Chapter 21
Competitiveness of Utility-Scale Wind Farm Development with Feed-In Tariff in Indonesia

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21.1 Introduction

The Indonesian government expressed its commitment to reduce the effects of greenhouse gas (GHG) emissions by 26% by 2020 by reducing the rate of deforestation and the conversion of fossil energy into energy that has a low carbon footprint or the new and renewable energy (Government of Indonesia 2011). In response to that commitment, the Ministry of Energy and Mineral Resources of Indonesia announced a nationwide target that in 2025 the composition of the new and renewable energy in Indonesia will be increased to 23% (Government of Indonesia 2014). On the other hand, to support national economic growth target of about 6–7% per year, Indonesian government launched an initiative to increase electricity supply by 35,000 megawatts (MW) throughout Indonesia within a period of 5 years (2014–2019). In order to meet these needs, the energy sector in Indonesia must use all its potential energy especially the clean and renewable energy such as wind energy. Wind energy utilization in Indonesia is only 1.6 MW from the total potential of 9.2 GW as claimed by Indonesian Board of Technology Assessment and Application (Martosaputro and Murti 2014).

Indonesian electricity sector is monopolized by Indonesian state electricity company (PLN), as part of government effort to maintain control of critical industry sector. PLN places itself in the full value chain of electricity sector from power generation to retail distribution. However, 25,900 MW of the 35,000 MW megaproject will be constructed and operated by independent power producer (IPP) which the electricity will be purchased by PLN per kilowatt-hour basis (Corporate

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Secretary PT PLN (Persero) 2016). IPP will sell the electricity to PLN to support PLN's existing generators which then will be distributed to PLN to its consumers.

The production of electricity from renewable energy especially wind energy requires a large investment in a long time with a relatively high degree of various risks (Kn et al. 2007). One of the risks is that the amount of money invested is lost because the electricity buy and sell tariff is not satisfactory which renders the project to be infeasible. Prior to the release of construction permit, IPP has to conduct wind profile measurement in the area using measurement tower for at least 1 year and conduct initial environmental examinations which require a considerable amount of money to be invested (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia 2013; Sumantri et al. 2014). Furthermore, there is no assurance that after the initial development and permitting stage is completed developer can sell its electricity to PLN through power purchase agreement (PPA) because there is no regulation forcing PLN to sign the agreement. Investment assurance is needed for investors to be confident about their initial investment in wind energy development, and without a clear and fair market, the IPP's investment will be exposed to unmeasured risks. IPP will be interested to invest in the research if the tariff is determined beforehand thru a Feed-in Tariff (FIT) scheme set by the government (Fell 2009). PLN will be interested to purchase the electricity from IPP when the price of electricity offered by the IPP is equal or lower than the average generation cost of PLN's own generator. This will provide a motive to assess the competitiveness of wind energy in Indonesia compared to other generation sources.

The key factor for renewable energy penetration including wind is the competitiveness in terms of price compared to other generation type competing in the same grid (Mengal et al. 2014). Assessing competitiveness of wind energy will be done by comparing levelized cost of energy (LCOE) of wind energy compared to other generation sources in Indonesia's existing electrical grids. This paper presents the comparison of wind energy's LCOE and other electricity generation source's LCOE in Indonesia's major grids based on the wind resource and variability of capital expenditures (CAPEX) in different areas of Indonesia.

21.2 Methodology

The study was conducted at selected locations which have a high installed capacity of thermal power plant that can act as a baseload for wind farm and an area with good wind resource. In this research, the site selection in terms of wind resource follows the map published by Ministry of Energy and Mineral Resources of Indonesia (MEMR) as can be seen in Fig. 21.1, which is based on mesoscale modeling. Wind farm capacity simulated in this calculation is 20 and 50 MW with consideration of the existing demand and grid size to accommodate intermittent power from the wind farms.

