ISSN No:-2456-2165

Application of LCA (Life Cycle Assessment) to Solar Energy Development in Indonesia

Ronald Sianipar[1], M. Sidik Boedoyo[2], Nugroho Adi Sasongko[3]
[1]Department of Energy Security, Republic of Indonesia Defense University, Indonesia
[2] Department of Energy Security, Republic of Indonesia Defense University, Indonesia
[3] Department of Energy Security, Republic of Indonesia Defense University, Indonesia

Abstract:- The application of Life Cycle Assessment (LCA) acts functionally to choose among the many available options with the least risk of damage to the environment. This is expected to be able to support the decision making of either a company or the government to improve the clean environment. This paper attempts to describe how the implementation of LCA is an effort by the State of Indonesia in realizing emission reductions, especially in terms of transitioning to the use of low-emission energy using the right instrument. Many sectors can use LCA on a large scale. However, the role of the government is very much needed as a pioneer, especially in developing countries like Indonesia. Furthermore, this paper will also discuss a review of some of the LCA literature, technology in general, and combine it with the use of solar energy sources as new energy and how the LCA framework when applied in Indonesia.

***Keywords**:- Life Cycle Assessment, Solar Energy, Energy Technology, CO_2 Emission, Renewable energy.*

I. INTRODUCTION

Based on research conducted by Ehsanul Kabir et al (2018) on the future use of solar energy to reduce emissions and Nawshad Haque's (2020) research on the application of Life Cycle Assessment (LCA) in energy technology, it will open new insights in the implementation energy, and of course will also cause new problems, namely how much emissions will be produced, and other impacts generated by these alternatives.

The application of LCA has a purpose as a tool to identify, provide calculations on the sustainability of resource use, measure the disposal of waste or emissions that have an impact on the environment, and as an evaluation tool for evaluating and implementing environmental improvement efforts. In Indonesia, LCA has referred to SNI ISO 14040:2016 dan SNI ISO 14044:2017.

This paper will discuss the literature review on the need to apply LCA for the use of solar energy in various sectors by considering existing technologies.

II. LITERATURE REVIEW: THE LATEST ENERGY TECHNOLOGY DEVELOPMENT

In a study conducted by Ehsanul Kabir et al (2018), they found that solar energy is a very potential energy and has good prospects in the future. This statement is also supported by the objectives of the 2021 Summit on climate change (COP26), which has set limits on the production of greenhouse gas (GHG) emissions in every country in the world. Indirectly, this condition forces a shift in the energy use of each country. Where many countries that use fossil energy and coal must innovate technology into energy that is more environmentally friendly (low emissions).

Solar power technology is starting to be considered as a solution to answer the energy shift innovation and to meet the ever-increasing energy demand. However, in its development, many challenges must be faced, ranging from costs, policies/regulations, resources, and human resources to build and in terms of management.

Ehsanul Kabir et al (2018) found that in solar energy technology, solar heat is used as an energy source that can be applied and commercialized. For example, for heating, cooling, for industry, and for generating electricity. Currently, Concentrated Solar Power (CSP) technology has been introduced, where this technology is already available on the global market, including the first is the Parabolic Trench (Parabolic) where its function is to concentrate incoming sunlight to heat the liquid tube, the second is the Fresnel Mirror which is used to concentrate the sun. for the receiving tube. The third is Solar Photovoltaic (PV) or super-thin solar cells which require 75 percent less energy to produce with 90 percent less silicon than commonly used panels.

