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LEVELIZED COST OF ELECTRICITY IN INDONESIA

Understanding The Levelized Cost of Electricity Generation

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IMPRINT

Levelized Cost of Electricity in Indonesia:
Understanding the levelized cost of electricity generation

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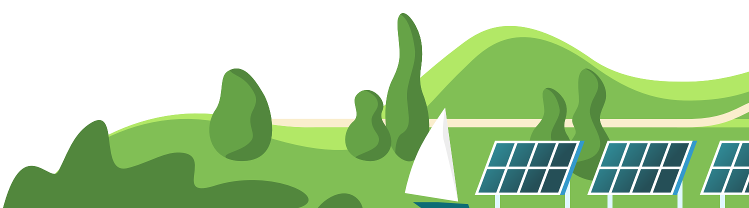

Dear reader,

Indonesia has set the objective for 23% share of renewables in their primary energy mix and 45 GW of renewable installed capacity by 2025 based on the national energy plan(RUEN). In reality, Indonesia is currently far from reaching the set target as renewables deployment has been slowing down in the past few years. Renewable implementation in the country still faces many barriers. One of them is that the renewable plant is still considered as expensive source of electricity. However, there is a lack of available information on why is renewable expensive in Indonesia and if there is a way to bring the cost of renewable down like what has happened in other countries around the world.

This study aims to understand what is the cost of generating electricity from renewables and fossil in Indonesia using an LCOE tool developed by IESR based on Agora Energiewende model. Through better understanding of the LCOE, we hope to develop a constructive fact-based dialogue that can help policy makers and developers alike to make an objective judgment on the energy plan and investment. Our key findings from the studies are:

1. **Policy analysis and considerations on renewable and fossil fuel should consider the differences in their cost structure**. Renewable and future energy infrastructure are capital intensive, therefore any policy concerning the cost of capital and technology cost has a higher impact on these projects compared to its fossil counterpart.
2. **Cost range of large-scale solar PV is already on par with those of new coal power plant.** With a suitable regulatory framework, e.g. bringing financing cost down to levels in other markets, large scale solar LCOE may go down further from 6-12 ct/kWh to 3.5 – 8 ct/kWh.
3. **The global trend will change the playing field as LCOE from renewable is getting cheaper.** The renewable (wind and solar) has experienced a massive deployment globally which has contributed to lowering the cost of equipment. Because equipment cost makes up a high share of capital cost, the LCOE of renewables is also expected to come down along with this phenomenon. On the other hand, the fossil fuel plant has experienced an increase in investment cost due to stricter emission and environmental standards.

We believe that all the related stakeholders could see and gain benefit from acceleration in renewable deployment by designing a balance and supportive policy towards renewable. We hope that this study could contribute towards achieving the said goal.

1 | Introduction

Renewable energy technologies have undergone dramatic cost reductions in recent years, making them broadly cost-competitive with fossil fuel sources in the markets around the world. The International Renewable Energy Agency (IRENA) reported that the global weighted average costs of electricity from solar PV have declined by 77% between 2010 and 2018, due to the decrease in solar module prices (90% reduction over the last decade) and balance of the system. Wind turbine prices have also decreased by 44-64% since 2010 and have driven the global weighted average costs of electricity from wind to drop from USD 0.085/kWh in 2009 to 0.056/kWh in 2018.

Despite the global trend, in Indonesia, renewables are still cited as expensive sources of electricity. For example, according to NREL studies, the average LCOE of solar in Indonesia is the highest among ASEAN member state, reaching 165 USD/MWh and far below Burma with an average of 79 USD/MWh (Lee, et al., 2019). A similar problem can also be expected from wind power. This condition affects how Indonesia's future electricity system is projected, the direction and the making of the energy policy, as well as attractiveness of the country to the investors.

This paper provides an analysis of the cost comparison between renewables and fossil generation, as well as the underlying conditions that make the cost difference. Calculating the Levelized Cost of Electricity (LCOE) makes it possible to compare the cost of electricity produced by different kinds of generation technology and cost structure. It is important to note that this method is a simplification from reality with the goal of making different sorts of generation plants comparable. It does not include other aspects in the electricity system such as the ability to react to the demand for electricity or determining the financial feasibility of a specific power plant. Regardless of the fact, understanding and transparency of electricity cost components between renewables and fossil will help the decision-making process towards a more sustainable energy system.

In this paper, we introduce a simple LCOE tool , with cost specific to the Indonesian context. We will discuss the major cost driver in LCOE calculation, the cost drivers for different power generation technologies, and the impact on LCOE if these component changes. In the chapter 'What If?', we discuss simulation of the Indonesian policy which makes the renewables cost higher (or cheaper).

The tool is available on our **website** , to increase transparency on cost of generation as well as support policymaking.

2 | Methodology

LCOE is a standard tool used in comparing the cost of different electricity generation technologies. It is a measurement of total cost and energy/electricity generated by an asset over its lifetime. The calculation results in a single value that represents each technological option available in a particular location. The single value can be easily compared and therefore can help businessman or policymakers in the decision-making process.

It is crucial to consider the method used in calculating LCOE to ascertain the benefits mentioned earlier. There are several commonly used methods: the discounting method , the annuity method, and the financial model method, each with its advantages.

This simple LCOE tool[1] is calculated using the annuity method, which allows quick LCOE recalculation and comparison of the sensitivity of different parameters to the LCOE outputs.

The Annuity Method

LCOE calculates the total cost occurred during the lifetime of an electricity generation plant and divide it with the total electricity produced during the lifetime. In the Annuity Method, the total cost accounted will be converted into an equivalent annual cost and the electricity generation value used is the average annual electricity generation.

$$\mathrm{LCOE}_{\mathrm{Annutizing}} = \frac{\mathrm{Ann(Costs)}}{\mathrm{Ave(Output)}} = \frac{\left(\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}\right)\left(\frac{r}{1-(1+r)^{-n}}\right)}{\left(\sum_{t=1}^{n} E_t\right)/n}$$

with C as cost, E as electricity, r as rate, and n is life time of the system in years

Figure 1. Formula for LCOE calculation using annuitizing method (taken from Lai and McCulloch 2016)

The main parameters considered and adjustable in the tool are investment costs, fixed and variable O&M costs, fuel costs (for thermal power plants), Weighted Average Cost of Capital (WACC), and efficiency (for thermal power plants), capacity factor, and the technical lifetime of a power plant.

[1] The LCOE in this study is calculated using a tool developed by IESR, which is based on a model from Agora Energiewende. The tool is available on the IESR website at the following link: **IESR LCOE tool**

The tool calculates the investment cost as cost unit per kW and corresponds to all costs that occurred during the development phase of the power plant (permit, feasibility study, component cost, civil, etc). We assume a constant annual operating cost in the calculation. With such an assumption, the investment cost at the beginning of the asset deployment could be converted using a specific factor into the annual investment cost that can be added directly with the yearly operating cost (Kost et al. 2018).

The investment cost is spread annually using WACC as the annuity factor. We use WACC instead of the standard discount rate to capture the financing cost in the calculation. We assume a constant value for power generation/capacity factor over the lifetime of the plant. Finally, by summing all the cost and divide the results with total electricity generated, we could get the LCOE value of the investigated power plant.

The tool uses the Technology Data for the Indonesian Power Sector report by Dewan Energi Nasional (DEN)[2] as the primary reference and refines with most recent data from other related market studies (BNEF, IRENA, etc) as well as surveys with the association, project developers, and PLN. The WACC is estimated through surveys and interviews over the value of debt, equity, and the cost of debt and equity with related stakeholders.

