238,565	
SC3_LOW_2030	Site 12	500	60,876,257	2500
	Site 13	500	52,829,531	
	Site 14	500	174,234,326	
	Site 15	500	168,026,842	
	Site 16	500	1,921,424	
SC4_ORD_2030	Site 8	500	1,058,109	3500
	Site 10	500	69,822,060	
	Site 12	500	161,409,336	
	Site 13	500	143,148,485	
	Site 14	500	275,880,032	
	Site 15	500	260,601,143	
	Site 16	500	94,391,089	

Source: Calculated by this study

FiT follows the proposal of FIT extension and is reduced by a sliding scale up to 2023 (SC2_FIT2 and SC3_FIT3), the economic potential of offshore wind power in Vietnam will reach zero. However, it is unclear whether this proposal will be adopted. It is worth noting that in 2020, EVN had a surplus of electricity due to the large uptake in solar. As a result, a reluctance can be seen in the suggestion of FIT extension. Assuming that the proposal will be approved, and the tariffs would be much lower than the current one, the sharp fall in electricity prices has made wind power investors worried and divert their investment to new planned wind power projects. Moreover, the Covid-19 pandemic has been slowing down wind power projects, making it difficult for many offshore wind power projects to come into commercial operation before November 2021 to be eligible for FiT and so they had to incur lower prices. The development of offshore wind power projects in current time, therefore, has faced many difficulties.

By 2030, the economic potential of offshore wind power will range from 2500 MW to 3500 MW. These estimates partly reflect the relatively low economic potential of offshore wind power before 2030. In addition, the NPVs of some potential areas with a capacity of 500MW each do not appeal to investors (Table 5). Besides, all economic potential areas are located in the South-Central region. In fact, the overloading of the 500kV line in this area is one of the toughest problems in operating Vietnam's power system which could not be solved in a short time. Therefore, continuing to promote offshore wind power development before 2030 is not suitable for Vietnam in both benefits and technical aspects. The period of 2035-2040 seems to be more suitable for promoting offshore wind power development once both the economic potential in this stage and the benefits obtained from each project are greater, and the problem of power transmission is also partly solved.

Another important point is that although the electricity purchase price in the scenarios for 2030 and 2035 is assumed to be less than that of FIT 3, the economic potential will increase rather than decreases as when FIT 2 and FIT 3 take effect. This difference mainly comes from reduced cost and increased CF. By 2035, the total economic potential coming from fixed bottom sites and its leaping increase in 2040 is the result not only of more fixed foundation areas with high economic potential, but also of the cost and CF' reaching the efficiency threshold of low-cost floating foundations, generating an additional 2500-3000 MW. In the 2050 scenario, it is assumed that cost will be halved, and CF will increase by 23%, but there are still some uneconomically viable floating foundations areas. Thus, it can be seen that Vietnam will find it difficult to effectively exploit offshore wind power without reducing costs and increasing CF. The development of offshore wind power in the coming decades will highly depend on these factors.

