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The Evaluation of Use Photovoltaics (PV) in Renewable Energy Technology as Sustainability Strategies

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Abstract

The United Nations (UN) proposed the Sustainable Development Goals (SDGs) to make the earth peaceful and prosperous by 2030. Abundant water and food supply, sustainable energy consumption, climate change mitigation, and sustainable energy consumption are considered the keys to better sustainability. For example, the food sector is responsible for 30% of global energy consumption, 21-37% of greenhouse gas (GHG) emissions, and 70% of global water withdrawals. Integrating renewable energy into a country's energy mix largely depends on the implementation of renewable energy policies. Sustainably developed solar photovoltaic options to meet energy. The main focus is to achieve energy security and independence with special emphasis on solar energy, to drive transformative change towards widespread adoption of renewable energy. The research method uses a literature study and the findings are in the form of the direction of the Indonesian Government's policy setting, namely the National Energy General Plan (RUEN) which is the basis for regulation through Presidential Regulation Number 79 of 2014 with the aim of changing the increase in the national energy share to 23% by 2025. This regulation aims to create opportunities for PT PLN (Persero) customers in the household, business, government, social, and industrial sectors to be actively involved in the utilization and management of renewable energy in a sustainable manner and provide insight into the sustainability of solar energy, including environmental and economic development.

Keywords: SDGs, Renewable Energy, Solar PV

INTRODUCTION

By 2030, the Sustainable Development Goals (SDGs) put out by the United Nations (UN) seek to make the globe a wealthy and peaceful place for all of its citizens. These objectives are complex and interconnected, with a plentiful provision of food and water, sustainable energy use, and the reduction of climate change all seen as critical building blocks for improved sustainability. For instance, the agri-food industry is responsible for 21-37% of world greenhouse gas (GHG) emissions, 30% energy and 70% water of global extraction (Gervais et al., 2021). Water availability fluctuations may have a significant effect on the agriculture industry. Food manufacturing, delivery and processing all need energy, as does the extraction of groundwater. Moreover, electrification is necessary to improve people's quality of life and requires energy. These three industries have a significant influence on climate change, which has an effect on the food, energy, and water industries. food, drink, and energy. All SDGs are thought to be connected by energy, nevertheless (Deng et al., 2019; L. Murphy, 2021). Concern over sustainable methods for the manufacture and disposal of photovoltaic (PV) modules has grown within the last 15 years.

Hotspots in the industry have included the use of hazardous and crucial components, instances that connect PV manufacture to chemical contamination, and lax waste regulations outside of the EU . The worldwide polysilicon industry depends on China's Xinjiang Province, where accusations of forced labor have surfaced recently. This underscores the supply chain's lack of traceability. They confirm the Business & Human Rights Resource Center's findings, which state that the majority of RE firms don't have the human rights policies in place to prevent exploitation of workers and communities (Business & Human Rights Resource Centre, 2020). Terawatt-scale solar energy deployment is necessary to keep global warming to 1.5°C over pre-industrial levels (Haegel et al., 2019), can widen the already existent disparities in the industry. It's important to take reputational hazards into consideration. Researchers, businesses, and politicians have all launched initiatives to increase PV sustainability, with a particular emphasis on lowering the solar carbon footprint. Depending on the location of production and the technique used to calculate the yield, the electricity-generated global warming potential, excluding balance of system (BOS), declines from 33–76 g CO2-eq/kWh in 2013 to 13–30 g CO2-eq/kWh in 2021 (Müller et al., 2021).

In order to accomplish a green transition, sustainable technologies are essential. The quantitative examination of innovation and interindustry interdependence has been the subject of recent research (Andersen et al., 2020; Andersen & Gulbrandsen, 2020), with the use of new technologies seen as essential to reaching sustainability goals (Silvestre & Ţîrcă, 2019). Sustainable innovations' effects on sustainable development depend critically on their adoption, dissemination, and analysis of the forces behind them. Still, there remains a deficiency in the adoption of green technology, which is mostly dependent on government assistance. Policies and regulations have a major role in the adoption of sustainable solutions. Businesses are mostly driven by compliance, not genuine motivation, when it comes to sustainability. Going green, though, might eventually save expenses and provide you a competitive edge. A few other motivators are managerial concern, customer pressure, cost savings, and efficiency. Development of competencies can give early movers a competitive edge, particularly as sustainable practices will probably become more and more significant in the future.