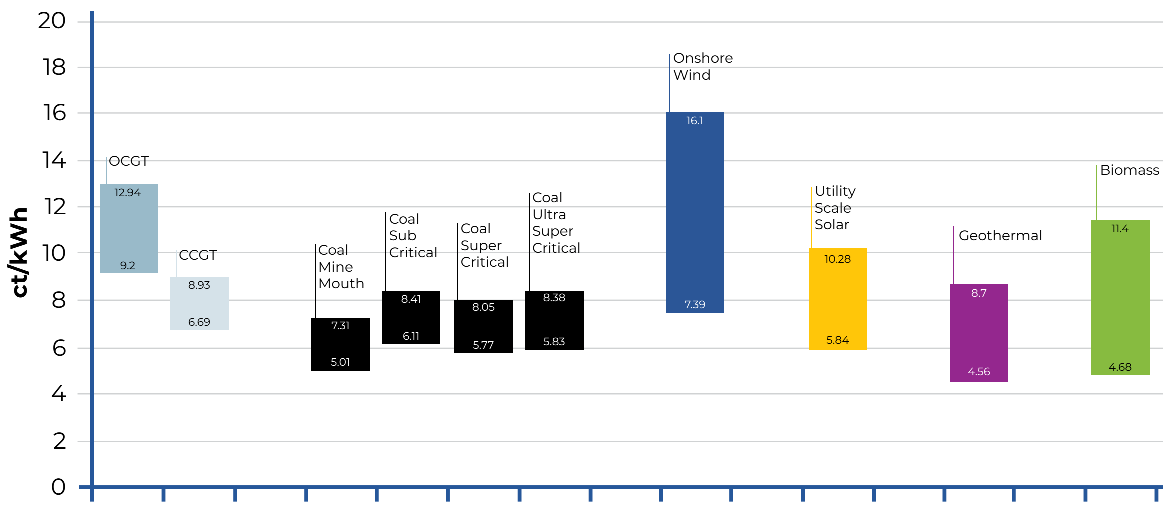

Figure 2. Levelized cost of renewables and fossil power plant in Indonesia in 2019. For further details and assumptions, please check the tool at iesr.or.id/lcoe-tools/

[2] In collaboration with the Danish Embassy, BPPT, EA, and Danish Energy Agency

3 | Major Cost Drivers

The structure of electricity production cost between renewables and fossils generally differs. For instance, wind and PV have high upfront investment costs, but negligible variable O&M cost, while the cost of fossil generation highly depends on the variable O&M cost. In this chapter, we will discuss the important parameters used in the calculation of LCOE, namely the capital expenditures (CAPEX), operational expenditures (OPEX), capacity factor and WACC, how would the settings differ from each generation technology, and how some changes in the parameters would affect the LCOE of a power plant.

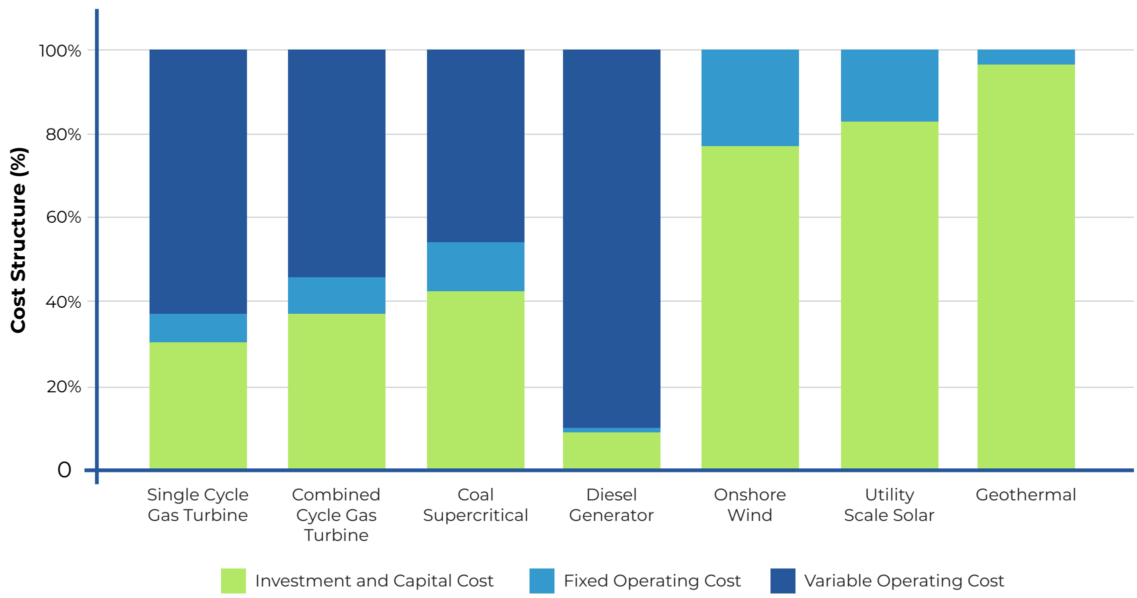

Figure 3. Cost structure of several generation technologies

3.1 Capital Expenditure (CAPEX)

Capital expenditures, or often described as investment cost, is one key parameter in calculating the LCOE. However, since there is no universally employed nomenclature, investment costs do not always include the same items. As LCOE often used as metrics to compare different technologies, it is very important to clearly define the boundary of which cost component is included in the investment cost.

- **What is included in capex?**

  In general, capex can be divided into 3 different segments: equipment cost, installation cost, and pre-development cost. Equipment cost covers the equipment itself and the installation cost covers connection to grid and installation of the equipment. In some LCOE studies, equipment and installation cost often also defined as the overnight cost of construction, which shall include all physical equipment or engineering, procurement and construction (EPC) cost. Pre-development costs include administration, consultancy, project management, site preparation, and approvals by authorities, e.g. obtaining sitting permits, environmental approvals and interest during construction.

  When categorizing the cost component, the term balance of system (BOS) or balance of plant also often used to simplify. It refers to all supporting components of generating units, other than the generating unit itself. For example, in the solar PV system, the BOS comprises all components of PV other than the panels. These may include wiring, switches, mounting system, inverters, etc. In case of large conventional power plants, it includes transformers, inverters, supporting structures.

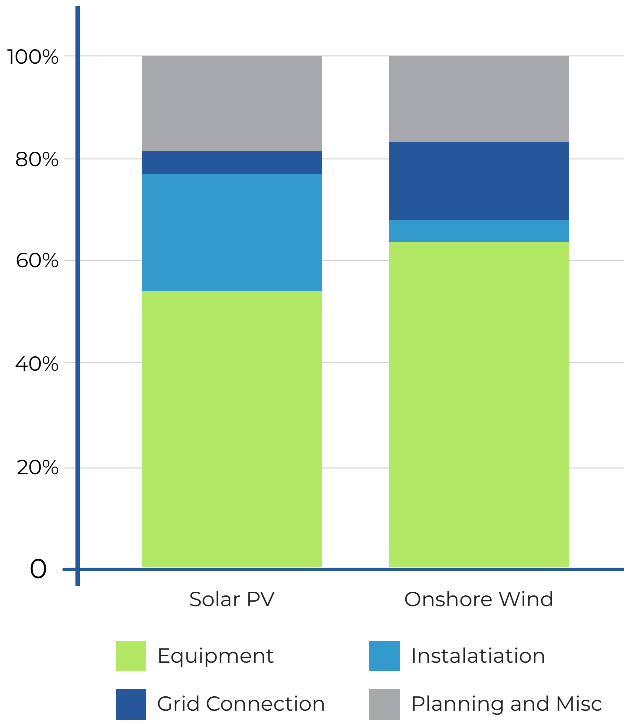

Figure 4. Average CAPEX structure of the technologies (general data). Source: ACE, 2019; Agora, 2017

- **How expensive is the capital cost in Indonesia?**

  Depends on the benchmark.

  The capital cost of coal and gas power plant in Indonesia is on par with China and India. In Europe, North and South America, as well as Japan and Australia, capital cost for new supercritical coal power plant ranges from 2000 to 4000 USD/kW, double the cost in Indonesia, partly due to higher environmental standards and flexibility requirements

  For renewables, as of 2019, there are only 2 large scale wind farms installed in Indonesia with capital cost ranges from 1400 - 2000 USD/kW. This is close to the average investment cost in Europe, but higher compared to the average cost in North and South America, Africa (up to 1300 USD/kW) and China and India (around 1100 USD/kW).

  Similar to wind, current installed solar PV capacity in Indonesia is only 90 MW, with the capital cost still ranges from 700 to 1200 USD/kW, higher than capital costs in Europe, China and India which mostly below 1000 USD/kW (IRENA, 2019). The cost in leading markets even reaches below 500 USD/kW in 2019 (Vartiainen, et. al, 2019). While capital costs for all generation technology in India and China are mostly lower than the global benchmark, the capital cost of solar and wind in Indonesia is still in the higher end, depicting the high potential of renewables cost reduction.

- **Why is it more expensive? What influences the cost?**

  Different factors affect each capital cost component which in the end influence the total capital cost, for example:

  - Equipment cost usually constitutes a large share (>50%) of total investment cost. Availability of local material and manufacturing capacity usually will drive the cost down. In contrast, solar pv module price in Indonesian solar project is one of the most expensive equipment compared to other projects in due to local content requirement. The local solar manufacturing industry has not been able to develop yet and thus the production cost of a local solar module is comparably more expensive to global market (further discussion see section 'Policy Discussion: What If?')

- Installation cost in Indonesia is generally cheaper due to low labour cost. However, it is important to note that critical infrastructure such as ports and roads[3] in necessary to support certain renewable investment. For example, the nature of wind projects, transporting rotor blades and tower segments, require that critical infrastructure much more than solar pv projects. Therefore, construction in a less developed area might increase installation and logistics cost.
- Pre-development cost generally depends on regulatory condition of the country, i.e. the predictability of certain key processes such as obtaining permits and securing land access, as well as the whole process governing grid access, including cost sharing between grid operators and project developers. In Indonesia, the dynamic of the bureaucracy processes may increase the pre-development cost.

