International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2021, 11(5), 52-58.

An Optimum Financing Scheme for Baseload Thin-film and Monocrystalline Photovoltaic Plants in Indonesia

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Received: 12 March 2021 **Accepted:** 16 June 2021 **DOI:** https://doi.org/10.32479/ijeep.11387

ABSTRACT

This paper investigates the most optimum financing scheme for medium-scale grid-connected photovoltaic (PV) plant investments in Indonesia. Eleven (11) financing schemes, composed through the combination of Viability Gap Fund (VGF), international grant, tax incentives, and low loan interest, are studied. The electricity tariff resulted from each financing scheme is analyzed and compared to the applicable feed-in tariff to find the optimum financing scheme. Moreover, this paper also includes two types of PV modules, such as thin-film and monocrystalline. The result shows that the funding combination consists of 50% of capital expenditure (CAPEX) from VGF provided by the Government of Indonesia (GoI), 30% of CAPEX provided by the international grant, and 5% of loan interest results in the optimum financing scheme. The resulting electricity tariffs from this financing scheme are 571.04 IDR/kWh and 761.76 IDR/kWh for thin-film and monocrystalline PV plants, respectively, which is below the lowest existing feed-in tariff (985 IDR/kWh).

Keywords: Thin-film Photovoltaic, Monocrystalline Photovoltaic, Feed-in Tariff, Economic Feasibility, Financing Scheme
JEL Classification: P41, P43, P49

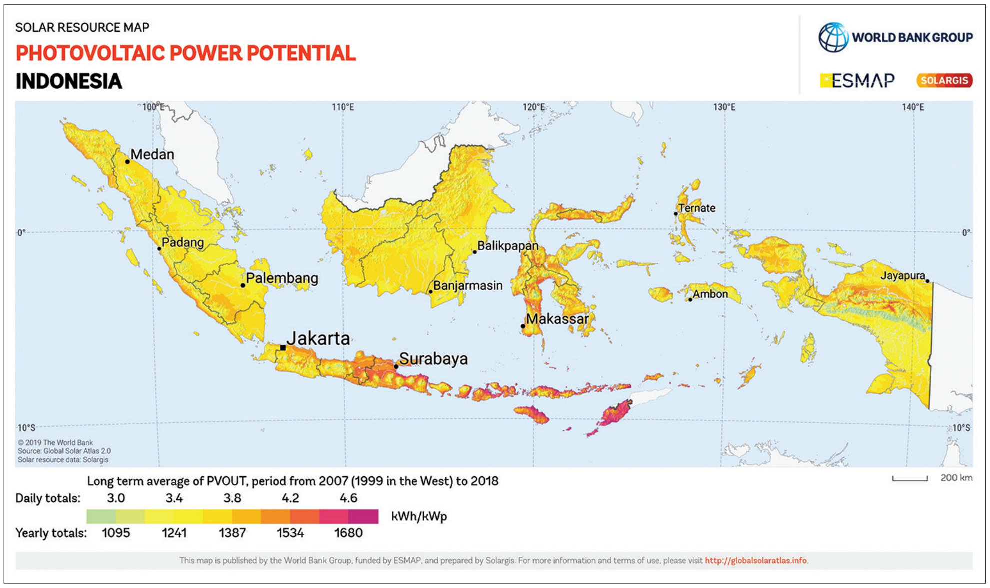
1. INTRODUCTION

The photovoltaic (PV) plants play an important role in achieving the Government of Indonesia (GoI) ambitious targets of increasing the share of new and renewable energy in the national energy mix up to 23% in 2025. Moreover, it has many advantages to provide electricity to the frontier, outermost, and least developed regions in Indonesia due to its energy available throughout the year, and it can be operated off the primary grid. Its implementation can also reduce the CO_2 emission generated by fossil-based power plants (Bimantoro et al., 2019). International Renewable Energy Agency (IRENA) estimated that the solar PV plant's potency might reach 3.1 GWp/year by 2030 (IRENA, 2020). However, the cumulative installed capacity of PV systems throughout Indonesia by 2019 is still about 0.05%.