The notion of sustainability has gained momentum, prompting more study and focus on the subject, especially since the Sustainable Development Goals were unveiled. Innovation is today considered to be greatly influenced by sustainable transition, and vice versa. Thus, it is essential for the green transition to investigate the mechanisms behind the spread of sustainable technology and to suggest ways to boost their uptake. Several techniques have been used to estimate diffusion and innovation in solar photovoltaic technology, with the learning rate model being the most often used in the literature. According to the learning rate, the cost of the technology drops by a certain percentage for every doubling of cumulative capacity. With the growing need for environmentally friendly transportation, installing photovoltaic (PV) panels on electric vehicles (EVs) is seen to be a viable way to boost energy economy and lower greenhouse gas emissions. (EVs) are seen to be a potential way to lower greenhouse gas emissions and increase energy efficiency (Trivedi, 2023). As well as a contribution to the reduction of their carbon footprint and to ameliorating the energy crisis to achieve a sustainable future (Dawood et al., 2020).

All the same, this is consistent with the fact that the present global energy crisis has affected economies all over the world, with emerging and developing nations in Europe and Central Asia being most affected. In 2022, Ukraine's economy is expected to significantly contract by -45.1%, according to the World Bank. In a similar vein, the Russian economy is predicted to experience a recession with a fall of -11.2% in the same year as a result of unprecedented sanctions (Das et al., 2019). With GDP growth predicted to drop by -4.1% in 2022, this negative trend in the economy is expected to spread to other parts of the world, especially to Europe and Central Asia, where the recession is expected to hit the Kyrgyz Republic, Moldova, and Tajikistan because of their close economic and financial ties to the Russian Federation (World Bank, 2022).

Several ASEAN Member States (AMS) enacted energy-related policies and regulatory measures in 2022 with the goal of quickening the energy transition and decarbonization efforts by increasing the adoption of renewable sources into their energy portfolios. Notably, Indonesia reached a crucial milestone in July 2022 with the issuing of MEMR Decision No. 135 of 2022, which addressed the Minimum Energy Performance Standard (MEPS) and the Energy Saving Label for Light Emitting Diode Lights (LED). This decision has significant implications for Indonesia's ADLIGHT initiative, which stands for Advancing Indonesia's Lighting Market to High Efficiency Technologies. The initiative intends to reduce power consumption and greenhouse gas (GHG) emissions by encouraging widespread use of high-efficiency lighting technology, revolutionizing the national market. It is important to note that this decision operates as subordinate law under Minister of Energy and Mineral Resources Regulation No. 14 of 2021, which focuses on the Application of Minimum Energy Performance Standards to Energy Consuming Equipment (A.Kenji, 2021; Minister of Energy and Mineral Resources Republic of Indonesia, 2021).

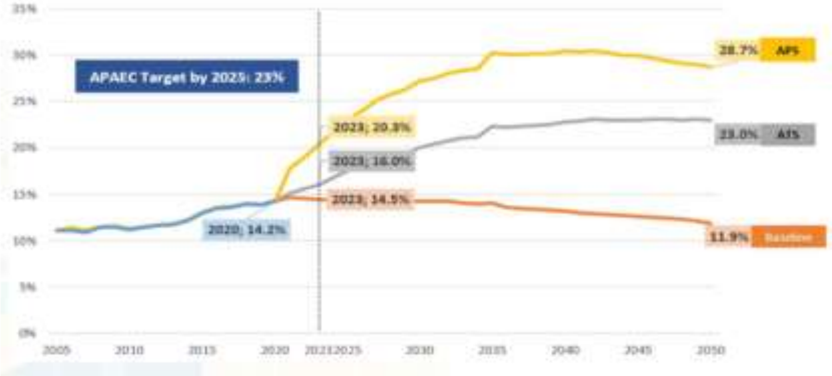

Figure 1. Renewable Share in TPES (2005-2050) [16]

The power grid's current paradigm is changing due to the growing demand for renewable energy technologies (RETs) and the widespread presence of distributed energy producers (Hossain et al., 2023) (Igliński et al., 2023). Photovoltaics (PV) is seeing significant development and expanding in importance as a contributor to renewable energy globally, with an anticipated capacity of 1,630 GW by 2030 and a potential expansion to 4,500 GW by 2050 (Garnett et al., 2021).