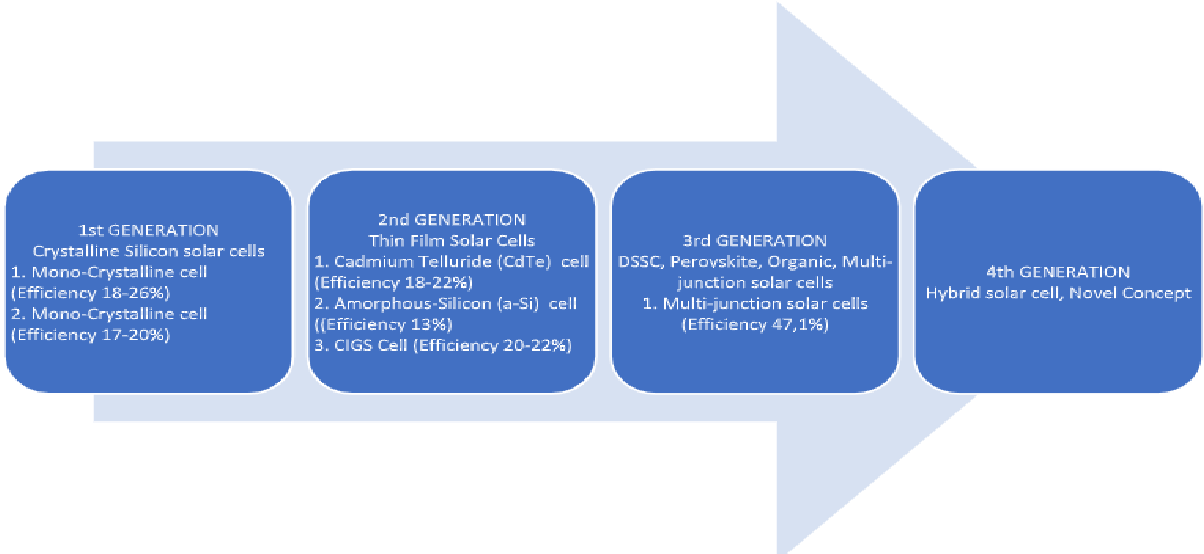


Fig 1: Solar Photovoltaic Technologies: From Inception Toward the Most Reliable Energy Resource (Nowshad Amin et al, 2017)

For Solar Power Plants (PLTS) which basically use PV technology, currently there are several kinds of configurations used depending on the desired needs and available resources. In accordance with its nature, PV is divided into two, namely, individual spread and centralized (centralized). According to the system, it is divided into two, namely: stand-alone which consists of PV only and hybrid which is a combination of PV with other generators such as PV-Diesel, PV-Diesel-Wind. As seen from the operating system, it consists of outside the PLN network (off-grid) and in the PLN grid connected (on-grid) network.

For the development of solar panels themselves, there have been several generations of changes, the development of each generation can be seen in Figure 1. According to Nowshad Amin et al (2017), currently solar panels have entered the fourth generation which has put forward hybrid concepts and new concepts that are more reliable. Besides that, in terms of prices, it is much cheaper and has been produced in large quantities, and the technology continues to develop.

According to research by Oktaviani (2020) and NREL (1976-2020) the greenhouse gas emissions produced by the first generation of solar panels (silicon crystalline cells), namely monocrystalline PV, amounted to 61 CO_2 eq./kWh with module efficiency of 18-25%, greenhouse gas emissions from poly-PV crystalline of 12 CO2 eq./kWh with a module efficiency of 17-20%. For the second-generation panels with thinner films, the greenhouse gas emissions of Amorphous-Silicon (a-Si) PV are 34.3 CO_2 eq./kWh with a module efficiency of 6.3%. sejauh ini solar panel paling efisien adalah multijuction-cells (2 terminal, monolithic) dengan efiensi energi mencapai 47,1%. From this research, in the future solar panels will be more affordable and more efficient.

III. SOURCES OF DATA AND ANALYSIS

- *Comparison of Current and Future Technologies*

When reviewing the comparison of current technology, global energy use is still very dependent on oil, gas, and coal. However, this energy will run out especially considering the increasing demand for energy. Therefore, it is necessary to anticipate with other energy alternatives.

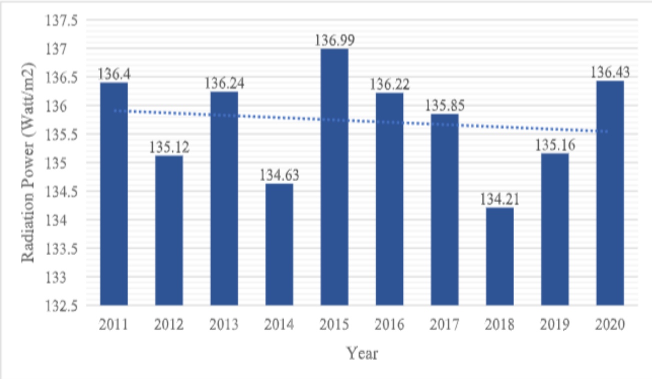
Ehsanul Kabir et al (2018) stated in their research that currently solar energy has the highest global potential because the supply of solar sources is unlimited and ubiquitous. The average amount of solar energy received by the atmosphere is about 352 W/m^2. The effective radiation annually on earth varies from 60 to 250 Watt/m^2.