Given its geography as an archipelagic country, most Indonesian people live in areas connected to electricity grids. The grids are operated and managed by a state-owned electricity company, namely PLN. PV systems are currently allowed to be integrated into the existing electricity grids. In (Kunaifi et al., 2020), the significant potential of the grid-connected PV systems, which is about 82%, can be installed in rural areas; roughly 17% in suburban areas and the remaining approximately 1% in city centers. The solar map of Indonesia is shown in Figure 1.

The transition towards sustainable energy has attracted academics' attention because of the need for financing schemes for renewable energy development. It is identified in (UNDP, 2012) that there were four broad categories of innovative finance mechanisms for development, which comprise: (1) Taxes, dues, or other obligatory

Figure 1: Solar map of Indonesia (SOLARGIS, 2021)



charges on globalized activities, which include initiatives such as carbon tax, (2) Voluntary solidarity contributions which include initiatives such as carbon footprint while booking an airline ticket, (3) Front-loading and debt-based instruments, and (4) State guarantee, public-private incentive, insurance, and other market-based mechanisms which the aims to correct market failures, reduce sovereign risk, and macroeconomic vulnerabilities. Along with innovative business models, it is argued that innovative financing schemes are essential drivers for the rapid growth of distributed solar PV power projects, particularly in the United States and China, calling for other innovative policies and government policy support (Zhang, 2016).

Between 2012 and 2016, the GoI implemented several financial instruments to support clean energy development, including PV development. The instruments include capital injection to state-owned enterprises, budget for line ministry, special allocation fund, and fiscal incentive. They provided at least IDR 12.4 trillion for the financial instruments, where investment on PV projects received approximately 2% of the total amount (Sitorus et al., 2018). Moreover, the other study reviewed several relevant and lessons on financing schemes for renewable energy deployment in Uganda, Sub-Saharan Africa, Finland, Central America, and Turkey (Asian Development Bank, 2019). These studies can be learned on creating the innovative financing scheme for PV plant investment in Indonesia. The GoI further prioritized the increase and promotion of renewable energy generation resources under the National Energy Policy and the Medium-Term Development Plan.

Many barriers to PV plant investments still exist, resulting in serious roadblocks, leading to mixed results and questions over the projects' long-term bankability and viability. In Indonesia, the barriers include high-interest rates, limited long-term debt funding, low power purchase agreement tariff, and risk aversion of the financial sector (Asian Development Bank, 2019; Hamdi, 2019; Sitorus et al., 2018). In (Sitorus et al., 2018), the financing scheme was studied by considering the Viability Gap Fund (VGF) and the tax incentive. Whereas, the authors in (Asian Development Bank, 2019) only examined the VGF for renewable energy financing schemes. On the other hand, Rubin et al. evaluated the feasibility of the solar PV plant investment in Indonesia through grants from international funds and loan interest (Hamdi, 2019).

This research develops eleven (11) financing schemes composed of VGF, tax incentives, international grants, and low loan interest. The economic feasibility of the configured financing schemes is assessed to create an adequate supply of finance for PV plant investments in Indonesia. The selection of the most optimized financing scheme is performed by comparing the resulted electricity tariff with the feed-in tariff determined by the GoI through the Ministry of Energy and Mineral Resources (MEMR) Regulation No. 55K/20/2019 on Amount of Cost of Energy for Electricity Generation in 2018 (Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia No. 55K/20/MEM/2019 Tentang Besaran Biaya Pokok Penyediaan Pembangkitan PT Perusahaan Listrik Negara (Persero) Tahun 2018, 2019). Besides looking at lenders' perspectives, this paper also looks at the perspectives of institutional entities in arriving at a balanced conclusion with respect to the two PV technologies.

This research focuses on baseload thin-film and monocrystalline PV systems with an installed capacity of 1 MWp and a lifetime of 20 years. The study is referred to the technical and economic aspects of PV plants located in Cirata, West Java Province, and in Bangli, Bali Province for thin-film and monocrystalline, respectively. As both PV plants were built in 2015 and 2013, the optimum financing scheme for future PV plant investment is obtained by implementing the learning rate on capital expenditure (CAPEX) as proposed in (Rubin et al., 2015) to formulate the new CAPEX.