By 2023 (see Figure 2), renewable power capacity will have increased significantly, reaching around 507 GW, representing over 50% growth over the previous year (2022). The exceptional acceleration on a worldwide scale in 2023 may be due mostly to the phenomenal year-on-year increase in China's rapidly developing markets for solar photovoltaics (PV) (Cárdenas, 2023)(+116%) and wind (+66%).The exceptional acceleration on a worldwide scale in 2023 may be due mostly to the phenomenal year-on-year increase in China's rapidly developing markets for solar photovoltaics (PV) (+116%) and wind (+66%) (Lee et al., 2020) Over the next five years, the capacity of renewable energy will grow, with solar photovoltaics (PV) and wind power playing a significant role—they will account for an amazing 96% of the entire expansion. In addition to being more cost-effective than non-fossil and fossil fuel alternatives, these sources are becoming more and more popular due to ongoing government programs and their typically lower generating costs in many countries (IEA, 2023).

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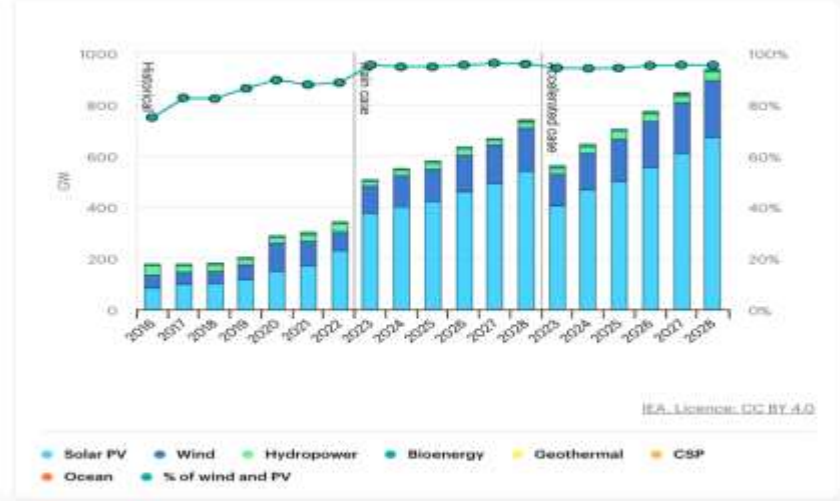

Figure 2. Renewable Electricity Capacity Additions by Technology and Segment

In line with the Nationally Determined Contributions, targeting a 31% share of renewable energy by 2050 (International Energy Agency (IEA), 2019) the Indonesian government intends to raise solar photovoltaic (PV) generation capacity to 4 GW in 2030, up from 0.06 GW in 2018 (ESDM, 2019). Nevertheless, many scholars view this target as insufficient. Various studies suggest that the potential of solar PV could exceed this projection. Liebman et al**,** contend that a total solar PV generation capacity of over 35 GW can be attained by 2027. IRENA anticipates that Indonesia could potentially achieve 47 GW of installed capacity by 2030 (Pastuszak & Węgierek, 2022). Given the abundance of solar resources in Indonesia throughout the year. it is commonplace to encounter studies examining how solar PV can technically integrate into the energy system [(Victoria et al., 2021).

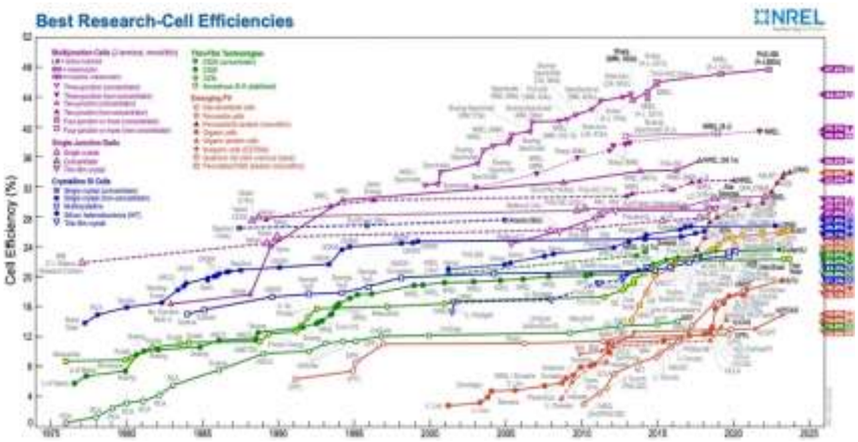

Figure 3. NREL Best Research-Cell Efficiencies Chart (NREL, n.d.)

