Solar power plant in Indonesia: economic, policy, and technological challenges to its development and deployment

Linus Andor Mulana Sijabat\textsuperscript{1} and Albayruni Mostavan\textsuperscript{1}
\textsuperscript{1} PT Len Industri (Persero), Jl. Soekarno Hatta No.442, Bandung 40254, Indonesia

*Email: linus.sijabat@len.co.id, albayruni.mostavan.k@len.co.id

Abstract. The conversion of solar radiation to electricity usually use photovoltaic device. The resource is always available daily. Indonesia is a tropical country that lies on the equator, so every day can receive, on average, the solar radiation energy of 5 kW hours/m\textsuperscript{2} every day with the best solar sunshine between 4 and 5 hours. Due to the regulation from the government of Indonesia to reduce the effect of global warming in the world, Indonesia will use renewable energy with the target of 23% on the national energy mix in 2025. One of the component solar power with the target of 6.5 GW. Solar power applies for a centralized and distributed power plant, which is installed on rooftop of building or a house, ground-mounted, and floating with an on-grid or off-grid system. Beside, solar power applies to the integration with other system like EV charging, pumping, cold storage, lighting and other. Furthermore, solar power will develop to downstream to build solar cell manufacture to increase domestic component level, decrease solar module price, and create job to improve the nation’s economy.

1. Introduction
Energy is very important for human life every day. The present condition is conventional energy, like oil and coal, which will reduce in use because it produces pollution in the air, and these stockpiles not renewable that affecting the earth. One of the energies that resource is always available daily by utilizing energy that comes from the Sun. To convert solar radiation energy to electricity, usually used a photovoltaic device, which arranges into a solar power plant [1]. Photovoltaic (PV) technology in the world is overgrowing in line with its business potential. This solar power plant reliable involves no moving parts, the operation and maintenance cost are shallow, easy to install and transport, and can be installed everywhere with other systems. Besides that, the operation of the solar power plant system is silent, and creates no atmospheric pollution [2].

Indonesia is a tropical country that lies on the equator in Southeast Asia. Every day, Indonesia can receive average radiation solar energy of 5 kW hours/m\textsuperscript{2} with the best solar sunshine between 4 and 5 hours. Therefore, Indonesia has the potential to utilize solar energy in the distribution of each province, which is up to 207 GW [3]. During the last five years, the installed capacity of solar has increased from with 51 MW in 2015 to 159.43 MW in 2019. However, Indonesia's current condition is in the sixth position below Singapore, Malaysia, the Philippines, Thailand and Vietnam [4,5]. However, the government is making efforts to develop new renewable energy (NRE), with a target in 2025 that can utilize new renewable energy by 23\% as stated in the National Energy General Plan (RUEN). With a target of using solar energy 6.5 GW in 2025 and 45 GW in 2045, following what is stated in the National Energy Policy (KEN) [6,7]. In addition, at the 21st Session of the Conference of the parties to the United Nations Framework Convention on Climate Change / COP 21 UNFCC in Paris. It held in 2015 and attended by 195 countries signed the Paris Agreement to the United Nations Framework Convention on
Climate Change, with the aim is to keep the temperature rise to no more than 2 °C and the target to be up to 1.5 °C. The President of Indonesia committed to reducing emissions by 29% under Business as Usual (BAU) in 2030, and it can increase by up to 41% with international cooperation. So that to control the sustainability of climate change, the Indonesian government enacted law number 16 of 2016 with a mitigation target in 2030 on the NRE side of 54% of the total sector [8].

With the higher demand for solar energy, solar power generation systems need solar modules. Currently, the total solar module factories in Indonesia can produce solar modules with a capacity of 546 MWp each year, which are members of the Indonesian Solar Module Manufacturers Association (APAMSI). However, the solar PV industry in Indonesia is underdeveloped. PT Len Industri (Persero) is one of the solar module producers since 1997, with an annual capacity of 71 MWp per year [9]. Also, the price of solar power systems annually decreases by 30% in 2030, with 50% of the decrease coming from the solar modules price. With this condition, its investments in solar PV technology have tended to fall in recent decades is expected to become a primary energy source and reduce the National Electricity essential cost of supply in Indonesia is called BPP [10].

In this case, it will be able to explain more related to solar power generation in Indonesia based on existing policies, economics, and technology that need to be developed and become challenges today. It can accelerate the use of solar energy in Indonesia and can meet the set target.

2. Method

The problem of using solar energy in Indonesia cannot increase significantly due to the lack of supporting regulations from the government’s support so that there are limitations in the use of solar power plants, and it is not economically attractive for the investment process. One way to increase the use of solar energy is by revising several regulations, especially in the use of solar power plants installed on the rooftop of a building. Apart from that, it requires support from banks and funding institutions with Green Interest Loans by changing the scheme to Build, Own, and Operate (BOO).

To accelerate the increase in the use of solar energy, support from the government is needed. One of the supports provided by the government is the formation of a team among State-Owned Enterprises to accelerate the development of solar power plants from the developer side for their construction and manufacture of solar cells to reduce the price of the engineering, procurement and construction (EPC) process.