The structure of this paper is as follows: Chapter 2 provides the setting, methodology, and data used in this study, Chapter 3 discusses the results associated with the developed financing schemes' economic feasibility, including the resulted electricity tariff and the comparison between thin-film and monocrystalline PV technologies, and Chapter 4 concludes this research.

2. FINANCIAL MODEL AND FINANCING SCHEME

2.1. Financial Model

Economic feasibility analysis and evaluation of the proposed financing schemes are critical to upscaling PV investment. They contribute to the selection of an optimum financing scheme in which the GoI explores continuously. The economic feasibility indices that are measured in this study include Net Present Value (*NPV*), Payback Period (T_{pb}), and Internal Rate of Ratio (*IRR*). The indices are the most accepted standard methods for financial assessments for long-term PV projects in many studies, such as in (Imam et al., 2019; Lang et al., 2015).

The NPV refers to the difference between today value of cash inflow and the cash outflow over a project or life business time, as follows:

$$NPV = \sum_{t=1}^{N} \left(\frac{R_t - C_t}{(1+d)^t} \right) - C_0 \quad (1)$$

where N is the number of years of the economic analysis, t is the year variable in each summation, d refers to the discount rate, C_0 is the capital expenditure (CAPEX) of PV plant, C_t is the operational expenditure (OPEX), including maintenance cost in year t, and R_t is the plant revenue in year t. A positive NPV indicates the investor is earning money, and vice versa. The assumption on the discount rate, d, is crucial since the rate may dynamically change, resulting in different assessment conclusions.

The T_{pb} refers to the time needed for an investment to offset the amount invested in profits or net cash flow. This study uses the simple T_{pb} for PV investment in Indonesia, as follows:

$$T_{pb} = \frac{C_0}{\left(\sum_{t=1}^{N} R_t - C_t \right) / N} \quad (2)$$

The shorter T_{pb}, the more desirable the investment. Conversely, the longer the T_{pb}, the less appealing it is from the lender's perspective.

The *IRR* corresponds to the discount rate value at which the NPV of a particular investment's cash flow is zero, which can be obtained by solving the following equation.

$$NPV = \sum_{t=1}^{N} \left(\frac{R_t - C_t}{(1+IRR)^t} \right) - C_0 = 0 \quad (3)$$

If IRR is larger than or equal to the Minimum Acceptable Rate of Return (MARR), the projects are feasible economically and financially to be implemented.

2.2. Financing Scheme

Eleven (11) financing schemes to achieve access to concessional capital at lower interest rates and longer tenures for PV investment are proposed and compared in this research. The schemes are composed of VGF, international grants, tax incentives, and low loan interest. The summary is presented in Table 1.

The governments provide VGF in cash support under a subsidy mechanism. It is discussed in (Asian Development Bank, 2019) that the VGF for renewable energy financing in Indonesia is split between the Independent Power Producer (IPP) or grid-connected projects on the one hand and electrification projects the other hand. The GoI can entirely fund the former, whereas, the latter can be financed for large part/entirely by external climate or development finance. Besides increasing the infrastructure projects' financial feasibility, in many cases, VGF helps increase the certainties in achieving the projects' standards and deadlines and obtaining affordable tariffs for the public utilizing the infrastructure projects. These days, the scheme is mainly available for large-scale projects developed under the PPP scheme. Adopting the strategy, it considers a scenario where the 1 MWp PV plant projects receive a fund of 50% investment from the GoI, according to the Ministry of Finance (MoF) Regulation on VGF.

The grant from international is provided and distributed by governmental organizations or a donor to non-governmental organizations. One of the challenges in implementing the grant from international is that the grant allocation is part of official development assistance (ODA) for Indonesia, which is necessary to be considered part of the pledge of Consultative Group on Indonesia (CGI). In the implementation, the grant from international is directly managed by the donors, and the utilization of the grant from international is directly given to the recipients, i.e., non-governmental organizations. It is, therefore, a challenge for reporting the financial flow of such allocation. In many cases, the donors are unwilling to be transparent on the list of organizations who received their grants, how much they provide grants for each organization and their activities. Moreover, as the financial scheme is provided bilaterally from donor to recipient or channeled through a multilateral development agency such as the United Nations or the World Bank, it can have serious issues regarding rules and regulations on the state or international levels. Adopting the funding scheme for a grant from international, it considers a scenario where the 1 MWp PV plant projects receive a fund of 50% investment from the GoI.