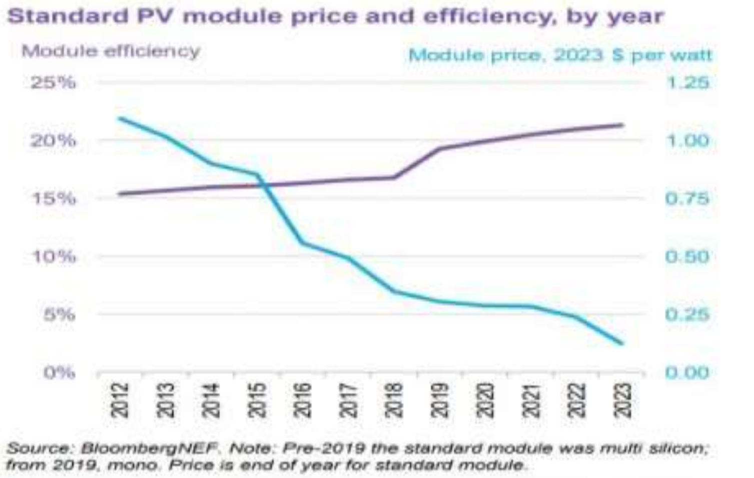

Figure 4. Standart PV Module Price and Efficiency by Year

Multicrystalline silicon, 15% efficient, and $1.09/W in 2023 was the standard solar module in 2012. 2023 standard is mono PERC, with a 21.3% efficiency and a $0.13/W cost. Indonesia, the country where the microgrid test case is situated, in particular, demand response installations, feed-in tariffs for using renewable energy, and net metering for power bills. The use of batteries to respond to price changes (Bista et al., 2019) between peak and offpeak hours in order to perform demand response (DR), with the assumption that compensation is given each time the microgrid is placed in islanded mode due to a disruption in the main grid (Astriani et al., 2019).

RESEARCH METHODS

This research involves literature research conducted to collect information related to the research topic. The data collection method was carried out by studying various articles on Photovoltaics. The data analysis approach used is to present data and information in the form of sentences that are easy to understand, which aims to find answers to problems regarding renewable energy management as a sustainable development strategy

RESULT AND DISCUSSION

1) The Scenario of Electrical Power Distribution in Indonesia

Indonesia, encompassing 17,000 islands, holds the status of the world's largest archipelago. The majority of its population resides in the five major islands: Java, Sumatera, Sulawesi, Borneo, and Papua. Additionally, significant communities inhabit the remaining 6,000 smaller islands [30]. Despite this widespread distribution, the primary demand for electricity originates from Java, Bali, and Sumatra (K. Kunaifi, 2020).

In accordance with a report, the statistical data for the year 2017 indicates that merely 60 million individuals were connected to the primary grid, leaving the remaining 227 million dependent on isolated grids or devoid of access to electricity. In addressing the absence of on-grid accessibility in certain areas, the prevalent recourse over the past three decades has been the

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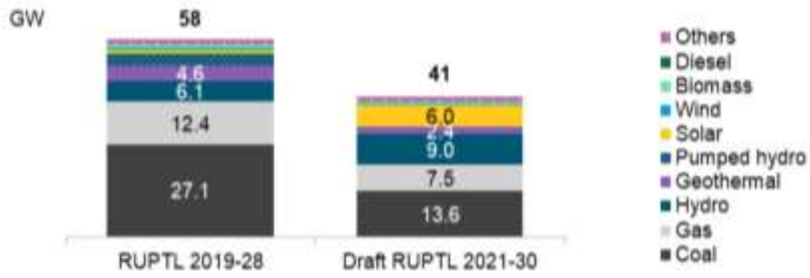
widespread utilization of diesel generators, primarily chosen for their straightforward installation procedures and relatively reduced costs (Burke & Kurniawati, 2018; K. Kunaifi, 2020).

To achieve zero emissions, short-term renewables growth would need to go significantly faster than Indonesia's existing plans. The IESR has created an Indonesian zero-emission scenario in association with Agora Energiewende and LUT University. A May 2021 research found that, compared to Indonesia's prolonged reliance on fossil fuels, renewable energy would be able to provide all of the country's energy demands by 2050 at a reduced cost. The research developed a Best Policy Scenario (BPS) to attain a lower system cost than alternative possibilities, such as one based on present policies (which would have higher system costs beginning in 2035). However, achieving zero emissions by 2050 would require building substantial amounts of renewable energy in the near future; the BPS anticipates adding 100GW of additional solar capacity between 2021 and 2030.