The author analyzes the radiation in the territory of Indonesia using NASA satellite monitoring, where the average temperature is 27-37 degrees Celsius and the catch of solar radiation in Indonesia is 200-300 Watt/m2. This hotspot shows that global demand for solar energy will continue to increase.

The author sees that several locations in Indonesia are very suitable for developing solar energy. Indonesia's geographical position (for example, Parigi - Moutong Regency) is at Latitude -0.038302 and Longitude 120.060753. This position makes this area located on the equator, which means it has a hotter area than other areas, especially on the island of Sulawesi (figure 3). This is because the sun is right at the latitude of the equator at zero degrees. This makes during the day the temperature ranges from 300 Celsius.

In addition, monitoring of the strength (power) of the sun's rays for 10 years was carried out in Indonesia. Based on the author's monitoring results from NASA satellites, the power absorbed from solar energy can reach 136 Watt/m^2. This analysis is also strengthened by data from Indonesia Central Bureau of Statistics (BPS) and Indonesia Meteorology Climatology and Geophysics Council (BMKG) where the radiation power in Indonesia (more specifically Central and

Eastern Indonesia) is greater than 120 Watt/m^2. For more details can be seen in graph 1.



Graph 1: The average power of the sun for 10 years in Central and Eastern Indonesia is above 120 Watt/m^2 (Source: access on 17 December 2021 website: https://power.larc.nasa.gov)

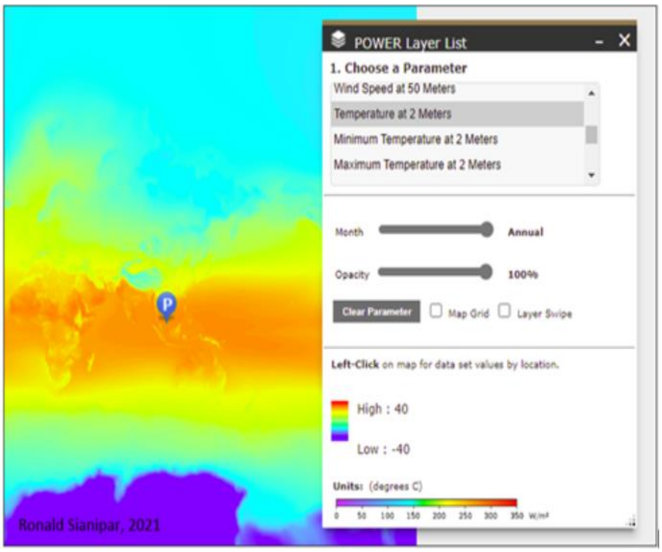


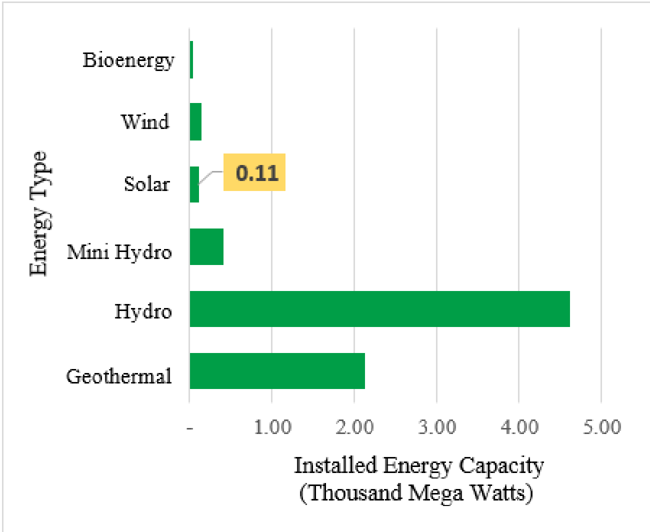
Fig 2. Earth's temperature (Indonesia) in 2021 (Source: NASA POWER | Data Access Viewer)

Ehsanul Kabir et al (2018) argue that nothing can match the potential of solar energy for the future, because theoretically it is very abundant and able to meet the world's electricity. It can be said that solar energy is not only sustainable, but renewable, it will never run out.