LCOE is a proven method to approximate the cost to generate electricity (Ouyang and Lin 2014; Wiser et al. 2015). There are four major factors affecting

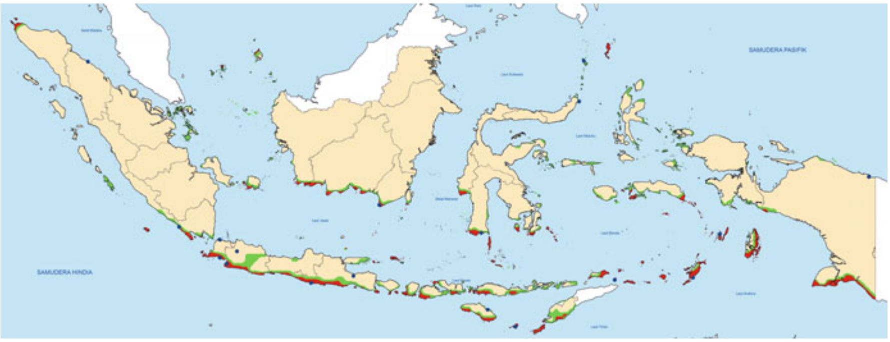

Fig. 21.1 Indonesia wind resource map. *Red* areas, wind speed average >6 m/s; *Green* areas, wind speed average 4–6 m/s (P3TKEBTKE 2014)

the LCOE which are capital expenditures (CAPEX), fixed charge rate (FCR), operation expenditures (OPEX), and annual energy production (AEP) based on formula (Eq. 21.1) used by NREL (Mone et al. 2015):

$$\mathrm{LCOE} = \frac{(\mathrm{CAPEX} \times \mathrm{FCR}) + \mathrm{OPEX}}{\mathrm{AEP}} \tag{21.1}$$

Since Indonesia is made of islands with unique geographic properties, a multiplying factor is included in the calculation of CAPEX to illustrate the unique site conditions. The factors are made based on focused group discussion conducted with wind farm developer and experts in Indonesia, and the value of the factors implemented in this research is based on actual site visit of the location. The factors can be divided into five categories as seen on Table 21.1. All the factors' multiplier for each sample location is determined based on site visit and rough approximation. Multiplier from each factor is accumulated and multiplied by initial CAPEX required to build a wind farm.

Annual energy production (AEP) is calculated from a wind resource assessment and wind farm layout optimization software "Openwind" (AWSTruepower 2014) that has been widely used to perform yield calculation and layout optimization (González-longatt et al. 2014; Wagner et al. 2013). Wind data used is published by Modern-Era Retrospective Analysis for Research and Application (MERRA) satellite managed by NASA (Rienecker et al. 2011). Openwind optimizes the turbine location to produce highest energy yield but constrained by noise and geographical feature.

FCR represents the amount of revenue required to pay the carrying charges and represented in percentage of CAPEX. FCR formula has been defined by NREL (Mone et al. 2015), which consists of discount rate (d), economic operation life (n), tax rate (T), and present value of depreciation (PVdep) as can be seen from Eq. 21.2. For research purposes, the assumption for project funding can be divided into 70% from loan with 8% interest rate and 30% from own equity with 10% return on equity. Indonesian income tax, depreciation, and amortization have been

Table 21.1 CAPEX multiplier factor due to variability in wind farm site conditions

Land price per hectare	Price	<$50,000	$50,000–100,000	$100,000–150,000	$150,000–200,000	$200,000
	Multiplier	1	1.1	1.4	1.8	2.0
Distance from port	Distance	<5 km	5–25 km	25–50 km	>50 km	Landing point
	Multiplier	1	1.15	1.3	1.5	1.7
Distance to connection point	Distance	<2 km	2–6 km	6–15 km	15–30 km	>30 km
	Multiplier	1	1.1	1.25	1.4	1.6
Road upgrade	Existing road	Concrete	Asphalt	Gravel	Dirt	No road
	Multiplier	1	1.03	1.05	1.1	1.25
Site topography	Slope (degree)	<6.5	6.5–11	>11		
	Multiplier	1	1.2	1.65		

adjusted to meet the Indonesian ministry of finance regulation on renewable energy tax easement (Ministry of Finance Republic of Indonesia 2010). Another addition to the FCR is 0.25% of the CAPEX allocated for insurance fee. Operation and maintenance fee has been previously defined for Indonesia by Asian Development Bank (Asian Development Bank 2015) for US$ 0.021 with an increment of 5% every year owing to inflation:

$$\mathrm{FCR} = \frac{d(1+d)^n}{(1+d)^n - 1} \times \frac{1 - (T \times \mathrm{PVdep})}{(1 - T)} \tag{21.2}$$

The Feed-in Tariff policy should ideally apply for the 20 years following the program's introduction (Rigter and Vidican 2010). Feed-in Tariff is calculated by adding internal rate of return (IRR) to the LCOE which creates a fair tariff with expected return for IPP (Ashadi 2012). Based on discussion with experts in wind industry in Indonesia and sample project that is currently under construction, the IRR is defined at 14.5%.