Source: Ministry of Energy and Mineral Resources, BloombergNEF. Note: Others include tidal, hybrid, EBT renewables and EBT peaker capacity. EBT refers to renewable energy. EBT baseload refers to solar-and-battery, wind-and-battery, geothermal or hydro projects.

Figure 4. Proposed Capacity Additions Under RUPTL 2019-28 and Draft RUPTL 2021-2030

This amount is 15.4 GW, or 27% less than the previous RUPTL, which projected an increase of 56.4 GW in 2019-28. Excluding anticipated capacity retirements, total capacity in 2030 would be 113.7GW, with 73% coming from fossil fuel production, down from 86% in 2020. The RUPTL plan for 2021 emphasizes renewable energy. Renewable energy will contribute for 49% of capacity expansions this decade, compared to 30% in the preceding RUPTL. The previously anticipated coal capacity of 13.5 GW and gas capacity of 5 GW are not included in the 2021 plan. Instead, the new paper proposes for a 5.1 GW increase in solar capacity and 2.95 GW in hydroelectric capacity during the 2019 RUPTL.

The connection of rooftop solar power plants to PLN's network, in accordance with the provisions stipulated in the Minister of Energy and Mineral Resources Regulation, aims to maintain the stability of electrical energy to be utilized by PLN customers. In addition, the cost of installing rooftop solar power plants becomes cheaper because the price of batteries is relatively quite expensive and has a limited operational period.

Referring to a study (Sakti et al., 2022), investigations into modeling solar photovoltaic (PV) systems also involve incorporating geospatial data related to urban building characteristics, solar radiation, and various meteorological factors within a cost-effective framework that has not been thoroughly explored (Kurian & Karthi, 2021) The power sector in Indonesia currently accounts for around 40% of total emissions. Indonesia's enhanced Nationally Determined Contribution (NDC) articulates a commitment to achieve a 23% share of renewable energy by 2025 and reduce emissions by 31.2% (unconditional) and 43.2% (conditional) by 2030 compared to the business-as-usual (BAU) scenario.

Currently, the share of renewable energy in the electricity generation mix is 12.8%, with a capacity of 8.52 MW. In line with this target, Indonesia is undergoing an energy transition in the electricity sector. The Ministry of Energy and Mineral Resources (MEMR) is currently centered on the natural retirement of coal-fired power plants and the deployment of renewable energy to achieve Net Zero Emissions (NZE) by 2060, Indonesia's Joint Emission Target Commitment (JETP) was introduced at the G20 event. The JETP commits Indonesia's power sector to peak emissions by 2030 and achieve NZE by 2050, with the goal of increasing the share of renewable energy to at least 34% by 2030 and retiring coal plants early. However, there are differences between the JETP's goals and PLN's proposal to retain 19 GW of coal-fired power plants and equip them with Carbon Capture, Utilization, and Storage (CCUS) by 2040, a technology that has limited implementation globally (IESR, 2023).

2) Improve Sustainability PV From Government Regulation

In Indonesia, the business case for utility-scale PV is growing. The levelized cost of electricity (LCOE) for solar installations is decreasing due to equipment cost decreases. At $64 per megawatt-hour, coal power plants are now Indonesia's least expensive option for producing large amounts of electricity, but solar is about to catch up. It is anticipated that by 2030, cheaper technology, lower construction costs, and better financing terms would cause the LCOE for utility-scale solar in Indonesia, which now ranges between $65 and $137/MWh (real 2020 USD).

PV will eventually drop in price to the point where it can rival the current coal fleet. By 2040, the marginal cost of operating an existing coal plant with a calorific value of 4,200–6,000 kcal/kg is expected to be $22–25/MWh, but the cost of PV generation will be less. Based on current fuel costs, diesel can cost as much as $200/MWh in remote areas, hence BNEF estimates that the LCOE of a PV-plus-energy storage (PVS) system in Indonesia is presently $113-251/MWh (actual 2020).

In the National Energy General Plan (RUEN), Indonesia has regulations outlined in Presidential Regulation No. 79 of 2014 (*Regulation No.79 on National Energy Policy 2014*, n.d.), By 2025, the national energy mix in Indonesia is expected to consist of 23% renewable energy, according to a decree issued by the government. A number of technical policies have been passed to provide the framework for execution in order to support these initiatives, especially those involving the use of solar energy. A policy of this kind is contained in the Minister of Energy and Mineral Resources (ESDM) Regulation No. 49 of 2018, together with the ESDM No. 13 and 16 Permen of 2019. The purpose of these laws is to especially target PT Perusahaan Listrik Negara (PLN) Persero consumers that use rooftop solar power producing equipment [36,37].