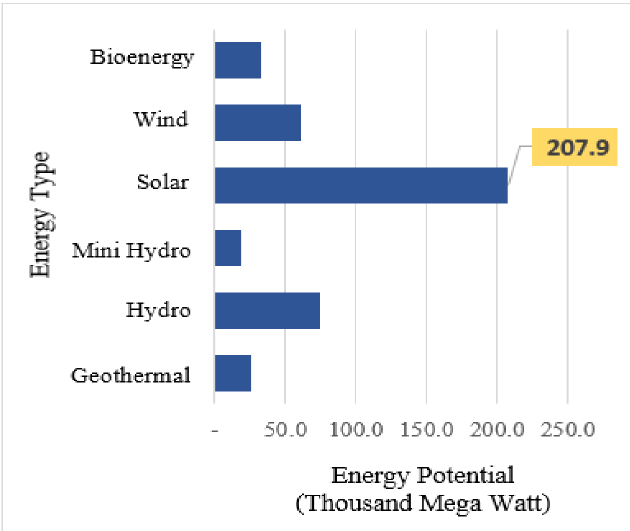
➢ *Energy and Technology Potential Analysis (Environmental Impact and CO_2 Emission Reduction Contribution)*

According to data presented by the National Energy Council (DEN, 2020), the utilization of energy from sunlight in Indonesia is around 110 MW spread throughout Indonesia.

Currently, the largest Solar Power Plants field in Indonesia is in Likupang, North Sulawesi Province with an area of 29 hectares. The Likupang Solar Power Plant can deliver 15 MWp of electricity (Mega Watt Peak) every day with an online grid system to support the electricity system of the Sulutgo PLN (North Sulawesi - Gorontalo) grid. This generating capacity generates electricity for about 15,000 households while reducing the effect of greenhouse gases by up to 20.01 kilo tons.



Graph 2: Installed Energy Capacity (DEN, 2020)



Graph 3: Energy Potential (DEN, 2020)

Given that Indonesia's main goal is to shift technology from fossil fuels (petroleum and coal) to low-emission energy, hydroelectric power plant (PLTA) and solar power plant (PLTS) can be the most superior alternatives. This is because the development costs for hydropower and solar power are cheaper than geothermal energy sources, bioenergy, and bioethanol (Boedoyo, 2021).

Moreover, the most implementable potential to encourage business actors in the field of solar energy is the large-scale application of state-built housing. Research conducted by Ehsanul Kabir et al (2018) regarding the development of solar energy can be related to what has been done by Nawshad Haque (2020) regarding LCA in Energy technology, including solar power.

LCA is one of the most up-to-date instruments in measuring the impact of a productivity or supply chain process. It can be said that LCA evaluates the costs and benefits of all cycles from upstream to downstream. Specifically, LCA examines each process or system in terms of environmental impact categories.

In using the LCA calculation, of course, one must follow the stages, namely determining the impact category, determining characteristics (indicators, models, and factors), determining classification, determining groups, and determining weights.

The use of solar energy technology has a positive impact on the environment with its potential to reduce the use of fossil fuels. However, even though solar power is an environmentally friendly energy source, it does not mean that there is no waste or emissions generated. Currently in the development of Solar Power Plant, the resulting environmental impact is related to the location of the Solar Power Plant installation, where if it is near an airport, solar panels may not use a glass cover because it can reflect light that can dazzle airplane pilots. The second is a very wide land use. For a capacity of 50 W peak, about 1 m^2 of land is required. Therefore, currently the use of SHS Rooftop and floating Solar Power Plants is one of the strategies in the development of Solar Power Plants.

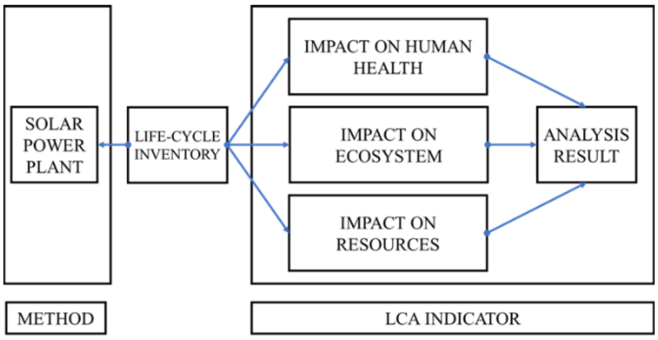


Fig 3. LCA assessment on solar power plant (PLTS) development (Source: modified from Nawshad Haque, 2020)

