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Literature Review

Literature Review: Solar Energy for Alternative Renewable Energy and Potential Application in Indonesia

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Abstract
Electrical energy has become a human need along with economic improvements and technological advances that require an unlimited supply of energy. Its nature is limited to fossil energy sources and also causes environmental pollution, so it is necessary to use renewable energy as another energy source to overcome this problem. Solar energy is freely available, is an environmentally friendly energy source whose application results have been proven and have promising prospects for the future. This paper presents the results of a research review on the use of solar energy as an alternative source of renewable energy, the basic concept of obtaining it and some results of using this energy. Next, we will briefly review the potential and use of solar energy sources in Indonesia. The high potential of solar energy in Indonesia needs to be processed and regulations that support the development of solar energy power plants as an alternative energy. Technically, solar photovoltaic energy has the potential to become an alternative energy source for the masses in the future as a substitute for fossil energy and to meet the electrical energy needs of remote areas.
Keywords: Renewable Energy, Solar Energy Power Plants, Alternative Energy, Remote Areas

Introduction
Global energy demand will continue to increase by 1.5% annually until 2030. This energy demand is usually used as electrical energy (Faisal & Martin, 2022) Energy demand is proportional to the increasing economic growth (Kannan & Vakeesan, 2016) Electricity production in general is still dominated by coal and will decrease from 2018 to 2050, but efforts to produce electricity from renewable energy will increase from 2018-2050 (Al Hakim, 2020). The increasing supply of fossil-based energy resources requires a continuous search for replacement resources (Khan et al., 2018). Conventional energy sources in practice have caused air pollution. Therefore, it is imperative to use environmentally friendly energy sources for the betterment of the world in the future. Considering renewable energy, energy sources such as solar energy, wind energy, hydropower, and geothermal, are very important as they are environmentally friendly energy sources. (Panwar et al., 2011).

Solar energy is the first solution scientists seek to overcome the global energy crisis (Shafiee & Topal, 2009). The most abundant energy source is renewable energy and solar radiation is 3.8x1023 kW, of which approximately 1.8x1014 kW is received by the earth (Panwar et al., 2011). Apart from that, this energy source is promising because it is inexhaustible, provides good and increased output efficiency compared to other energy sources (Nozik, 2003). Solar energy has always been a source that attracts the interest of scientists and engineers because of its availability at every point on the earth and is unlimited in total (Desideri et al., 2013). Solar energy at the equator, including Indonesia, is energy that can be managed and developed as an energy storage source where the sun shines throughout the year (Wullur et al., 2020). There are many remote areas in the world where electricity is not available, but solar radiation is abundant, so the use of solar energy to produce electricity in these areas is very possible (Demirbas, 2007). With many studies in an effort to utilize solar energy as an energy source, the Indonesian region which is located on the equator makes solar energy has great potential as a renewable energy to reduce dependence on conventional energy, especially for the Indonesian region.

Technology of Capture Solar Energy
Direct solar radiation as a renewable energy source is used in several renewable energy technologies, both solar photovoltaic (PV) power and solar thermal technology with various types of collectors used (Ali & Windarta, 2020). There are two main techniques that can be used to convert solar energy into electrical energy sources. The first technique is PV, where sunlight shines on panels made of semiconductor materials (Li et al., 2019) and the second technique is solar thermal technology (solar heat concentration), where solar energy is transferred into mechanical work through thermodynamic cycles and then converted into electricity (Desideri et al., 2013) Concentrated solar thermal power (CSP) and concentrated photovoltaic technology (CVT) are commonly used to capture solar energy by converting solar energy into electricity (Kannan & Vakeesan, 2016).

Photovoltaics Technology (PV)

Solar cell or photovoltaic cell, is a a semiconductor device that has a large surface area and consists of a series of p-type diodes and n, which converts solar energy directly into electrical energy (Kholiq, 2015). The photovoltaic (PV) effect is the basis for the conversion of light into electricity (Parida et al., 2011). Photovoltaic technology is used to convert sunlight into electricity directly. This technology has the ability to provide greater output from smaller input (Kannan & Vakeesan, 2016). There are four types of PV installations: centralized grid-tied (large power plants), distribution grid-tied (roof/ground-mounted small installations), off-grid commercial (power plants and industrial installations in remote areas), and off-grid (mainly stand-alone roof/ground based systems for homes and isolated applications) (Desideri et al., 2013)