By means of the issuance of Ministerial Decree Number 188.K/HK.02/MEM.L/2021, PT Perusahaan Listrik Negara (Persero) has ratified the Electricity Supply Business Plan (RUPTL) for the period 2021 to 2030. This plan outlines the future growth of power-generating facilities that get their energy from New and Renewable Energy Sources (NRE), which account for a significant 51.6% of total power generation. By the conclusion of the 2025 calendar year, the RUPTL sets a goal for the NRE energy power generation amalgam to achieve a remarkable 23% share.. Concurrently, Presidential Regulation Number 112 of 2022, denominated as the "Acceleration of Renewable Energy Development for Electricity Supply" (Perpres No. 112/2022), has been instituted to expedite the progress of power facilities harnessing renewable energy sources. The primary objective is to realize the prescribed renewable energy composition target within the national energy matrix, harmonious with the overarching national energy policy. Perpres No. 112/2022 mandates the formulation of a RUPTL that prioritizes the precedence of renewable energy development and facilitates the formulation of a trajectory for the expeditious phasing out of steam power plants (PLTU) within the paradigm of the ongoing energy metamorphosis in the electricity domain. Additionally, the regulation addresses the intricacies of determining the electricity procurement rates from renewable energy-powered facilities and provisionally delineates fiscal or non-fiscal inducements within the domain of power facility development incorporating NRE (Pertamina Energy Institute, 2022).

The essence of this directive is to create avenues for the comprehensive involvement of all customers under PT Perusahaan Listrik Negara (Persero), spanning across residential, commercial, governmental, societal, and industrial domains, in the utilization and governance of renewable energy. This collective endeavor is geared towards realizing energy security and autonomy, particularly in the domain of solar energy. In a bid to stimulate widespread adoption across Indonesia, the government has issued Circular Letter Number 363/22/MEM.L/2019 from the Minister of Energy and Mineral Resources. Addressed to ministers within the Working Cabinet, the attorney general, the commander of the Indonesian National Armed Forces (TNI), the head of the Indonesian National Police, heads of non-ministerial government agencies, governors, and regents/mayors throughout Indonesia, the circular letter extends an earnest plea for the installation of rooftop solar photovoltaic (PV) systems on various structures, encompassing offices, official residences, warehouses, parking facilities, and other public amenities.

According to the Indonesian National Standard (SNI 8395:2017), a solar power plant refers to a power generation system harnessing energy from solar radiation by converting it through photovoltaic cells. Photovoltaic systems transform sunlight radiation into electricity, with the electrical power output being directly proportional to the intensity of solar radiation (irradiation) reaching the photovoltaic cell. Given Indonesia's geographical location in the tropics and on the equator, characterized by abundant sunlight, Solar Power Plants (PLTS) emerge as a highly viable technology for power generation. PLTS can be implemented in various configurations, adopting centralized or dispersed systems, and can function either on-grid or off-grid, depending on the specific application.

The widespread adoption of solar PV is expected to result in both positive and negative consequences for key participants in the electricity market (Kelsey & Meckling, 2018). Customers, the Central Government of Indonesia, independent power producers, and the national electricity company (PLN) are the main players in the Indonesian electricity market (IPP). The purpose of this study is to identify the important parties that the integration of solar photovoltaic (PV) in Indonesia may benefit or harm. In order to do this, a detailed examination of the evolving electrical scene, prospective benefits and drawbacks from the perspective of each stakeholder, and the regulatory adjustments that come with the growing switch to solar PV in the electricity sector are needed.

CONCLUSION

Energy transformation represents a fundamental change in the generation, distribution and utilization of energy, which entails a shift from the conventional model that relies largely on fossil resources towards more sustainable and environmentally friendly alternatives. This shift primarily involves the use of renewable energy sources such as solar, wind, hydro, biomass and others. The energy transformation process includes the development of innovative technologies, restructuring of energy markets, and implementation of government policies that support the use of clean energy. PV provides a clean and sustainable source of renewable energy. By utilizing sunlight, PV helps increase access to affordable and reliable energy, in line with Sustainability Development Goal.

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