21.3 Results and Discussion

Yield calculation in each wind farm location as calculated is shown in Fig. 21.2. Yield calculation from Openwind shows that highest energy production in Indonesia is located in Papua for both 20 and 50 MW wind farm. Contrary, Java has the lowest energy production compared to the rest of the site even though the area initially shows a good prospect for wind farm development. The difference in energy production results are primarily caused by the superior wind resource in Papua. Based on long-term wind resource assessment, wind speed at 100 m in Papua could reach up to 8.4 m/s, whereas in Java it sits around 5.9 m/s. The variation of capacity factor between 20 and 50 MW wind farm in the same location shows that energy production did not increase in direct proportion of the generation capacity. The increase of wind turbine quantity in the area will increase the wake which is generated by the turbine that reduces the wind speed in other downwind turbines and therefore reduces the capacity factor of the wind parks.

LCOE calculation result can be seen in Fig. 21.3b. Apart from Sulawesi and West Nusa Tenggara, the LCOE for wind farm in Indonesia is higher at 50 MW capacity wind farm compared to the 20 MW capacity wind farm. This indicates that the increase in energy production of a 50 MW wind farm is not proportional to the increase of cost to develop a 50 MW wind farm. This result can also indicate that if the wind farm capacity in Sumatera, Java, Kalimantan, and Papua is increased beyond 50 MW, the LCOE is predicted to be higher compared to a 50-MW-sized wind farm.

Assessing the competitiveness of utility-scale wind farm will require a comparison data of the existing average cost to generate electricity by PLN. Based on yield calculation gained and total investment cost to build wind farm in Indonesia, the

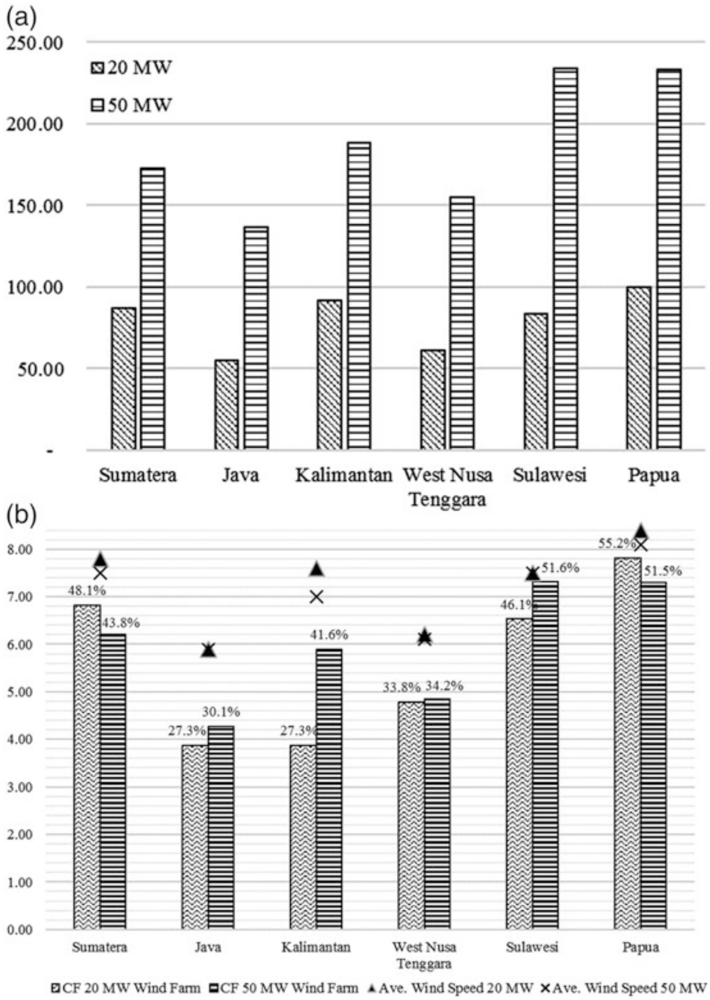

Fig. 21.2 Wind farm annual energy yield in GWh (**a**) and wind farm gross *capacit*y factor and average wind speed at turbine hub height (**b**)