Solar cells require light-absorbing materials in the cell structure to absorb photons and produce free electrons through the photovoltaic effect (Hidayat, 2013). Solar cells convert the energy of sunlight photons into electricity through the photoelectric phenomenon of semiconductor materials such as silicon and selenium (Mekhilef et al., 2011). Monocrystalline silicon, polycrystalline silicon, microcrystalline silicon, copper indium diselenide and cadmium telluride are commonly used as semiconductors in photovoltaic systems. This semiconductor material is used to induce electricity (Kannan & Vakeesan, 2016). Solar PV modules are solid-state semiconductor devices that convert sunlight into direct current electricity (Razykov et al., 2011)

The working principle of semiconductors as photovoltaic cells is similar to diodes as pn-junctions. (Assiddiq et al., 2018). The working principle of the device is to activate electrons by providing a potential difference. This device works on the principle that electrons are activated from a lower energy state to a higher energy state under the influence of sunlight. This activation will produce holes and free electrons that will fill the semiconductor, thus producing electricity (Green, 2002). Solar energy, when it hits a PV cell, provides enough energy to some electrons (negatively charged atomic particles) to increase their energy level. The potential barrier present in the cell acts on these electrons to produce a voltage, which in turn is used to drive current through the cell circuit. The PV system has a quantity in peak Kilowatts (kWp) which is the amount of electrical power supplied by the PV system when the sun is present on a clear day (Parida et al., 2011).

PV systems consist of many components such as cells, modules and arrays to generate power. In addition, various means of organizing and controlling structures, electronic devices, electrical connections and mechanical devices are used for operations (Kannan & Vakeesan, 2016). Developed PV panels can operate for up to 10 years at 90% capacity and 25 years at 80% capacity (Devabhaktuni et al., 2013). However, the system still needs to be improved to produce better output, due to the inconsistency of the solar energy produced, the development of sunlight as an energy source has been carried out with a hybrid electricity system (Parida et al., 2011).

Photovoltaic devices as stand-alone systems produce output from microwatts to megawatts. A solar module or photovoltaic system with a capacity of 50 Wp provides an electrical energy output of 200 Wh/day so that a solar module with this capacity is able to meet electricity consumption needs and has the potential to become an alternative energy source (Gultom, 2015). From the report results, in 2013 a significant increase of around 39% occurred in solar panels (Kannan & Vakeesan, 2016). photovoltaics is one of the fastest growing industries worldwide and in order to maintain this growth rateneed for new developments with respect to material use and consumption, device design, reliability and production technologies as well as new concepts to increase the overall efficiency arises (Jäger-Waldau, 2006). This means that PV systems have been improved for household scale needs so that they have the potential to be used as an alternative energy source to replace fossil fuels.

Concentrated Solar Power (CSP)

A solar thermal electric power system is a device that utilizes solar radiation to generate electricity through solar heat conversion with the basic principle being that collected solar energy is converted into electricity (Mills, 2004). PV/T which is a combination of PV components and solar heat to produce electricity and heat from one integrated system (Li et al., 2019).

Solar collectors convert solar radiation energy into heat energy through which fluids (water, air, glycol, oil, etc.) pass through are the key to PV/T systems. The collected energy can then be used to heat a room or water, produce steam, or stored in thermal storage (Kumar & Rosen, 2011). This CSP or PV/T technology uses mirrors to reflect and concentrate sunlight onto the receiver. Energy from concentrated sunlight heats a high-temperature fluid inside the receiver. This heat is known as energy that can be used to spin turbines or drive machines to produce electricity. These utility-scale CSP plants can be configured in a variety of ways. It can be used in a variety of industrial applications, such as water desalination, enhanced oil recovery, food processing, chemical production, and mineral processing (Solar Energy Technologies Office, n.d.).

Concentrated solar power known as solar thermal energy, involves heating a working fluid using concentrated sunlight. The heated fluid can then be used with conventional power generation equipment (Powell et al., 2017). Solar thermal energy operates with a low maximum temperature (generally lower than 120 C), used for sanitary hot water production, for swimming pools or space heating. To be used in electric power generation, solar thermal technology must operate at medium (around 400–500 C) or high temperatures (around 1000 C) (Desideri et al., 2013).