- **How do changes in CAPEX affect the LCOE?**

The higher the CAPEX, the higher the LCOE. As renewable is more capital intensive compared to the conventional generation, changes in CAPEX has a higher impact on renewable. Around 20% decrease of CAPEX will lower renewables LCOE from 15-20%, while the similar change will only affect coal and gas LCOE 5.5-9.5%. One key to the low cost of renewables lies with improvement in technology cost and the balance of system.

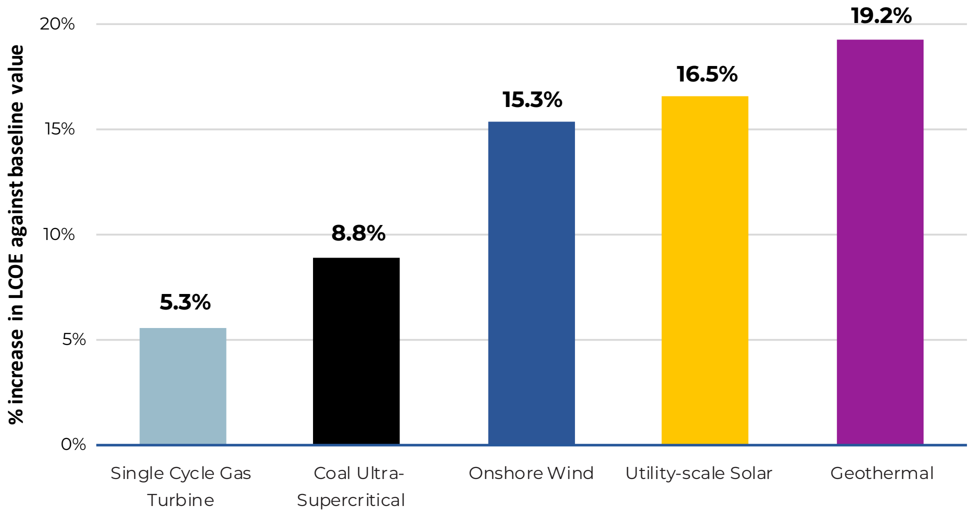

Figure 5. Sensitivity of LCOE for several generation technologies to 20% increase in cost of CAPEX

[3] In collaboration with the Danish Embassy, BPPT, EA, and Danish Energy Agency

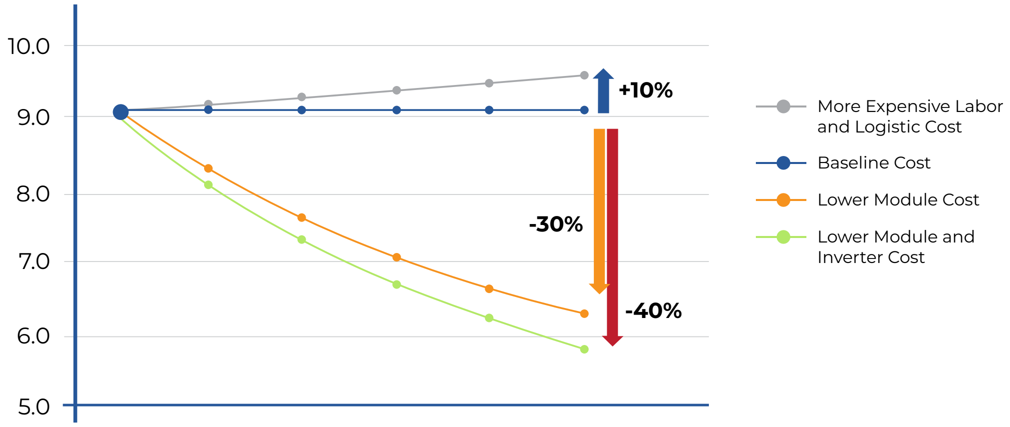

Figure 6. Changes in solar LCOE related to changes in solar capex component. Each point represents 20% change of the capex component relative to the previous point.

Module prices in the global market will decrease irrespective of local conditions. In the case of solar PV, module prices in Indonesia (both local and imported ones) are generally higher than in the global market. Should Indonesian prices follow the global market, further reduction in PV module cost will lower LCOE up to 30%, and combination of PV module and inverter reduction will lower LCOE even higher (figure 6).

While the installation cost in Indonesia is already low compared to the global benchmark, different location affects labor and logistic cost. PV installation cost in Nusa Tenggara Timur will generally be higher than PV installation in Java. Irrespective of the base module price, increase in labor and logistics costs affect up to 10% of the LCOE.

In contrast to wind and solar, where technology cost is expected to go down further in the next decade, investment cost for conventional power plants is likely to increase along with stricter environmental standards.

3.2 Operational Expenditure (OPEX)

Operation and maintenance costs (O&M) are recurring cost component associated with maintaining and operating the equipment. The cost varies depending on the technology, the size of the system, the scope of the O&M, and location.

- **What is included in OPEX?**

  It is generally divided into 2 main components: fixed and variable O&M cost. Fixed O&M costs are cost component that will occur regardless of the electricity output and operating hours of the plant. For example, a company still have to pay insurance, land lease, utility, and salaries regardless of the electricity it sells. In contrast, variable costs depend on the electricity output as well as maintenance costs in the event of some issues. Fuel cost is one example of variable cost, as the higher the electricity production from conventional generation, the more fuel it requires.

- **How expensive is the O&M cost in Indonesia?**

  As solar and wind generation have very small, if not zero, fuel cost, the variable O&M cost is almost neglectable. For biomass, the substrates costs vary considerably depending on the share of various substrates as well as the option to obtain or purchase the substrate. If the substrate is a waste product or produced in-house, the cost can be assumed to be near zero. Fuel for the conventional generation (coal and gas) will generally follow the global market price or through contract agreement between suppliers and power plant owner. Indonesia has one of the lowest domestic coal prices which influence the competitiveness of coal generation. In several countries and market conditions, CO2 tax or certificate can be imposed to fuel cost. While this is not the case in the current Indonesian power system, adding CO2 tax will increase the variable cost of fossil generation.

  For all generation type, fixed O&M cost in Indonesia falls in the lower end of the global range. Low cost of land and labor contributed to the modest fixed O&M cost. Improvement in O&M practices, strategy, and market size of solar and wind can improve O&M cost further.

- **How do changes in OPEX affect the LCOE?**

  There are 2 main components of O&M cost with different level of impact to the Renewables and fossils LCOE generation. Improvement in fix O&M cost has a slightly larger impact on Renewables LCOE compared to fossil generation. Taking solar PV as an example, most of the fix o&m components depend on the improvement of module efficiency. The higher the module efficiency, the lower area it needs, thus lower fix O&M cost. Larger O&M portfolios of the company and optimisation of the O&M

processes will also drive the cost down. This also depicts further cost reduction potential in Indonesia, should the PV market grow. According to (Vartiainen, et. al, 2019), fixed O&M price for PV in the mature market could go down from 20000 to 5000 USD/MW/year.

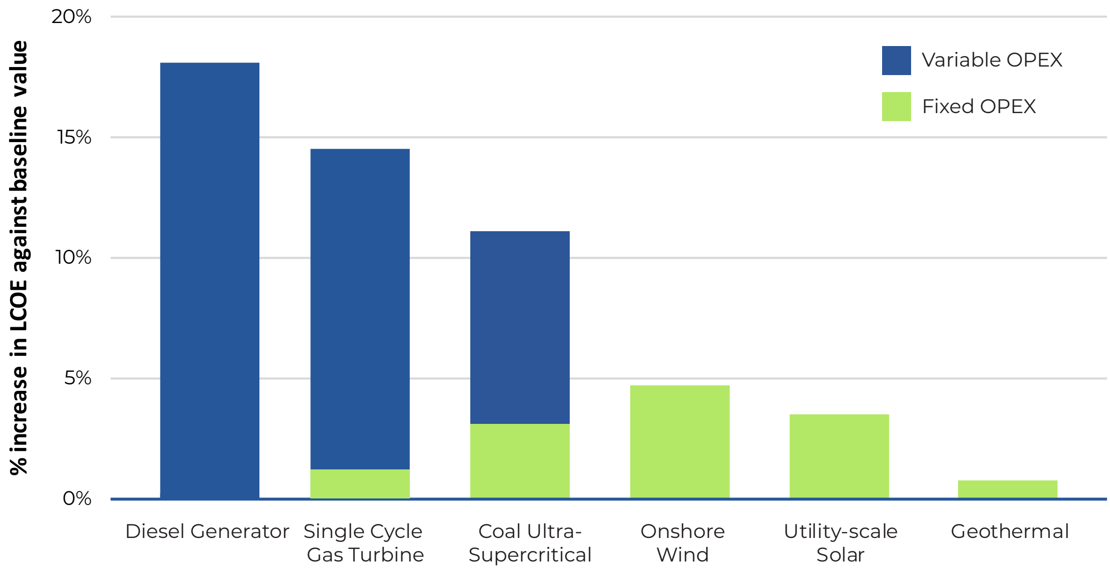

Figure 7. Sensitivity of LCOE for several generation technologies to 20% increase in both fixed and variable OPEX

Variable O&M cost is mostly dependent on capacity factor, which will be discussed in the next chapter, and fuel cost. As renewables do not need fuel, any changes in fuel price do not impact renewables LCOE, while around 20% of changes in fuel price will affect up 18% of fossils LCOE. As a global commodity, fuel has many external factors that drive changes in the price. During the last decade, fossil fuel prices have seen large fluctuation, which consequently also created variation in price projection. On top of that, fuel cost also differs between locations due to its transport cost. Because most renewable energy technologies provide energy with no fuel costs, the projections of investment costs become more important than the fuel cost projections, which limits the impact of fuel price volatility on the renewables LCOE.