LCOE for wind energy sits at 0.16 US$/kWh for 20 MW wind farm and 0.17 US $/kWh for 50 MW wind farm. Wind energy ranked fifth cheapest compared to existing generation type LCOE, which points out that it is cheaper than diesel, machine gas, and gas as can be seen in Fig. 21.4a. Comparing the LCOE of wind in respective sample site by subtracting the average generation cost (AGC) with the LCOE, the gap between LCOE and AGC is produced and can be seen in Fig. 21.4b. Area in the upper part of the black line implies that the regional AGC is higher than wind LCOE which means wind is competitive enough in the region. The lower area from the black line indicates where the existing AGC in that region is already

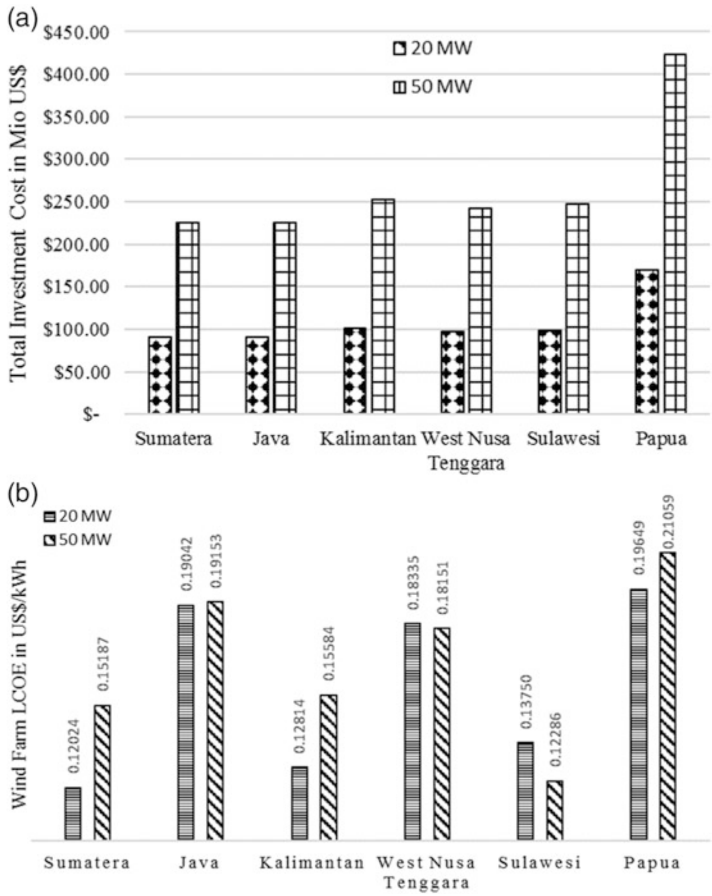

Fig. 21.3 Wind farm total investment cost in million US$ (**a**) and LCOE in US$/kWh (**b**)

cheaper than wind LCOE which makes wind energy not competitive enough in that region.

Figure 21.5 shows similar competitiveness analysis with Fig. 21.4, but instead of comparing LCOE, Fig. 21.5 compares the FiT with AGC. It shows that applying FiT will reduce the competitiveness of wind energy even further. The cost of buying electricity from wind through FiT scheme will cost almost the same with using existing diesel power plant.