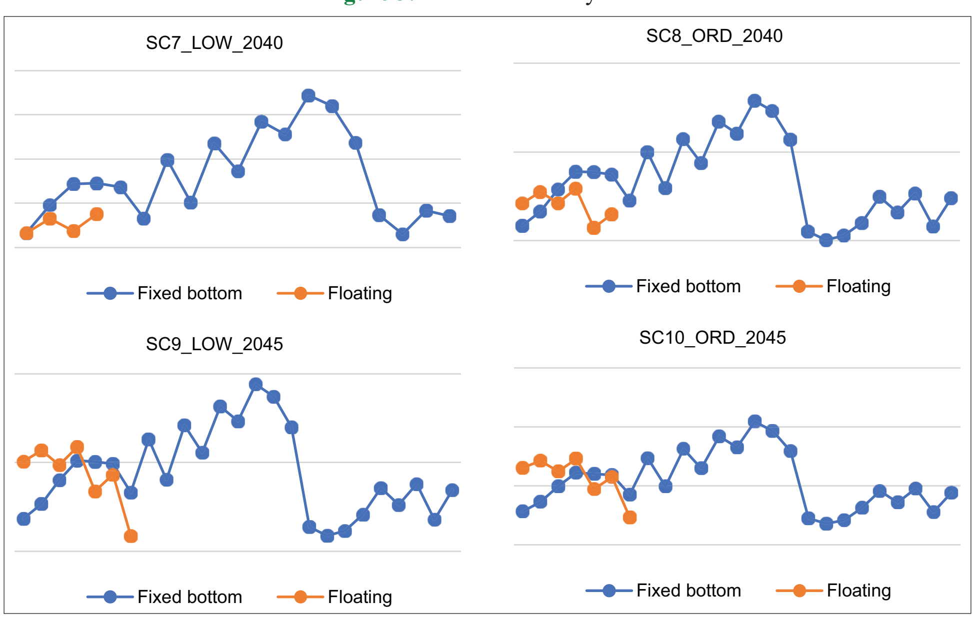
However, these factors are dependent on technology development, and this seems to be beyond Vietnam's control (Vietnam can only rely on the technology from developed countries). The potential change resulting from this can be viewed as raw potential and what the Vietnam government needs to do now is to calibrate this potential through policy tools. FIT policy mechanism is the most suitable tool for this purpose when considering such factors country's legal tradition and policy history or the developments of technology. Vietnam is in the early stages of offshore wind power development with the aim of diversifying the power supply source and investment portfolio to ensure energy security. Competitive tenders may introduce more transparent prices. However, it is typically offered periodically and required developers to incur transaction costs to compete which is not suitable for thinly capitalized projects (Richkerson et al., 2012). Therefore, bidding is not suitable for diversifying the project scale or attracting a broad range of capital providers to participate in the market and it is also unbecoming for the current conditions in Vietnam. Another reason is that Vietnam still lacks the technical and management resources for the management of complex renewable energy policies. The benefits of FIT in reducing the burden, not only for investors but also for managers (Haas et al., 2011), making it suitable for continued application in Vietnam.

The characteristics of the influence from FiT policy are different from costs and CF. First, the potential change brought by the change in FIT policy is usually smaller than the change resulting from other factors because too much change in electricity prices cannot occur at each adjustment. Therefore, the FIT mechanism will be responsible for adjusting the marginal potential to fit the plan, and it is not the core factor for potential increase. On the other hand, it takes a long time for certain technology development to help reduce costs and increase CF while the impact of FIT on the policy zone in effect can be immediately seen. This can be proved by the results of SC2 and SC3 when the economic potential is no longer decided by the change in FIT price. However, this change is not considered bad outcome of the two scenarios as Vietnam does not prioritize offshore wind power development in the period 2020-2025. But the rapid potential change due to FIT price needs to be carefully considered. The construction and grid-connected process of a wind farm takes relatively long, so any change in electricity price policy during these periods, especially a downward change, may make it difficult for investors to accelerate the progress to reach the initial high price. Offshore wind power projects in Vietnam are currently facing this situation. In contrast, the upward adjustment of FIT price also needs careful consideration because the price increase may cause the projects to develop massively, leading to broken planning or the incompletion of many proposed projects. As a result, there need to be a suitable roadmap for every change in FIT pricing policy, avoiding sudden changes and adopting a suitable FIT price not only to stimulate the development of offshore wind power but also to ensure that the number of new offshore wind plants does not exceed the government's original plan.

FIT policy can be used when the economic potential of the source is higher than the required capacity, so the reduction of electricity purchase price can alleviate the attractiveness to investors and the increase in price can promote the development when the change in cost and CF has not been able to create the planned capacity. From the results of the scenarios, the economic potential of offshore wind power by 2030 will have ranged from 2500 MW to 3500 MW while the PDP 8 only proposes 500 MW, which is relatively lower than the potential. Thus, the FIT price can be further reduced while ensuring that the economic potential will be greater than the required capacity. In the period 2035-2040, the economic potential is slightly greater than the expected capacity in the base scenario, and it is smaller than this capacity in the low case. From 2040 to 2045, there will be a slow increase in the economic potential whereas an additional 5000MW of capacity during this period is addressed in the PDP 8. Although FIT price is assumed to increase after 2040, which is still not sufficient to create the desired capacity. As such, Vietnam's policymakers should maintain low FIT price over the next decade. If there is no breakthrough in technology, the FIT price should be increased after 2035 and it should be higher than the suggested one in analytical scenarios.