3. Results and discussions

3.1. Regulation support for solar power plant in Indonesia

When viewed from the development of solar energy use capacity in ASEAN, Indonesia's increase is less than Vietnam, as shown in Figure 1. So that support from the government in determining regulations dramatically affects the development of solar energy use to achieve the previously planned targets. Readiness for regulatory supports in the use of solar energy use in Indonesia has a target based on the RUEN and KEN with a planned capacity installed in 2025 of 6.5 GW. However, several regulations need to be proposed a revision, is Ministerial Regulation No. 49 of 2018 concerning the use of the Solar Power Plant rooftop system by PT PLN (Persero) consumers. It is necessary to implement 1: 1 of the amounts of power exported from the Solar Power Plant system contained with the amount supplied from PLN. It needs to remove the capacity limitation due to current conditions if PLN cannot record the rooftop area for Solar Power Plant produced on the electricity meter. Besides, it is necessary to eliminate the minimum bank account for the investment from the Solar Power Plant Development.

A follow-up needed from Presidential Regulation No. 22 of 2017 regarding the General Plan for National Energy related to the installation of a Solar Power Plant with an area of 30% of the rooftop. This situation hoped can spur the use of Solar Power Plant to execute immediately. With the revision of Ministerial Regulation No. 50 of 2018 with a scheme that initially BOOT can change to BOO, it is hoped that this will get support from banks and Funding Institutions to receive loans with Green Interest.
In the process of accelerating the use of solar energy, the Government has issued the Ministry of State-Owned Enterprises Decree by creating a team. This team focuses on developers for installing Solar Power Plant rooftops in a company, factory environments, and a suitable place to be used as an Independent Power Produce (IPP) for Solar Power Plant and development to help solar cell material requirements as the basis of PV.

### 3.2. Financial and subsidy support for solar power plant in Indonesia

In terms of financial feasibility, installing Solar Power Plant has problems that slow down the growth of solar energy use. Table 1 showed the comparison between the feasibility of using Solar Power Plant between Indonesia and Saudi Arabia so that we can create several scenarios in the PV mini-grid development process so that growth is faster. However, there are several factors to note in this comparison process. The most decisive factor is the amount of electricity sales price, namely the IRR Target and Revenue. Geographically, Saudi Arabia has a higher level of solar radiation, so the resulting energy production is higher (Revenue is more significant). But it has a more stable risk profile (WACC), so it has a low-interest rate and the IRR value accepted by investors with a ‘not so high’ value. Even though Indonesia has a lower investment cost threshold rates achieved is higher than those in Saudi Arabia.

| PARAMETER                  | UNIT     | INDONESIA | SCENARIO 1 | SCENARIO 2 | SAUDI ARABIA |
|----------------------------|----------|-----------|------------|------------|--------------|
| Energy output (PV Output)  | kWh / Wp | 1.36      | 1.36       | 1.36       | 1.97         |
| Investment Cost           | Mio USD/MW | 0.7     | 0.6        | 0.6        | 1.03         |
| Loan to Equity Ratio      |          | 70 : 30   | 70 : 30    | 70 : 30    | 70 : 30      |
| PPA Period                | Year     | 20 years  | 25 years   | 25 years   | 25 years     |
| Interest rate             | %        | 10% (DR)  | 6% (USD)   | 4% (USD)   | 2% (USD)     |
| Income Tax                | %        | 22%, will be 20% starts in 2022 | - | - | - |
| VAT                       | %        | 10%       | -          | -          | -            |
| PPh 22 (tax)              | %        | 1.5% (PPh 22) | - | - | - |

Results

| WACC | % | 9% | 7% | 5% | 2-3% |
|------|---|----|----|----|-----|
| Tariff | cents | 0.094 | 0.056 | 0.047 | 0.023 |
| Tariff escalation | USD/kWh | flat | flat | flat | Yes, yearly |
| IRR  | % | 11% | 8% | 7% | 4-5% |

Figure 1 Solar energy development in ASEAN

![Solar energy development in ASEAN](image-url)
To increase the electrification ratio an electricity subsidy of 59.3 trillion Rupiah is provided with 450 VA to 23.2 million customers and 900 VA to 6.1 million low customers. Therefore, the existence of this subsidy can change the electricity subsidy system by building a Solar Power Plant on the rooftop or in the area so that it can increase the use of new renewable energy. So that it can reduce the cost of subsidies in the long run and with this system can improve the target in the accuracy of distribution to residents in remote and remote areas with scattered areas without the entry of PLN's network.

3.3. Technology support for solar power plant in Indonesia

To achieve a gap of 16.72% or 6.5 GW of the energy mix from 2017 to 2025, one requires support for the construction of a solar cell factory in Indonesia. With the supply chain from the type of crystalline solar cell from this solar power plant, starting from silica sand into silicon ingots. It is carry out by pushing it into a wafer that uses as a solar cell later, where this solar cell material will make into a solar module that installs into a system that produces electricity for customers. Nevertheless, if we look at the current conditions, companies that are already in Indonesia, namely from solar modules to the downstream direction, while the upstream has not developed. With the increasing need, a solar cell factory will build as shown in Figure 2.