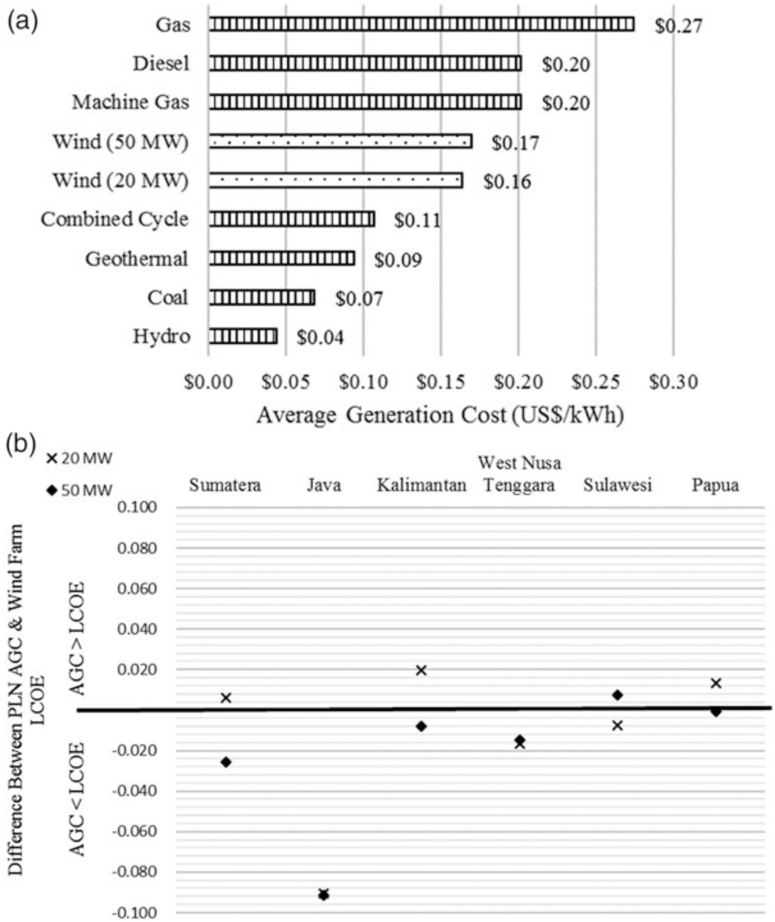

Fig. 21.4 Wind LCOE compared with other existing generation type (**a**) and difference between PLN's AGC and calculated wind farm LCOE in US$/kWh (**b**)

21.4 Conclusions

In order to gain competitiveness over other electricity generation units, wind farm must have a good wind resource and/or a low CAPEX. Competitiveness of wind energy in Indonesia is marginal at best. Only some region in Indonesia with good wind resource and low CAPEX can compete with existing generation units. The simulated Feed-in Tariff does not help this condition. By adding additional 14.5% to the LCOE, the wind energy is not competitive enough compared to existing generation. Incentive and subsidy will need to be given by the government to increase the wind energy penetration in Indonesia without sacrificing PLN as a state-owned enterprise.

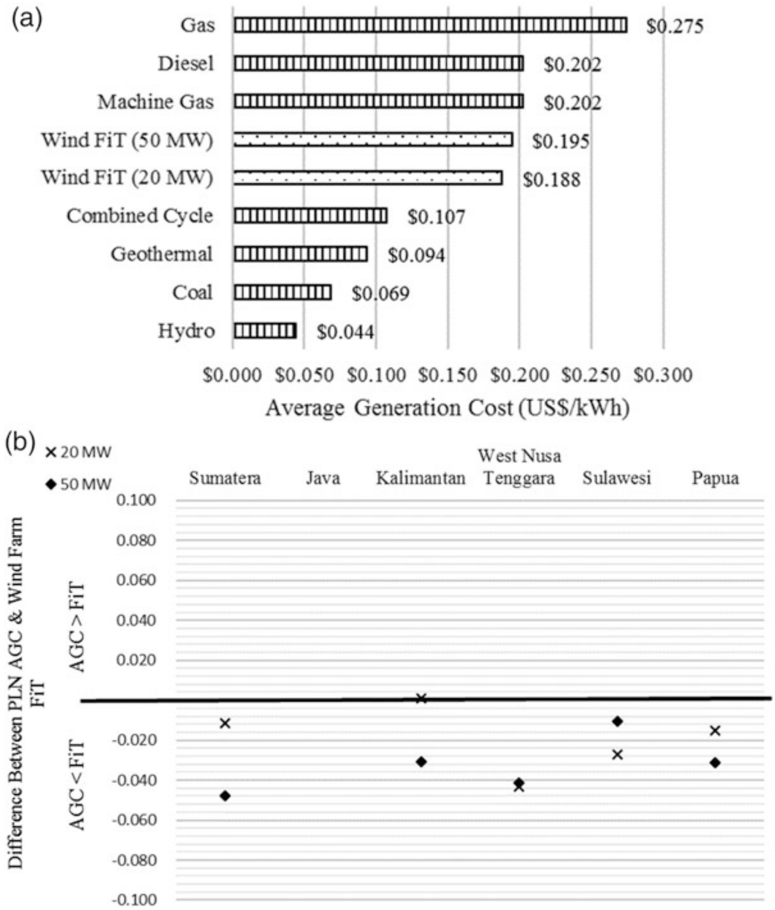

Fig. 21.5 Wind FiT compared with other existing generation type (**a**) and difference between PLN's AGC and calculated wind farm FiT in US$/kWh (**b**)

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