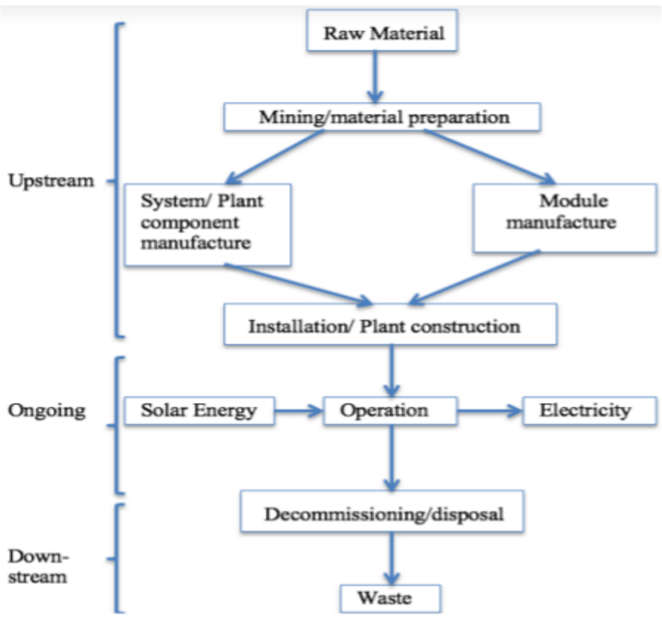


Fig 4: LCA Framework dengan konsep Upstream, Ongoing and Downstream (Ludin, 2017).

In Nawshad Haque (2020) LCA certainly doesn't only look at the time of its construction, but also looks at the impacts downstream or at the time of use.

In the life cycle inventory on solar energy, it can be described based on research conducted by Oktaviani et al (2020), described material and energy at each stage, starting from raw material acquisition, material processing, manufacturing, use, decommissioning, during treatment/disposal, and recycling.

Waste that may be generated from the use of Solar Power Plant is that generally VRLA batteries (dry batteries) have a short life and tend to be disposed of carelessly, so it is necessary to find a solution in the replacement schedule as well as in the application of better quality and longer-lived batteries.

The application of LCA to more technical energy can be seen from a study conducted by Ludin (2017) in the Asia Pacific Region. The LCA research is implemented in 3 stages, namely upstream, ongoing, and downstream as shown in Figure 4. More specifically, this LCA framework can also be used in the implementation of solar energy in Indonesia in several phases called the Cradle-to-Grave approach. The assessment is carried out in 5 phases, namely Manufacturing of Photovoltaic, System Construction, Transportation, Operation and Maintenance, and Dismantling and Disposal of course with assumptions and regional conditions.

At the manufacturing stage there are emissions produced into the air that need to be measured such as CO_2, Argon, SiC/CU slicer wire, micron powder residue, defect wafer, slurry fume, KOH dan Silane, Phosphorus/Boron, Heavy Metal. Furthermore, at the material transportation stage there are also emissions produced, but this is difficult to measure because it depends on the transportation equipment used. But in practice it will be visible and measurable. Emissions and waste that are clearly visible are CO_2, CO, and residual materials. At the construction stage, the biggest impact that needs to be measured is the solar panel pedestal, usually requiring a large area or on the roof of a building. The greatest concentration of impacts is land erosion and ecosystem damage. The next stage is during operation and maintenance, where waste that can be measured and assessed to have a major effect on the environment is the replacement of solar panel and battery parts which if not disposed of in a special place it will harm the environment.

The batteries used in solar energy installations are generally lithium-ion batteries, lithium polymers, and lithium sulfur (Oktaviani and Ulfa 2020). Lithium batteries have the highest energy efficiency compared to other batteries. Its performance at high temperature is also good. This battery can work at a voltage of 4 Volts with an energy range of 100-150 Wh/kg. Batteries contain nickel, cadmium, and mercuric oxide. This material is very dangerous if not disposed of in a special place (AMPL, 2008).