Solar Radiation Collector

The heating temperature and effectiveness of solar energy utilization can be achieved higher by using a heat collector, namely a solar energy collector. Sunlight that falls on the surface of the collector is concentrated/focused on a certain point or object so that a very high temperature is obtained (Wullur et al., 2020). Linear concentrated solar power collectors capture solar energy with large mirrors that reflect and focus solar energy into a linear receiver tube. This system uses a parabolic, through-shaped mirror to thermally focus solar energy on a receiver tube containing a heat transfer fluid. This fluid is heated to a temperature of about 390 1C (734 1F) and pumped through a series of heat exchangers to produce superheated steam that drives a conventional turbine generator to produce electricity (Devabhaktuni et al., 2013). The CSP system can be used to overcome temperatures dropping to very low at night or when the sun is not shining, with this system high temperatures can reach above 350°C during the day using parabolic troughs (Li et al., 2019).

Other forms of collectors that have recently been developed are electricity towers and parabolic/machine antenna type CSP systems. Electric towers consist of an array of relatively small flat glass mirrors placed around a receiver (solar boiler) that convert the received light into heat (Devabhaktuni et al., 2013). The power tower system arranges mirrors around a central tower that acts as a receiver. A linear system has an array of mirrors that concentrate sunlight onto parallel tube receivers placed above them. Smaller CSP systems can be placed directly where power is needed. For example, a single dish/engine system can produce 5 to 25 kilowatts of power per dish and be used in distributed applications (Solar Energy Technologies Office, n.d.). The cost of producing electricity through solar energy is much higher than conventional power plants but the advantage is that solar power plants releases almost zero carbon (Panwar et al., 2011).

Efforts to Increase Solar Energy Efficiency

The electrical efficiency of photovoltaic modules is influenced based on module construction and climate parameters, such as solar radiation, packing factors and module temperature. The efficiency of a PV cell increases with solar irradiance, as the greater number of photons associated with higher solar irradiance creates more electron-hole pairs and consequently more current into the photovoltaic cell. PV efficiency decreases as PV temperature increases, mainly because higher cell temperatures decrease their voltage significantly (although their current increases by a very small amount). The PV packing factor, defined as the fraction of the absorber area occupied by a photovoltaic cell, significantly influences the electrical output. A higher packing factor will increase the electrical output per unit area of the collector, but also increase the module temperature (Kumar & Rosen., 2011).

Solar Energy Tracking

The source of solar radiation energy is inconsistent because it is influenced by the amount of use, environmental conditions, especially the intensity of sunlight so that this PV system is sometimes inefficient in capturing the available energy so that fluctuations in solar flux cannot be planned for longer periods. To get maximum energy from sunlight. Methods that can be used include concentrated solar thermal power and concentrated photovoltaic technology (CVT) (Wullur et al., 2020). Solar tracking is a general concept used to improve the capture of available solar energy (Helwa et al., 2000). Dish Stirling is a 25 kW solar power system that has been designed to automatically track the sun and focus the sun's heat into a power conversion unit (PCU). The concentrator consists of a 38-foot diameter disk structure supporting 82 curved glass mirror sides, each measuring three feet by 4 feet. These mirrors concentrate solar energy into the heating heads of a high-efficiency, four-cylinder, reciprocating Stirling cycle engine producing up to 25 kW of electricity per system (Devabhaktuni et al., 2013). Usage Real Time Clock (RTC) and Arduino applied to the solar panel tracking system to increase the absorption of solar energy with sample results for 10 days obtained that the solar panel with a capacity of 10 Wp in the tracking system is 35,392 Wh, while the non-tracking solar panel produces a total energy of 19,658 Wh. The difference between the two is 15,732 Wh. Thus demonstrating the effectiveness of solar tracking in maximizing energy collection in tropical regions such as Indonesia (Sibarani et al., 2022). By tracking the sun, the position of the sun will be obtained so that maximum energy will be obtained.

Materials for Efficient Light Absorption

The selection of materials in the PV system as light absorbers is used so that the maximum amount of solar energy can be used. Therefore, using efficient light absorption materials is very important to produce as much solar power as possible from the variety of solar power available. Such materials are present in the cell structure to absorb photons and generate free electrons through photovoltaic effects. This is the basis of the conversion of light into electricity in solar cells (Kannan & Vakeesan, 2016). There has been a lot of research using silicon or cadmium to obtain high efficiency in solar energy. Silicon technology is becoming dominant for the supply of power modules into cation photovoltaic applications and the possibility of multi-crystalline silicon and monocrystalline silicon being used for high efficiency solar cells (Bruton, 2002). Crystalline silicon offers increased efficiency when compared to amorphous silicon having an efficiency of around 14–19% (Parida et al., 2011).