3.3 Capacity Factor

- **What factors influence the capacity factor?**

Capacity factor (CF) is a ratio between the actual output of a power plant with the theoretically maximum possible output based on the power plant nameplate capacity on a particular period. There are many factors that can influence CF of a power plant and will be different depending on the power plant technology. For example, a thermal power plant CF in Indonesia would vary depending on the power plant condition, maintenance, availability, price of fuel, and the design of the power plant to meet the electricity demand load profile (as baseload, load-follower, or peaker).

On the contrary, variable renewables (VRE/wind and solar) CF depends on its location that would result in resources availability (high solar irradiation and wind speed will give better CF). Another factor that could affect the CF of VRE is the curtailment which commonly happens due to power system ability to integrate VRE. On the other hand, with more renewables, the new fossil power plant might need to reduce the utilization (and thus lower their CF).

- **How is the capacity factor in Indonesia?**

Capacity factor of renewables is generally tied with resources availability. Being located on the equator line, Indonesia has a relatively constant but average solar irradiation, which leads to above average solar capacity factor (between 12-19%). However, it is still far better compared to several countries who had led the installation of solar PV globally (e.g. Germany with CF of 11-14%, UK with CF of 8-13%) (Global Solar Atlas, 2019). There is also difference in solar irradiation from location to location which gave varying CF potential across Indonesia.

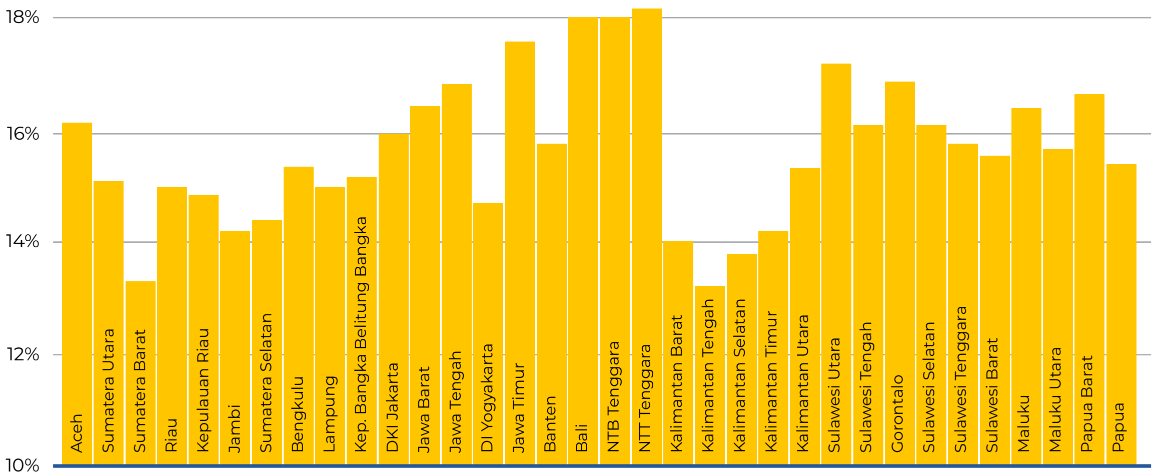

Figure 8. Solar capacity factor across Indonesian provinces

The table below provides a summary of capacity factor from various sources (in %). The survey results column shows the range of capacity factor from investor/developer input and reflects their existing projects. The RUPTL number shows the average capacity factor of the Indonesian power plant, which is calculated from the installed capacity and electricity generation data taken from RUPTL 2019-2028.

Table 1. Capacity Factor (%) of Different Types Power Plant in Indonesia

Power Plant Type	Capacity Factor (%)						
	NEC 2017		BNEF 2018		Survey		RUPTL
	Low	High	Low	High	Low	High	
Geothermal	70	100	70	80	-	98	73
Mini/Micro Hydro	50	95	23	50	65	71	32
Large Hydro	20	95	-	-			
Solar PV Large Scale	14	22	14	17	16	20	7
Wind	20	45	21	25	-	-	26,5
Biomass	-	-	67	77	70	85	35
Coal	-	-	51	51	80	80	57
Gas	-	-	50	50	-	-	37

- **How does change in capacity factor affect the LCOE?**

The CF of a power plant contributes directly to the LCOE results. Higher CF means that more electricity is generated and would significantly lower the LCOE.

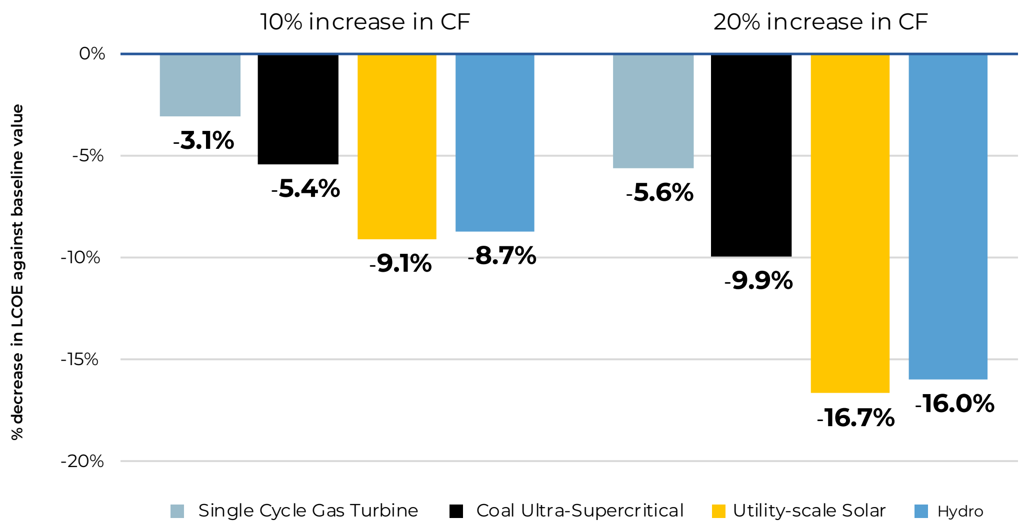

Figure 9. Sensitivity of LCOE for several generation technologies to 10% and 20% increase in capacity factor

Figure 9 shows that renewable LCOE is more sensitive to changes in the CF value. The main reason that caused differences in the rate of change in LCOE is the percentage of variable O&M cost and fuel cost against the total cost. Wind, solar, and geothermal have a close to non-existent variable and fuel cost. Therefore, a change in electricity generation will affect the resulting LCOE directly.

On the contrary, the fossil fuel plant has a significant percentage of variable & fuel cost in their cost structure. Variable and fuel cost of coal plant ranged from 37-53%, between 48-64% for CCGT plant, between 54-76% for an OCGT plant and more than 81% for diesel power plant. As a result, the lower capacity factor would also means lower cost for fossil generation (due to less fuel being burned and less total variable cost)

Since CF has significant influence over the LCOE of renewable plants, then it is vital to have a regulation that can assure the integration of renewable electricity into the system. Therefore, a policy that prioritizes renewable electricity feed-in to the grid as well as preventing the curtailment of RE is essential to increase the interest of investors on renewables. Additionally, a proper assessment of the resource's potential of renewables (wind and solar) combined with electricity demand assessment can help identify best location that could help bring down the cost of electricity from renewables.

3.4 Weighted Average Cost of Capital (WACC) and financing parameter

- **What factors determine the WACC and financing parameters?**

Constructing a power plant will require a large sum of capital initially and thus will introduce a cost that will have to be paid overtime (the cost of capital). Additionally, the capital comes from the shareholders (equity) and the loan from a financial institution (debt), each with its own expected return (cost of debt and cost of equity). A parameter that can evaluate and reflect this cost is the weighted average cost of capital (WACC). The WACC can be calculated by averaging the interest of debt and expected return of the equity investors proportionately with the shares of debt and equity in the capital(CFI; Vaidya). The formula is as follow:

$$WACC = \left(\frac{E}{V} \times Re\right) + \left(\frac{D}{V} \times Rd \times (1 - T)\right)$$

E : value of equity
D : value of debt
V : total value of capital (equity + debt)
Re : rate of return for equity
Rd : cost of debt
T : the tax rate

The WACC is very much determined by the perceived risk by lenders and investors. There are several categories of risk:

- Technology risk, which goes higher with newer technology
- Regulatory risk, which depends on the regulatory framework
- Country risk, which typically similar for all technologies

- **How is the WACC in Indonesia?**

A financial institution will look at the potential risk and decide whether or not the institution is willing to finance a project. As there is less portfolio of renewable projects in Indonesia, the local financial institution is not as confident when deciding to invest in renewable projects compared to the already established conventional power plant projects such as coal. The government intervention is necessary to mediate a supportive investment environment that can boost the financial institution confidence in renewables project.