In Indonesia, the development of Solar Powerplant (PLTS) in various regions has not been optimal because the regulations regarding PLTS have not yet been discussed in parliament. However, before the regulation is finalized, it is necessary to analyze the steps that become operational standards in implementation, one of which is the LCA analysis. Thus, energy business actors know the financial burdens they will incur in implementation. Meanwhile, with the LCA, the government can calculate how much incentive will be given so that this Solar Powerplant can be realized.

IV. CONCLUSION AND POLICY IMPLICATIONS

Solar power technology is starting to be considered as a solution to answer the energy shift innovation and to meet the ever-increasing energy demand. Technology for the development of solar energy continues to improve with new innovations. In response to the planned 26th UN Climate Conference (COP26) target of limiting temperature rise to 1.5° Celsius, with more than 100 countries making net-zero commitments by 2050.

Globally, the use of solar energy still has great potential for developed, especially in Indonesia. Solar energy is not only sustainable, but renewable, it will never run out. In large-scale solar power plants, Indonesia greatly benefits from its location on the equator because it has a high level of solar radiation, including the provinces of West Sumatra, Riau, West Kalimantan, Central Kalimantan, East Kalimantan, Central Sulawesi, Maluku Islands with a total untapped potential of 207,900 MW. Apart from the equator, several areas that have high heat radiation are Jakarta, Semarang, Surabaya, and East Nusa Tenggara.

Moreover, currently there is also known LCA technology to evaluate any environmental impacts caused using solar energy. Recommendations that can be submitted in the development of the use of solar energy are consistent and integrated policies from the government regarding the development of new and renewable energy. The second is to introduce this high-tech product so that the public can be educated so that they can maintain it properly, the third is to encourage the use of solar powerplant (PLTS) by providing incentives to business actors engaged in solar energy and subsidies for people who use solar energy.

REFERENCES

[1]. Agency for the Assessment and Application of Technology-BPPT. (2021). Outlook Energi Indonesia. BPPT Indonesia.
[2]. Air Minum dan Penyehatan Lingkungan. (2008). Limbah Baterai Buang Ke Mana Ya?. http://www.ampl.or.id/. Jakarta. Indonesia
[3]. Central Bureau of Statistics-BPS. (2021). Indonesia Dalam Angka 2020. Jakarta. Indonesia.
[4]. Kopidakis, Nikos. (2020). National Renewable Energy Laboratory (NREL) 1976-2020. NREL Tranforming Energy. United State.
[5]. National Development Planning Agency - Bappenas/Kementerian PPN. (2021). Strategic Plan (Neraca Renstra) 2020-2024. Jakarta. Indonesia
[6]. National Energy Council-DEN. (2020). Indonesia's Energy Security. 2020. Jakarta, Indonesia.
[7]. Ekonomi Bisnis. (2021). This is the location of the largest solar panel field in Indonesia (Ini lokasi ladang panel surya terbesar di Indonesia).
[8]. https://ekonomi.bisnis.com/read/20200313/44/1212897/ini-lokasi-ladang-panel-surya-terbesar-di-indonesia). Indonesia
[9]. Haque, Nawshad. (2020). The Life Cycle Assessment of Various Energy Technologies. CSIRO Energy, Clayton, Vic, Australia.
[10]. Kabira, Ehsanul. Pawan Kumar, Sandeep Kumar, Adedeji A. Adelodun, Ki-Hyun Kim. (2018). Solar energy: Potential and prospects. Renewable and Sustainable Energy Reviews 82 (2018) 894–900.
[11]. Ludin, Norasikin Ahmad. (2017). Life Cycle Analysis (LCA) and Life Cycle Cost Analysis (LCCA) Framework of Photovoltaic Systems in the APEC Region. Solar Energy Research Institute (SERI). National University of Malaysia (UKM). Malaysia.
[12]. Ministry of Energy and Mineral Resources-KESDM. (2021). Research and Development Center for Electricity Technology, New Energy Resources and Energy Conversion. https://p3tkebt.esdm.go.id/esmart/. Jakarta. Indonesia
[13]. National Aeronautics and Space Administration (2021). Plotted from satellite data supplied by NASA Clouds and the Earth's Radiant Energy System (CERES).
[14]. Markandya, A,P Harou, L.G. Bellu, V. Cistulli (2002). Environmental Economics for Sustainable Growth: a Handbook for Practicioners. Cheltenham, UK: Edward Elgar.