Table 1: Eleven financing schemes of grid-connected PV plant investments in Indonesia

Financial scheme	VGF	International grant	Tax incentives	Low loan interest
1	√	-	-	-
2	-	√	-	-
3	-	-	√	-
4	-	-	-	√
5	√	-	-	√
6	√	-	√	-
7	-	√	√	-
8	-	√	-	√
9	-	√	√	√
10	-	-	√	√
11	√	√	-	√

The GoI provides fiscal incentives for renewable energy development through tax holidays, tax allowance, im- port duty, and value-added tax exemption. Based on Government Regulation No. 94/2010 (Peraturan Pemerintah Republik Indonesia No. 94/2010 Tentang Penghitungan Penghasilan Kena Pajak Dan Pelunasan Pajak Penghasilan Dalam Tahun Berjalan, 2010), MoF Regulation No. 159/PMK.010/2015 (Peraturan Menteri Keuangan Republik Indonesia No. 159/PMK.010/2015 Tentang Fasilitas Pengurangan Pajak Penghasilan Badan, 2015), and Chairman of BKPM Regulation No. 18/2015 (Peraturan Pemerintah Republik Indonesia No. 18/2015 Tentang Fasilitas Pajak Penghasilan Untuk Penanaman Modal Di Bidang-Bidang Usaha Tertentu Dan/Atau Di Daerah-Daerah Tertentu, 2015), the income tax holiday is granted for a period of 5–15 years from the start of commercial production is given for company with a minimum investment project value of IDR 1 Trillion (approximately USD 69 Million). Adopting the financial incentive, it considers a scenario where the 1 MWp PV plant projects are granted a reduction of holiday tax up to 50% for the first 5 years.

As discussed in (Asian Development Bank, 2019), one of the main challenges financing renewable energy power generation investments in Indonesia is the high interest rates of loans, resulting in low returns of typically capital-intensive renewable energy investments. To overcome the concern, relevant financial institutions are expected to provide financial support in the form of loan interest lower than the interest rate of loans determined by the World Bank. Adopting the low loan interest scheme considers a scenario where the 1 MWp PV plant projects are eligible for receiving 5% loan interest, which is about a half lower than the interest rate of loans determined by the World Bank in 2018.

3. REFERENCED DATA

This research focuses on baseload thin-film and monocrystalline PV systems with a capacity of 1 MWp and a lifetime of 20 years. The financing schemes for thin-film PV plants are technically and economically referred to as the Cirata PV plant located in Cirata, West Java Province. Whereas, the financing schemes for monocrystalline PV plants are based in Bangli, Bali Province.

The business model used in this study follows the Built, Operate, and Transfer (BOT) scheme, referring to the initial concession by the GoI to a private corporation to both build and operate the project. After a certain operation period (in years), control over the project is returned to the GoI. The BOT scheme promotes private investment, on-time delivery with no additional cost, technology transfer, and capability in utilizing relevant multi-national companies.

3.1. Cirata Thin-film PV Plant

The Cirata thin-film PV plant's installed capacity is 1 MWp, with a capacity factor is 14.7%, peak production of 3.53 h/day, and a performance ratio of 82.8%. The lowest and highest monthly production occurs in February and September, with 89.9 MWh and 125 MWh, respectively.

The CAPEX of the Cirata Thin-film PV Plant in 2015 was US$ 2,000,000. The CAPEX is adjusted to find the optimum financing scheme in the year 2019. The estimation of the adjusted CAPEX is performed through the learning curve method, as follows (Rubin et al., 2015):

$$\log Y = \alpha + b \log x \quad (4)$$

where learning rate $LR = 1 - 2^b$, parameter Y is the unit cost of the technology, constant α determines a learning index, constant b represents the rate of cost reduction, and x refers to installed capacity (MWp). This study defines the LR at 23% and α at −0.38. These result in the new CAPEX of US$ 1,626,483, with a currency exchange rate, which is assumed as US$ 1 equals IDR 14.000.