In 2018, a report from PWC revealed that 61% of surveyed private investors think that the regulatory framework in the power sector is not supportive of private investment. Moreover, there is also a lack of transparency and predictability on the procurement process of a new power plant in Indonesia. As a result, the expected equity return for power plant projects soars to between 15-30%, according to the same survey (PWC 2018).

- **How does change in WACC affect the LCOE?**

The cost structure of renewables power plant, which mainly consists of investment cost/CAPEX, make them very sensitive to the changes in WACC. The geothermal power plant is most sensitive to WACC changes, having the highest share of investment cost in the cost structure due to exploration and exploitation activities conducted at the beginning before a geothermal power plant can be designed and built. On the other hand, the diesel generator experience almost no changes in the LCOE since the price of fuel overwhelm the investment cost in the cost structure.

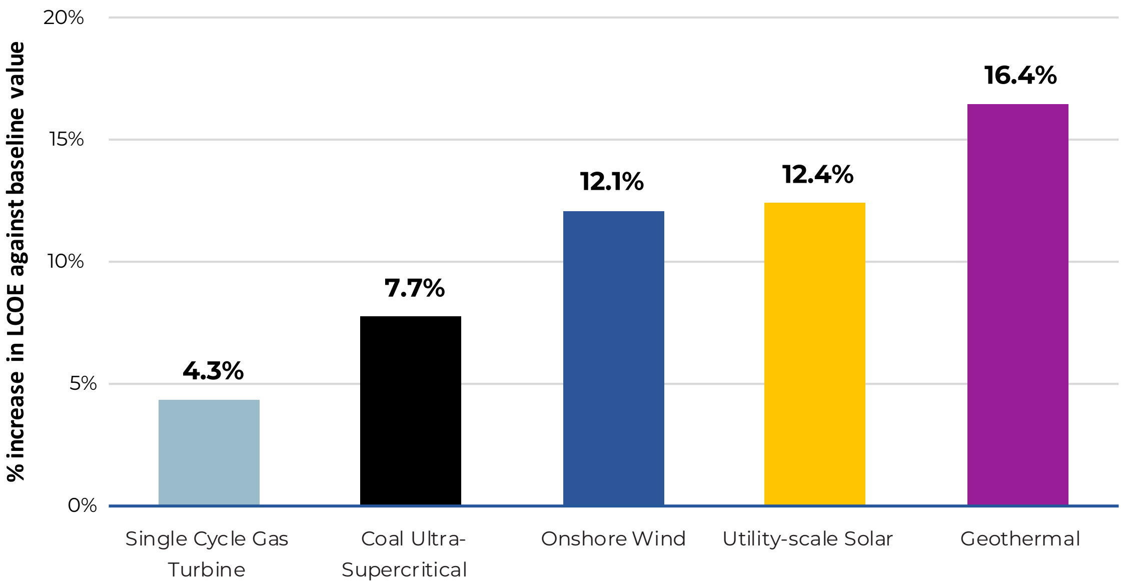

Figure 10. Sensitivity of LCOE for several generation technologies to 20% increase in WACC

Because of the sensitivity of renewable power plant against changes in WACC, there should be careful consideration in designing the regulation not to put unnecessary risks for the private investor nor PLN. As there are also different types of risks related to each renewable energy project (e.g. exploration risks in geothermal, land use & social risks in hydropower), the government should also assess and build a relevant regulation addressing each. Doing so will create a more transparent framework for investing in Indonesia and might increase investment appetite. The investment may also attract foreign debt with low-interest rate from for a large scale project which could bring the WACC down.

4 Policy Discussion: What if?

Each cost component has a different magnitude of impact on the levelized cost of electricity. As an example, the cost of solar PV is more sensitive to similar percentage of changes in capacity factor, WACC, and investment cost compared to coal. Understanding how a slight policy change might impact the cost is important for better-achieving policy goals. In this chapter, we will discuss the policy surrounding those cost elements and how the changes in the policy could pave the way to higher renewables deployment.

4.1 Local content requirement

- **What is local content requirement?**

  Local content requirement (LCR) policy is an industrial policy expected to incentivize local firms to produce and innovate in response to the demand. This is seen as encouraging the development of the local industry as well as local job creation. LCR policy has a high potential of price trade-off due to inefficient resource allocation (i.e. limit the lower-cost foreign suppliers). Sourcing the plant component locally frequently increases the costs of renewable energy projects. Low manufacturing cost will highly depend on the economy of scale and the gap of local manufacturing condition (e.g. advancement in R&D, manufacturing process technology) and international benchmark.

  LCR in Indonesia is regulated under the Ministry of Industry (MoI) regulation no. 52/2012 on Local Content Requirement for Power Infrastructure Project Development and the LCR for solar PV is under MoI regulation no. 5/2017. The regulation set the threshold for local content both for materials and services in power generation projects.

- **How does the local content requirement impact LCOE?**

  Local content requirement will typically impact the CAPEX and OPEX component of the LCOE. Taking solar PV as an example, despite the low local labour and land cost, the local module prices in Indonesia are significantly higher compared to the global market due to higher margin. China's manufacturing capacity and its government incentive make importing only the solar cells from China cost almost as much as importing the complete solar module. The current global market price of Chinese module ranges from 0.1 to 0.3 USD/Wp, while Indonesian prices are in the range of 0.3 - 0.4 USD/Wp (pvinsights, 2019). Accessing module price at global market price would decrease the solar LCOE up to 50%. This level of cost, which is on par and even lower than coal LCOE, would trigger more solar PV development.

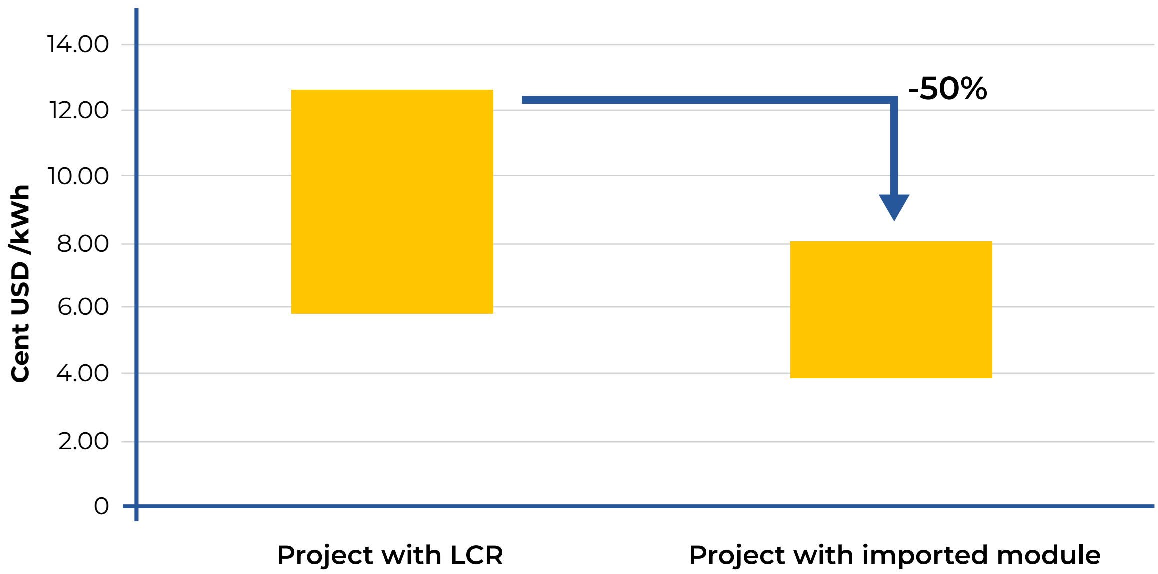

Figure 11. Changes in solar PV LCOE with and without LCR

Decreasing the price would mean increasing the local production capacity, but the local solar PV manufacturer also struggled due to limited market opportunity, i.e. miniscule current installed capacity of 90 MW and no clear outlook from the government. The current scale-up speed of local solar industry is too slow to increase the PV deployment. Currently, the local manufacturer only has capacity in assembling the solar panel (and has no capacity in the ingot, wafer and solar cell manufacturing) with 450 MW production capacity per year (Nurrachman, 2019). The LCR regulation also hinders the developments as it mandates the LCR for solar PV to be minimum 50% for 2018 and 60% for 2019 while according to (IEEFA, 2019) the current local content of Indonesian solar panel manufacturers mostly range from 40-50%.