The difference in the economic potential of the two types of foundations is also a matter of concern. Before 2040, all economic potential comes from fixed bottom sites. The slowdown in potential growth in the period 2040-2045 is partly because all fixed bottom sites will have had their economic potential by 2040, so increased potential can only come from floating foundation areas. However, these areas have much greater costs (CAPEX and OPEX), especially those that are far from shore. In addition to cost reduction and capacity factor increase, these areas require a higher electricity purchase price. Another concern is whether it is appropriate to apply the same FIT to both types of foundations when there is a great difference in the benefits obtained from these two types of farms (Figure 3). Besides the type of foundation, the location also leads to a disparity in the obtained benefits. The areas with the earliest potential and the greatest benefits are usually located in the South-Central Coast. Wind power project operation is greatly affected by the wind regime and topographical characteristics of the farm. Fixed bottom foundation sites in the north and south should be given more attention than the potential areas in the central region due to the overload of 500 kV transmission lines in this area. Overall, focusing on developing

Figure 3: NPV of feasibility areas



Source: Results of this study

low-cost areas is not necessarily a good choice as it may worsen the local overload in these areas.

Baulch et al. (2018) concluded that the current market-independent fixed-price FiT model is incapable of promoting renewable energy supplies. This research proposes that if the Vietnamese government maintains the present FiT price, it needs to be adjusted for local inflation and the technology for each renewable resource should be considered. For example, Tran et al. (2019) proposed that the Vietnamese government set a different FiT price for rooftop solar panels from what it does for ground-mounted solar panels. The same principle can be applied to offshore wind power due to the seclusion between the two types of foundation and location of the offshore wind farm in order to state the new tariff to balance the profits earned among these projects. Moreover, if the differential FIT rates are applied early, electricity is possibly purchased at a higher price from floating foundation wind farms in unfavorable locations so as to mobilize a larger amount of capacity in the period 2040-2045.

5. CONCLUSION AND POLICY SUGGESTIONS

Developing renewable energy helps combat climate change, environmental pollution and improve safety in the electrical industry. Offshore wind power is one of the renewable sources that has been exploited for a long time in many countries around the world and Vietnam is still in the early stages of research and electricity harness from this source, thus, the potential assessment is an essential key to effective policy research and investment orientation.

The results of the study indicate that the potential of offshore wind power before 2030 is still low and will strongly develop in the period 2040-2045 based on the development of technology, which helps improve costs and CF. Even so, the offshore wind power potential before 2030 will be significantly higher than the required capacity in PDP 8, and the ability to meet the desired capacity will decrease over time. The future FIT price, therefore, should be lower than that in the pre-2030 scenario and higher than that in the later scenarios.

The results also show the limitations of the current FIT pricing mechanism, and thus, some recommendations and notes should be given. Firstly, MOIT and the Vietnamese government should develop a long-term roadmap for FIT price for offshore wind power, and all cost and CF variations should be carefully considered in decision making. Secondly, a new FIT tariff needs developing based on the type of foundation and location of the wind farm. The benefits from the floating and fixed bottom foundation wind farms or from the wind farms located in different places are comparatively different. Hence, in order to motivate the development of floating foundation wind farms and harmonize the benefits obtained from such farms, a differentiated electricity tariff should be applied.

Much more research needs to be done for considerable examination of the economic potential and adopting more suitable policies to motivate the development of offshore wind source to meet the energy demand in the coming decades while avoiding the fact that the installed capacity greatly exceeds the national power development plan as can be seen in the case of solar energy.

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