The operational expenditure (OPEX) of PV plants includes fixed and variable operation and maintenance (OM) cost. Fixed OM cost includes insurances, taxes, and distribution costs, whereas, variable OM costs include employment expenditure, utility, and waste costs. The annual OPEX of PV plants is approximately 0.8% of CAPEX (US Energy Information Administration (2020), 2020), or around US$ 11,814.

3.2. Bangli Monocrystalline PV Plant

The Bangli monocrystalline PV plant's installed capacity is 1 MWp with a capacity factor of 13.34% (Nathawibawa et al., 2016). The CAPEX in 2013 was US$ 1,785,714, so that the estimated CAPEX in the year 2019 is US$ 1,093,447. Whereas, the OPEX is approximately US$ 8,747 annually.

3.3. PV Feed-in Tariff

Indonesia promulgated a feed-in tariff for solar energy in 2016. The Regulation of the Minister of ESDM No. 55K/20/MEM/2019 regulates purchasing electric power from PV systems by PLN. Instead of using the previous single feed-in tariff for the whole country, each PLN regional area applies its feed-in tariff. The feed-in tariff is compared with the electricity tariffs associated with the proposed financing schemes. Notably, the electricity tariffs related to the proposed financing schemes for Cirata Thin-film PV Plant are compared to the feed-in tariff of West Java Province, which is IDR 985/kWh or US$ 6.81/kWh. Whereas, Bangli Monocrystalline PV Plant is compared to the BPP of Bali Province, which is also IDR 985/kWh or US$ 6.81/kWh. This tariff is currently the lowest feed-in tariff for solar energy among all regions in Indonesia.

4. RESULTS AND DISCUSSION

The assessment of all financing schemes is based on the profitability analysis by employing the NPV, Payback Period, and IRR. This study's discount rate is referred to as the interest rate defined by the Bank of Indonesia (BI), which is 5.75%. The minimum attractive rate of return (MARR) is set to be 8%, which will be compared with the IRR of each financing scheme. Furthermore, the electricity tariff generated by each financing scheme is evaluated with the feed-in tariff applied in West Java and Bali Province. The technical data of the PV module and inverter used in this study are presented in Table 2.

The economic calculation results for each financing scheme for thin-film and monocrystalline PV plants are provided in Tables 3 and 4, respectively.

4.1. Profitability Analysis

Tables 3 and 4 show that the baseline scenario for both 1 MWp thin-film and monocrystalline PV plants is not viable. The feed-in tariff applied to Java and Bali Regions, 985 IDR/kWh, is lower than the electricity tariffs associated with the baseline scenarios, which are 1642.22 IDR/kWh for Thin-film PV and 2144.69 IDR/kWh for Monocrystalline PV. On the other hand, the feasible financing schemes for thin-film PV plants are schemes 2, 6, 8, 10, and 11, as shown in Table 3. Whereas, the feasible financing scheme for monocrystalline PV plants is scheme 10 and 11.

Among the viable scenarios, scheme 11 for both thin-film and monocrystalline PV plants results in:

- The highest value of *IRR*, where the *IRR* of scheme 11 for thin-film and monocrystalline PV is 25.30% and 13.63%, respectively, and
- The lowest number of years to recover the CAPEX, where the T_{pb} of scheme 11 for thin-film and monocrystalline PV plants are 5 and 9 years, respectively.

Furthermore, the IRR of scenario 11 is higher than the MARR (*IRR* >MARR). Hence, financing scheme 11 is the most attractive, stable, and profitable scenario among the other financing schemes. It is also shown that scheme 11 provides the lowest electricity tariff, which is 571.04 IDR/kWh for thin-film PV plant and 761.76 IDR/kWh for monocrystalline PV plant. These two tariffs are below the lowest feed-in tariffs currently implemented in Indonesia, which is 985 IDR/kWh.

4.2. Comparative Assessment between Thin-film and Monocrystalline PV Plant

All stakeholders in both thin-film and monocrystalline PV sectors are currently still on a learning curve. The perspectives of lenders and institutional entities are included in the comparative assessment.