It means there is a necessity for redesigning the LCR policy. In some cases, direct financial support to manufacturers can be more efficient to improve local industry rather than imposing LCR without any incentives. LCR can also be designed as part of the auction qualification[4], be it as minimum threshold or as weighting criteria for winner selection. Moreover, the requirement can be graded into different local content levels and LCR for projects under state budget support and other large-scale project can be separated, so that the industry can benefit from economy of scale while also increasing local capacity.

4.2 Ease on import duty and taxes

- **How are import duty and taxes arranged in Indonesia?**

One strategy to drive down the LCOE of renewable power plant in Indonesia is by tapping into renewable equipment available in the international market at a lower price. The potential for cost reduction in the renewable power plant is enormous as there is quite a disparity between the manufacturing capability (and price) of local industry and international one (such as China). However, importing a piece of equipment from overseas in Indonesia introduces an extra cost: import duty, VAT, and income tax.

The value of VAT and income tax are generally fixed at 10% and 2.5% of the value of the goods plus the import duty value. The import duty ranges from 0-450% depending on the products imported and the availability of imported goods industry in Indonesia. Ministry of Finance(MoF) regulation 6/PMK.010/2017 stipulated the latest import duty for imported goods in Indonesia. Generally, for power plant equipment, the import duty ranges between 0-10%.

[4] This has been the case in Brazil, Morocco, South Africa, Turkey, and the United Kingdom, India, with mixed outcome depending on the design, industrial potential, and context.

Table 4 Sample of Import Duty for power plant components regulated in MoF Regulation 6/PMK.010/2017 Capacity Factor (%) of Different Types Power Plant in Indonesia

HS Code	Description	Import Duty
8402.12.11	Boilers	10%
8406.81.00	Steam Turbine	0%
8406.82.10	Steam Turbine >40 MW	5%
8504.40.40	Inverter	10%
8541.40.21	Photovoltaic cells <5 MW	0%
8541.40.222	Photovoltaic modules	5%
8502.31.10	Wind Turbine <10 MVA	5%
8502.31.20	Wind Turbine >10 MVA	5%

In MoF regulation 66/PMK/010/2015, the government provides a facility that allows exemption from import duty for equipment in power sectors. PLN, an entity with Electricity Supply Business Permit (IUPTL), and IPP holding PPA are eligible to submit a request for import duty exemption by completing prerequisite documents. VAT exemption is also regulated under government regulation no 81/2015 where strategic goods (electricity) and equipment which can provide the strategic goods are exempted (PWC 2018b).

- **How does import duty and taxes impact LCOE?**

  If the import duty and taxes enforced for Chinese solar module (0.1-0.3 USD/Wp) imported to Indonesia, the solar module prices could rise by almost 20% (0.12-0.36 USD/Wp). Therefore, it may increase the investment cost of a solar power plant by about ~10% (assuming a 45-50% share of investment cost is from solar module cost) (IRENA, 2019). The increase in investment cost is relatively marginal and may still give a better price compared to local solar module price (0.3-0.4 USD/Wp). The LCOE of solar power plant with exempted import duty and tax is only 2-5% lower compared to the one with import duty and tax imposed. The LCOE reduction could be expected to be even lower for a less capital intensive power plants such as coal and gas power plant.

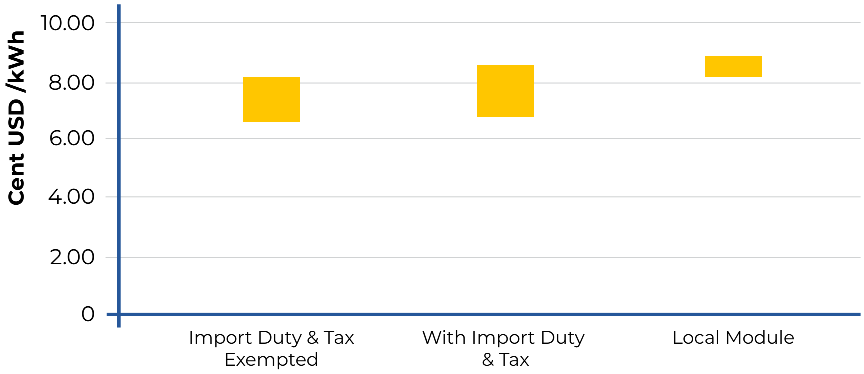

Figure 12. Comparison of ease of import duty impact on solar module

The ease of import duty and tax is a form of incentive for renewable development in Indonesia. However, there is a bureaucratic process to go through to obtain it. On the other hand, the benefit that it gives is marginal and therefore may not look appealing for the investor.

4.3 Viability Gap Fund (VGF)

- **What is viability gap fund?**

The VGF is a policy that aims to directly support a project to make it financially viable and attractive for the investor. The support can come in different forms such as a capital grant, O&M support grant, loan, or even an interest subsidy. The policy is commonly used in an infrastructure project and usually conducted under a public-private partnership (PPP) schemes. In Indonesia, a VGF support is regulated under Ministry of Finance Regulation no 143/PMK.011/2013 and is given in a form of a construction grant for an infrastructure project (Deulkar and Shaikh 2013; Mahani et al. 2019).

Example of VGF policy application in the power sector can be seen in India. The government of India has announced the VGF scheme since 2004 for infrastructure projects with the PPP scheme. The VGF policy was then stipulated for the power sector (solar power plant) under the Jawaharlal Nehru National Solar Mission (JNNSM) Phase-II policy document in 2012. The VGF given from the government is in the form of a grant of up to 20% of capital cost and an additional grant with a maximum of 20% is possible with the local government/sponsoring Ministry/statutory entity support (Jose 2016). The scheme will start with the set of a base tariff by the

Ministry of New and Renewable Energy. The project developers would bid and propose for the amount of VGF required to meet the tariff, and the one with minimum VGF requirement is selected. However, such policy scheme offers some disadvantages as there is no incentive for developers to assure an excellent performance over the lifetime of a project (MNRE 2012).

- **How does VGF policy impact LCOE?**

We will consider the impact to LCOE from two different forms of VGF in Indonesia: capital grant, and equity gap fund. The analysis will calculate how LCOE is affected by a capital grant of 20% and if government finance half of the equity financing needed in project development with a low expected rate of return. The first VGF will directly cut the investment cost, while the second one will reduce the cost of capital (WACC) of the project. We will consider a utility-scale solar power plant project (installed capacity > 10 MW) in the calculation.

Assuming a 750 USD/kW investment cost for solar power plant with 10% WACC (70:30 debt to equity ratio, 15.8% cost of equity, 10% cost of debt, and 25% tax rate) as a baseline, we have LCOE of USD 7.06 ct/kWh. The 20% capital grant would bring down the investment cost to 600 USD/kW, and thus the resulting LCOE will be reduced to USD 5.95 ct/kWh (15.7 % reduction). On the other hand, if the government supports 50% of the equity with low expected return (assumed to be 10%), the WACC would decline to 9.13 %, and thus the LCOE decreased to USD 6.69 ct/kWh (5.2% reduction).

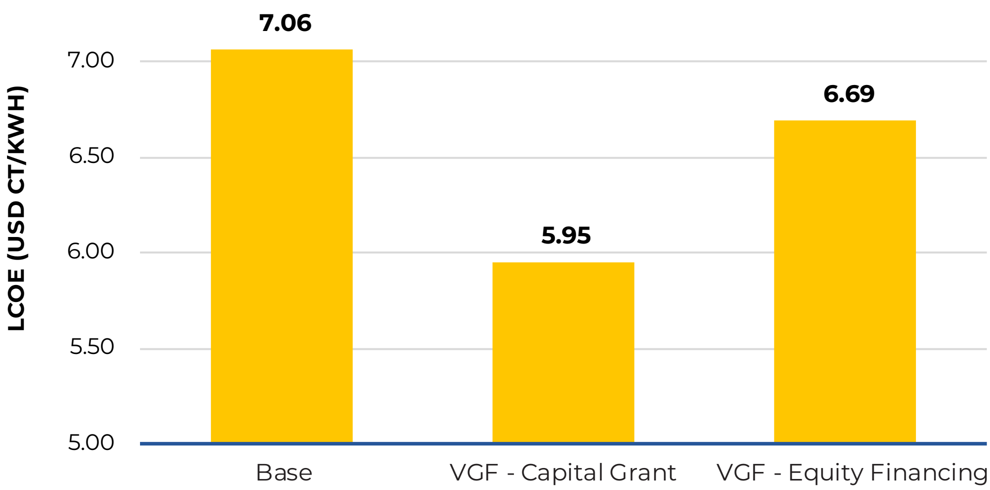

Figure 13. LCOE comparison of utility-scale power plant with and without VGF policy in Indonesia

The capital grant scheme may allow project developer to achieve lower LCOE compared to the equity financing scheme. However, the government will need to prepare a larger fund with the capital grant scheme (about 1.5 million USD for 10 MW project). Moreover, the nature of the grant scheme means that the government will also not be able to recover the funds. One alternative to recover part of government investment in this grant VGF scheme is by recovering the land value through BOOT agreement with the developer (given that the developer owns the land).