![Figure 2 Solar Power Systems Supply Chain](image)

With the construction of a solar cell factory, there are several advantages in the development and utilization of solar energy in Indonesia, namely by building national capacity in solar cell technology. The increase in the level of domestic content initially at PT Len Industri could reach 43.5% with the presence of a solar cell factory, which will increase this so that it can support according to government regulations, which require that the value of domestic content levels reaches 60%. The construction of a solar cell factory will open up new jobs so that it can absorb new workers. As well as lowering the cost of material imports, which initially had to import solar cells into the country to only silicon wafers, the raw material for solar cells. Also, in the future, it can reduce the cost of producing national electricity by building a solar cell factory.

Besides, there can also be the potential to be developed upstream. However, it is not feasible to build now unless the solar module needed for power generation in a year requires approximately 1–2 GW, and the cost of electricity for manufacture a factory in silicon ingots is 3 cents. USD / kWh. With this whole process developed in Indonesia, it will make the price of modules sold domestically decrease and make it possible to compete with solar module factories abroad.

3.4. Application Solar Power Plant

Based on the use of solar energy, it can use in various ways, not only in generating electricity for each building, but as a source of electrical energy in various applications. The system is divided into two, namely off-grid and on-grid, as shown in Figure 3. The on-grid system connects to the available network and utilize in a centralized manner, such as in IPP. It is built above ground level or floats in the water. The decentralization with a spread system can apply on the rooftop or integrated with the building, attached to glass or claddings. With this spread system, it will be a power plant in every building. The maintenance is not complicated. Just make sure dust impurities or something like that is not covered the
solar module. The market potential in this solar power plant is in state-owned facilities such as toll roads, airports, gas stations, stations, mines, factories, offices, agriculture, ports and warehouses. Besides that, it can build on the roofs of houses owned by residents.

Most of the off-grid systems integrate with other systems, which utilization requires energy. The solar energy obtained is stored in the battery first before being used. Apart from being a source of electricity, solar energy can be used in the industrial world as cathodic protection to resist corrosion in metal. In Indonesia, mostly used are off-grid systems utilized, such as solar street lighting, solar home systems, and etc. In the future, this system can also be used as a substitute for gas stoves to become electric stoves from solar energy. Apart from that, it can use as a place for charging from batteries in electric tubes (Talis) and also electric cars for people's daily needs. With this solar energy can be utilized in some area like water pumping and treatment systems, health care system, communication, agriculture, transport aids, security systems, corrosion protection system, income generation, and electric power for satellites, because can be used in remote area and stand-alone.

Figure 3 Application of solar power systems

4. Conclusions
To be able to accelerate the development of solar energy in Indonesia by implementing 6.5 GW in 2025, support is required in terms of government regulations and supporting technology to achieve economic improvement. In regulation terms, there is a need for changes by implementing a 1:1 application for the export and import of electricity, eliminating the limiting capacity, eliminating minimum accounts, and using 30% rooftop area. Apart from that, the bank and financial institutions need to give support related to the provision of green interest loans for changes to the existing BOO scheme. Also, a change in the electricity subsidy system needs by building a solar power plant on a subsidized rooftop. The financial feasibility arrangement on the tariff value, with certainty IRR and revenue targets, will increase investors to build solar power plants in Indonesia and assist the development process.

In the future, with the increasing use of solar energy, solar cell factories are also needed to increase the capacity of national technology, increase the value of domestic content levels, absorb labor, and reduce the cost of national production, which has an impact on the domestic economy. By utilizing solar energy, it can use on-grid and off-grid systems. Besides that, it can be integrated to other systems installed in remote areas and stand-alone.
References

[1] Luque H and Hegedus S, 2002, Handbook of Photovoltaic Science and Engineering
[2] Markvart T, 1996, Solar Electricity
[3] Ministry of Energy and Natural Resources, Kebijakan, Regulasi, dan Inisiatif Pengembangan Energi Surya di Indonesia
[4] IRENA, 2020, Renewable Energy Statistics
[5] Ministry of Energy and Natural Resources, 2020, Handbook of Energy & Economic Statistics of Indonesia
[6] Gov. of Indonesia, 2014, Peraturan Pemerintah Republik Indonesia no 77 tahun 2014 Kebijakan Energi Nasional
[7] Gov. of Indonesia, 2017, Peraturan Presiden Republik Indonesia no 22 tahun 2017 Rencana Umum Energi Nasional
[8] Gov. of Indonesia, Undang-undang Republik Indonesia no 16 tahun 2016 Pengesahan Paris Agreement to The United Nations Framework Convention on Climate Change (Persetujuan Paris Atas Konvensi Kerangka kerja Perserikatan Bangsa-Bangsa Mengenai Perubahan Iklim)
[9] PT Len Industri, Pengembangan EBT di PT Len Industri (Persero)
[10] International Technology Roadmap for Photovoltaic (ITRPV) 11th edition, 2020