4.2.1. Lenders perspective

Due to lower efficiency, the thin-film technology requires a larger area than monocrystalline technology for the same power plant capacity. For an installed capacity of 1 MWp grid-connected PV, thin-film PV technology also requires more capital and operational expenditures. Under the term of an expected lifetime and limited warranty, the field condition risks must be covered and considered for a bank guarantee.

In enriching the study, the optimum financing scheme's performance for both thin-film and monocrystalline PV are compared, as provided by Table 5 and Figure 2. Both *IRR* and *NPV* of thin-film PV investment are higher than monocrystalline PV investment. Whereas, the payback period (T_{pb}) is higher for monocrystalline PV investment. Figure 2 depicts that the electricity tariffs (at NPV = 0) of the thin-film PV investment financing scheme are always lower than monocrystalline PV tariffs. The comparative assessment currently makes thin-film PV technology more acceptable than monocrystalline PV technology from the lenders' perspective.

Table 2: Technical characteristics of thin-film and monocrystalline PV modules and inverters used in Indonesia

Component		Thin-film	Monocrystalline
PV module	Module efficiency	13.80%	15%
	Max power	170 Wp	200 Wp
	Open circuit voltage (Voc)	112.0 V	44.2 V
	Short circuit current (lsc)	2.2 A	5.5 A
	Power tolerance	±5%	0–3%
Inverter			
Input (DC)	Max input voltage	1000 V	1000 V
	Min input voltage	570–620 V	620 V
	MPP voltage range	580–800 V	480–800 V
	Max input current	36 A	42 A
Output (AC)	Rated power	20,000 W	20,000 W
	Max apparent AC power	20,000 VA	22,200 VA
	Nominal AC voltage range	230–400 V	310–480 V
	Rated power frequency	50 Hz	47–53 Hz/57–63 Hz
	Max output current/max THD	29 A	≤3% (nominal power)

Table 3: Economic feasibility of the financing schemes for on-grid Thin-film PV plant

Scheme	*NPV* (US$)	*IRR* (%)	T_{pb} (year)	Feasibility	Tariff (IDR)
Baseline	−1,340,420	-	-	-	1,642.22
1	−100,961	-	-	-	964.70
2	383,776	15.48	8	Yes	706.77
3	−1,276,683	-	-	-	1,606.03
4	−922,313	-	-	-	1,401.74
5	−70,953	-	-	-	949.61
6	48,363	8.69	12	Yes	885.25
7	−882,404	-	-	-	1,391.38
8	400,888	15.95	8	Yes	692.73
9	69,861	9.00	-	-	872.95
10	437,533	16.69	8	Yes	678.17
11	638,870	25.30	5	Yes	571.04

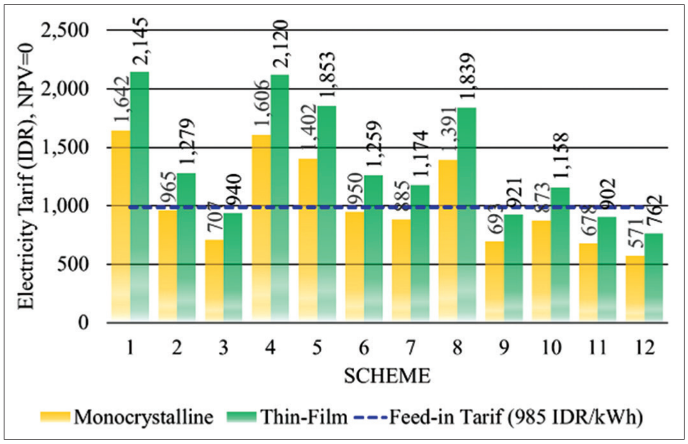
Table 4: Economic feasibility of the financing schemes for on-grid monocrystalline PV plant

Scheme	*NPV* (US$)	*IRR* (%)	T_{pb} (year)	Feasibility	Tariff (IDR)
Baseline	−1,307,421	-	-	-	2,144.69
1	−389,666	-	-	-	1,278.68
2	−30,750	-	-	-	940.00
3	−1,252,777	-	-	-	2,120.40
4	−997,823	-	-	-	1,852.56
5	−360,014.53	-	-	-	1,258.56
6	−279,101.92	-	-	-	1,174.35
7	−960,839	-	-	-	1,838.64
8	−10,647	-	-	-	921.26
9	−255,751	-	-	-	1,157.90
10	9,053	8.27	12	Yes	902.44
11	158,129	13.63	9	Yes	761.76