On the contrary, equity financing scheme will require less capital (1.125 million USD for 10 MW project) and will also give a return over the lifecycle of the project. Moreover, the private investor will only need less equity to develop the project. Additionally, government participation in the equity may also reduce the risk perceived by the financial institution while assessing the project (and thus, increase the chance for the project to get into financial closing status).

VGF policy can be used to bridge the financial gap in constructing critical infrastructure. The policy has a tremendous impact upon viability of infrastructure projects with high capital cost (e.g. renewable power plant). Note that the policy has to be carefully designed to achieve a particular goal with optimal efforts and fund. In Indonesia case, the goal may be whether to provide cheap electricity for PLN to off-take or promoting renewable deployment to achieve the RUEN goal.

4.4 Low Interest Debt (Soft Loan)

- **What is low interest debt/soft loan?**

  A soft loan is a loan with a below-market rate of interest. The term soft financing also could refer to the flexibility for the borrower to pay back the loan, such as long repayment periods or interest holidays. The soft loan typically provided by government or development bank/institution for priority projects.

- **How does soft loan impact LCOE?**

  Depending on the share of debt and equity, having low-interest debt will drives down the cost of capital which eventually will lower LCOE. A higher interest rate will mean that the LCOE of a project will be higher, as the revenues from selling electricity will need to cover not only the project's high fixed costs but also the higher interest rates used to finance those costs. This is one reason why having access to cheap capital is one of the most critical factors for bringing down the cost of renewable electricity. Most power plant projects in Indonesia have 70-80% of debt in its financing and depending on the funders, the interest rate ranges from 5-8% (international funding) and 7-12% (local funding). Getting a below-market rate of interest (in Indonesia means below 5%) will also reach WACC to below 5%. This significantly reduces solar LCOE to the range of 3.5 - 8 centUSD/kWh, a reduction of 40% from the current level.

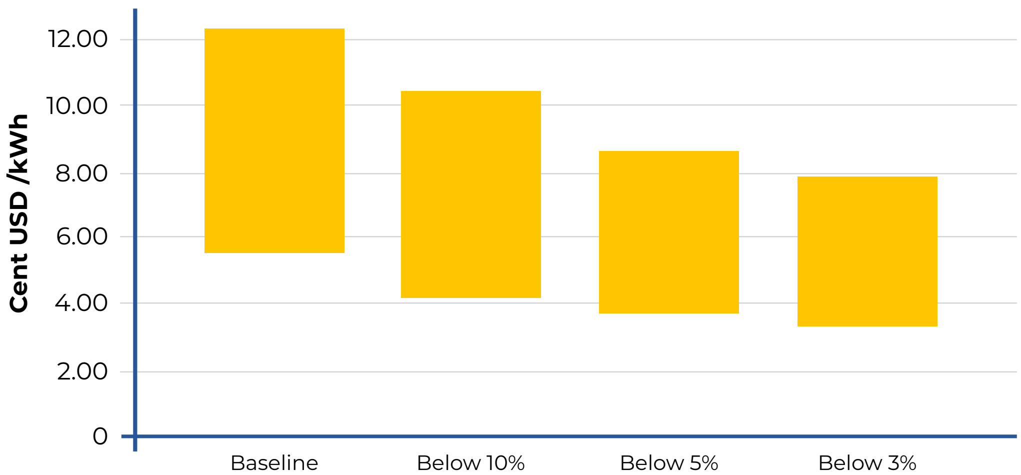

Figure 14. Impact of lower interest rate to solar PV LCOE. Similar CAPEX (650-1200 USD/kW), Fixed O&M Cost (15-30 USD/kW/year) and with equity IRR 12%

- **How can we get the lower debt rate?**

Especially in nascent markets, local and international banks might still be reluctant to finance renewable energy projects or ask for relatively high-interest rates. Therefore, many national governments have been supporting renewable energy projects[5] by providing them with cheaper capital. The German Development Bank (KfW) provide credit terms with interest rate 1-2% lower below market level, and the bonds are guaranteed[6] by the federal government. Thailand, for instance, has established the ENCON Fund, a revolving fund that has significantly reduced the cost of capital for RE investment. Loans have a maximum period of 7 years and they typically have a 4% interest rate or lower (compared to a market rate of 9%). Similar supports are provided by Brazilian Development Bank (BNDES), with interest rate from 1.7% to 0.9% for solar project and Malaysia's Green Technology Financing Scheme (2% interest rate for a maximum of 7 years), which also add government guarantee on technology cost.

In addition to setting up a dedicated fund (where the soft loan can also be made available as credit lines to local banks), providing guarantee schemes to local banks to cover losses and thus reduce their risk, also helping to lower interest rates.

[5] While some of the foreign development banks/agency provides low-interest rate, it is usually followed by specific concession, e.g. using technology from the donor country.

[6] The exemption from corporate taxes and unremunerated equity from public shareholders allows it to have a low cost of funds and to lend at lower rates than commercial banks.

5 | Conclusion

- **It is important to align the purpose of an LCOE analysis with a suitable calculation method and assumptions.**

  LCOE tool is useful to compare the different cost of generating electricity from various technology. It is crucial, however, to first understand the methodology used and know the benefit and limit that the chosen methodology offer. When we want to compare only the technological cost of renewables and fossil fuel power plants, it is better to use discounting or annuitizing method with same financial cost/WACC. We may, therefore, compare only the cost of procuring, operating, and maintaining the technology and avoid any possible bias (for example the risk perceived by investors and financial institution).

  On the other hand, a decision on investment will probably need LCOE coming from a financial model method to consider all affecting parameter including regulations, taxes, and incentives that may be specific for each technological options. Reflecting on the methodology used, the web-tool discussed in this report should be able to provide pre-assessment/comparison of LCOE from different technology as well as how will changes in particular parameter affect the LCOE of a specific technology.

- **Policy analysis and considerations on renewable and fossil fuel should consider the differences in their cost structure.**

  Renewable technologies have a higher share of capital cost (CAPEX) and are more sensitive to the financial cost (WACC) and the assurance of revenue stream from selling the electricity (capacity factor). Therefore, supportive policies that can accelerate the deployment of renewable support policies should address the issues that could affect the three parameters substantially. For example, setting up a good procurement model and/or supporting the local manufacturer may bring down the capital cost while providing guarantee fund will reduce the risk in obtaining debt and drive down the WACC. On the other hand, implementing a high local content requirement but not addressing the status and development of local manufacturers may result in higher component cost (and thus higher CAPEX).

- **The global trend will change the playing field as LCOE from renewable is getting cheaper while fossil fuel (coal) is not.**

The renewable (wind and solar) has experienced a massive deployment globally which has contributed to lowering the cost of equipment. Because equipment cost makes up a high share of capital cost, the LCOE of renewables is also expected to come down along with this phenomenon. On the other hand, the fossil fuel plant has experienced an increase in investment cost due to stricter emission and environmental standards. Additionally, financial institutions around the world have stepped out from coal investment which could increase the financing cost for coal power plant. The renewables have already become cheaper than fossil fuel in some parts of the world and will be so for the rest of the world in the next decade.

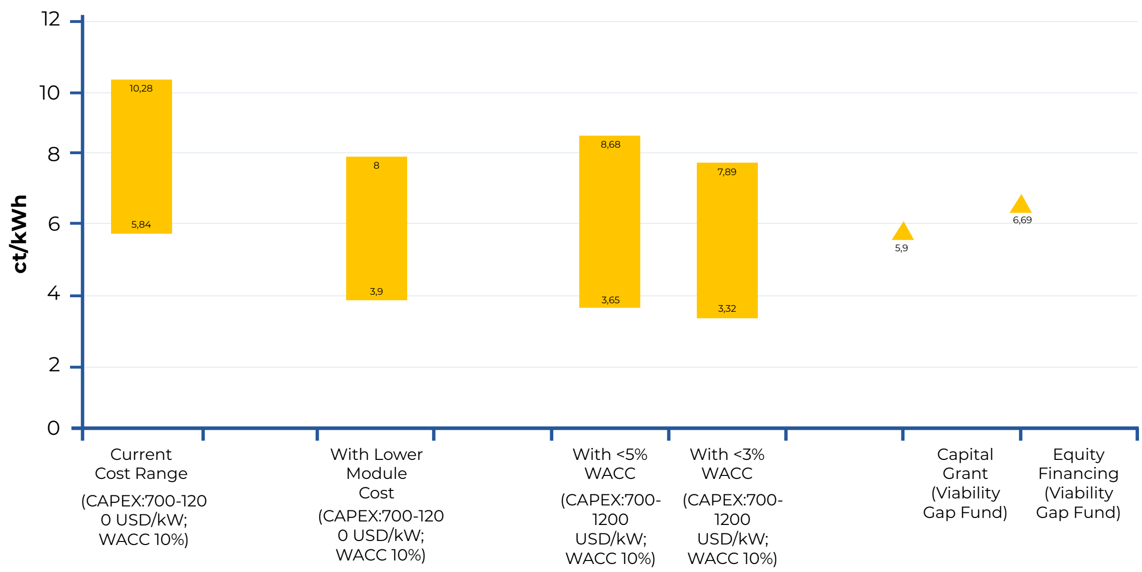

Figure 15. LCOE of solar power plant in Indonesia with several impacts of changes in the cost of components and implementing policies.