Table 5: The comparison of financial of the optimum financing scheme

Financial performance	Thin-film PV	Monocrystalline PV
NPV (US$)	638,870	158,129
IRR (%)	25.30	13.63
T_{pb} (year)	5	9

Figure 2: Thin-film and Monocrystalline PV tariffs in comparison with the lowest feed-in tariff in Indonesia



4.2.2. The institutional perspective

Thin-film and monocrystalline PV technologies are primarily different from each other, potentially employing different policy and regulation treatments. The GoI is responsible for ensuring the efficient utilization of land resources, long-term power availability and reliability, and avoiding the large-scale dumping of low-efficient energy technologies. Therefore, the GoI includes PLN to keep eyes widely open on these technologies' research and market directions. It is undesirable that the directions may pose a setback to the energy policymakers in achieving ambitious targets of increasing the share of new and renewable energy in the national energy mix up to 23% in 2025 and electrifying the frontier, outermost, and least developed regions in Indonesia using PV technologies.

5. CONCLUSION AND FURTHER RESEARCH

This paper presents and analyzes the economic feasibility evaluation of eleven financing schemes for baseload Thin-film and Monocrystalline PV technologies. Performance indicators, including NPV, IRR, and T_{pb}, and comparative analysis of the two technologies with a capacity of 1 MW and approximately a lifetime of 20 years is assessed. The electricity tariffs associated with the financing schemes are compared to the feed-in tariff determined by GoI on the MoEMR Regulation No. 55K/20/2019 to select an optimum financing scheme. Results reveal that the funding combination of VGF with 50% CAPEX funded by the GoI, grand from international with a total amount of 30% CAPEX and 5% loan interest, is the optimum financing scheme. When setting NPV at zero, the scenario generates electricity tariffs currently below the lowest feed-in tariff applied in Indonesia, 985 IDR/kWh.

Based on the research findings, policy recommendations related to the VGF and grants from international schemes are made. The VGF scheme is mainly available for large-scale projects developed under the PPP scheme. The international's grant scheme generally has serious issues regarding rules and regulations on reporting the financing flow at both state and international levels. These have significantly constrained the availability of financing a 1 MWp PV plant project at the current moment. With some adjustment and justification, the VGF scheme shall possibly be applied to such a project. Moreover, the financing flow on the allocation of the grant from international shall be transparent and accountable. In this way, the study's optimum financing scheme can be implemented to supply finance for the PV plant projects.

For a long time, the most common type of PV technology used worldwide is Monocrystalline PV. However, findings confirm that baseload Thin-film PV technology utilized in Indonesia is more acceptable than baseload Monocrystalline PV technology. The confirmation supports studies, e.g. (Amin et al., 2009; Carr and Pryor, 2004; Walsh et al., 2012), stating that the Thin-film PV technology is more acceptable for tropical areas than the Monocrystalline PV technology under tropical conditions. Particularly, the high temperatures and shading have less impact on the Thin-film PV technology than Monocrystalline technology.

The technology and cost competitiveness of PV systems have continuously been developing to become more attractive and dominant. Because Thin-film and Monocrystalline PV technologies are primarily different from each other, it is of interest for future work to study different treatments and economic supports for each technology. To achieve the ambitious targets of the GoI in increasing the share of new and renewable energy in the national energy mix up to 23% in 2025 and of electrifying the frontier, outermost and least developed regions in Indonesia, an examination of various financing schemes with different sizes and purposes (besides baseload 1 MWp PV power plant) is also interesting for the further research.

6. ACKNOWLEDGEMENTS

This research was funded by a research grant of HIBAH PUTI Q2 2020 of DRPM UI from Universitas Indonesia (UI).

This research is supported by the Graduate Program on Energy and Power of Electrical Engineering Magister Program, Institut Teknologi PLN.

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