Annex 1. LCOE Methodology

1 The Discounting Method

Generally, LCOE calculates the total cost occurred during the lifetime of an electricity generation plant and divide it with the total electricity produced during the lifetime. In the discounting method, the cost and the electricity produced are both discounted to present day using a specific discount rate (Lai and McCulloch 2016). The general equation is as follows:

$$LCOE_{Discount} = \frac{PrV(Costs)}{PrV(Output)} = \frac{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{E_t}{(1+r)^t}}$$

Figure 1 Formula for LCOE calculation using discounting method (taken from Lai and McCulloch 2016)

The discount on cost and electricity generation will assure the comparability of LCOE (Kost et al. 2018). The difference in share and time of cost occurrence between different technologies are solved by using this discount factor. The discount for electricity generation is done because of its direct relation to the revenue through the sale of the electricity generation (Kost et al. 2018).

The LCOE can also be defined in real or nominal value. The real LCOE would consider the inflation rate and will use a constant real value in the calculation. Usually, the government and policy makers prefer to use the real LCOE as it would remove the impact of inflation towards OPEX (e.g. fuel cost, people cost). On the contrary, the project developers would prefer to input inflation assumptions on their project calculation and may use nominal LCOE instead (Black & Veatch).

The cost included in this calculation can be divided into investment cost (CAPEX), operation and maintenance/O&M cost (OPEX, which include fixed O&M and variable O&M) and fuel cost. The calculation can also include other cost factors to make it more case-specific (e.g. externalities such as the cost of CO2 emission). What is important is the transparency in the factors and assumptions used for the LCOE to avoid misleading information for the users.

Another cost factor that can be included in the calculation is the financing cost. The discount rate used can be replaced with the weighted average cost of capital (WACC). By doing so, we can integrate the financial factor in the calculation which consists of the share of debt and equity, the expected return on equity as well as the interest rate of debt (Kost et al. 2018). However, other financial parameters such as taxes, fiscal incentives, developer margin, or even the variation in the value of electricity generation due to the electricity market (for example German power market) are usually not captured. A different model such as the financial model should be utilized for this purpose.

The important thing to note is that the LCOE methodology basically represents the cost of generating electricity and does not necessarily represent the price of electricity delivered to the end-users. The price of delivered electricity could differ considerably from the LCOE depending on factors considered in the power system structure. These factors may consist of the existing regulation, the power market structure, externalities cost, integration cost (Ueckerdt et al. 2013), and others.

2 The annuity/annuitizing method

The annuitizing method has a similar concept with the discounting approach except that the total cost accounted will be converted into an equivalent annual cost and the electricity generation value used is the average annual electricity generation. Both discounting and annuitizing method will give the same number if the energy output of technology assessed is constant over its lifetime (Lai and McCulloch 2016).

$$\mathrm{LCOE}_{\mathrm{Annutizing}} = \frac{\mathrm{Ann(Costs)}}{\mathrm{Ave(Output)}} = \frac{\left(\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}\right)\left(\frac{r}{1-(1+r)^{-n}}\right)}{\left(\sum_{t=1}^{n} E_t\right)/n}$$

Figure 2 Formula for LCOE calculation using annuitizing method (taken from Lai and McCulloch 2016)

The formula can be further simplified if we also assume a fixed annual operating cost in the calculation. With such an assumption, the investment cost at the beginning of the asset deployment could be converted using a specific factor into the annual investment cost that can be added directly with the yearly operating cost (Kost et al. 2018). The disadvantage of this method is lower accuracy compared to the discounting method because of the simplification made in the calculation that might not reflect the actual cost. However, with the advantage of a more moderate calculation effort, we can quickly recalculate LCOE using different parameters and therefore introduce a sensitivity analysis over a variety of input parameters.

3 The Financial Model Method

The financial model method simulates the cost and revenue of an asset throughout an entire lifetime. The nature of the model allows for more parameters to be introduced in the calculation even including the taxes, incentives and other valid regulation on a specific technology. An example of financial model LCOE is presented by Lazard and Black & Veatch (Black & Veatch; Lazard 2018). The LCOE is calculated by finding the electricity tariff that can satisfy the required return of the equity for the investor.

As there are more parameters involved in the calculation, the results should present value that is close to the actual cost of generating electricity. However, the complexity of the parameters used makes the calculation outputs project-specific and arguably reduces the comparability of the outputs. The model could be better used to help investors make the final investment decision on a specific project.

Annex 2. Capacity Factor and Seasonal Variation of VRE

The CF of a power plant contributes directly to the LCOE results. Higher CF means that more electricity is generated and would significantly lower the LCOE. Annual CF factor should be used when comparing the CF from the thermal and VRE power plant. The reason is to take into account of seasonal variation of the resources for VRE. A sample of the available resources for VRE (average global horizontal irradiation for solar and average wind speed for wind) in Surabaya shows that there is a variation of solar global horizontal irradiation (GHI) which will result in a month-to-month change of CF. For a solar power plant in Surabaya, the CF will be peaking in August and September. On the other hand, a wind power plant CF in Surabaya will be at the highest in January, July, and August.

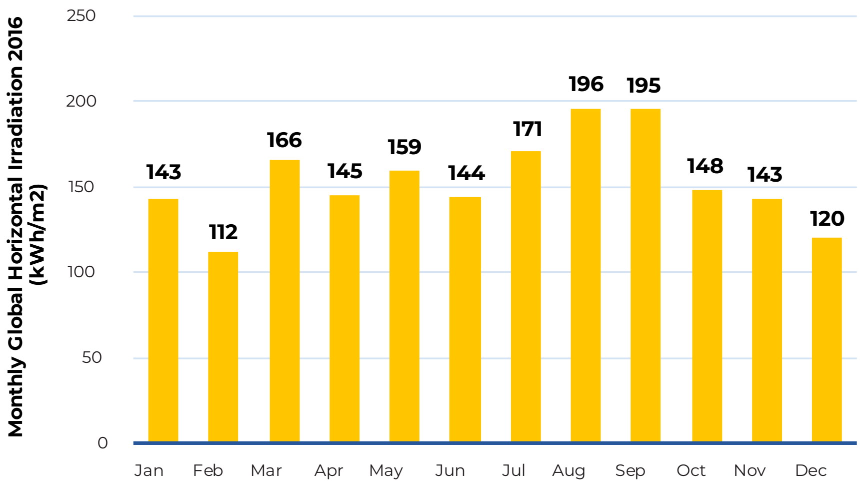

Figure 16. Solar monthly horizontal global irradiation data in Surabaya 2016 (kWh/m2) (adapted from European Commission 2017)

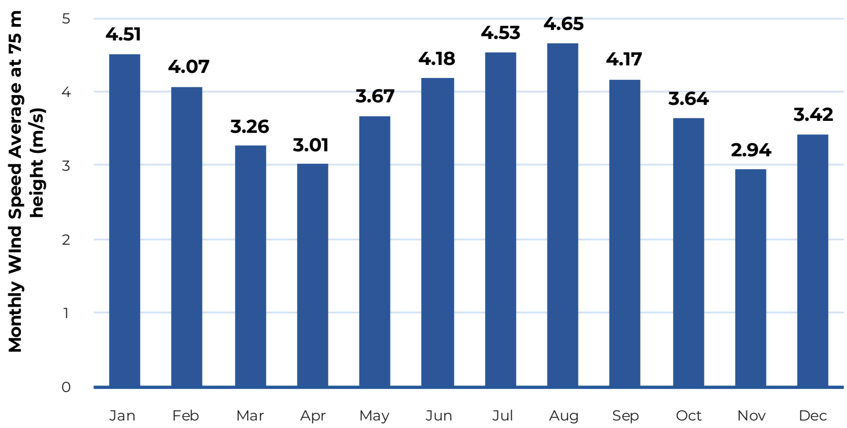

Figure 17. Monthly wind speed average in Surabaya at 75 m height (m/s) (adapted from EMD International A/S)

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