Thin film solar cells are essentially a layer of semiconductor applied to a solid support material. The presence of ultrathin films reduces the amount of semiconductor material required for each cell. Gallium arsenide (GaAs), copper, Cadmium telluride (CdTe), indium diselenide (CuInSe2) and titanium dioxide (TiO2) are materials that are widely used for thin film PV cells (Parida et al., 2011). Solar cells utilizing thin-film polycrystalline silicon can achieve photovoltaic power conversion efficiencies greater than 19% as a result of light trapping and back surface passivation with optimum silicon thickness (Ford et al., 1999).

Hybrid PV System

One solution to the inconsistency of solar energy sources is to use a hybrid PV system. Hybrid PV is a combination with other energy sources. PV systems are combined with other forms of electricity generation, usually diesel-powered generators or even hydroelectric turbines or wind turbines for reduced use of fossil fuels and consistent electricity supply (Parida et al., 2011). Hybrid systems can be positively combined to create a consistent energy supply system so that there is no interruption in daily activities. Different collector configurations and module arrangements have also been investigated to produce good throughput. It has been proven that 50 percent efficiency is obtained when combining PV collectors (Kannan & Vakeesan, 2016). Hybrid solar-geothermal power plants have great potential, with important economic benefits, for the Australian geology with its unique climatic conditions (Zhou et al., 2013). A hybrid system is a solution to increase power to achieve capacity so as to reduce carbon production (Sawle et al., 2016)

Storage Systems

CSP systems can be specifically integrated with storage systems that can use solar energy after sunset or may also be used in hybrid operations with fossil fuels, thus allowing electricity generation regardless of the presence of the sun (Desideri et al., 2013). Utilizing solar heat as an energy source in CSP makes low-cost energy storage feasible because heat can be easily stored with Thermal Energy Storage (TES) (Powell et al., 2017). A widely used electricity storage method is electrochemical battery storage. Proposed based on gel electrolytes, Valve-Regulated Lead-Acid (VRLA) batteries represent the most suitable solution to provide advanced batteries for solar energy (Lambert et al., 2000).

The distribution of solar radiation and its intensity are two key factors that determine the efficiency of solar PV. These two parameters vary greatly in each country (Kannan & Vakeesan, 2016). The efficiency of solar cells depends on temperature, insolation, spectral characteristics of sunlight and so on. Currently, the efficiency of photovoltaic cells is around 12-19% under the most promising conditions (Mekhilef et al., 2011). A long amount of research has been done on PV devices to increase their efficiency and it is important to note that it is now said to be a fast growing industry and is doubling its production growth every two years with an average increase of 48% since 2002 (Kannan & Vakeesan, 2016).

Applications

There are various applications of solar energy due to its free nature available with a low level of environmental damage. This section of the paper briefly describes the applications that currently exist and will continue to develop for a better future.

Building Integrated Photovoltaic (BIPVs)

Building Integrated Photovoltaic Systems (BIPVs) are one example of concentrated photovoltaic technology (CVT). Integrated photovoltaics for energy consumption for households in areas where there is no installed power grid. The solar energy produced is also entered into the system to store the resulting excess energy. This helps deliver electricity to these areas with little or no emissions (Kannan & Vakeesan, 2016).

Heating, Cooling and Drying

Flat plate and evacuated solar tube heating and cooling systems are now commonly used to facilitate commercial and residential sectors, water and air solar heating systems (Devabhaktuni et al., 2013). A cooling system is used in the agricultural sector to store agricultural products to avoid unwanted damage. Solar thermal refrigerators are now becoming popular in the agricultural sector, which are divided into sorption refrigerators, and solar thermal mechanical refrigerators with certain configurations (Kannan & Vakeesan, 2016). Solar dryers are able to protect grain and fruit, dry more quickly and evenly, and produce better quality products than open methods (Devabhaktuni et al., 2013).

Solar Energy for Green Houses

Solar greenhouses utilize solar energy for both heating and lighting. A greenhouse is a structure commonly used in agriculture to grow plants with intensive care for better production. This system is able to retain heat well at night and on cloudy days (Kannan & Vakeesan, 2016). This will greatly reduce the need to use fossil fuels for heating.

Solar Energy Systems may be much cheaper than installing power lines and step-down transformers in applications such as electricity, fencing and lighting. PV water pumping systems for agriculture or livestock are the most cost-effective water pumping option in locations where there is no electricity grid (Devabhaktuni et al., 2013). Solar energy is further useful for charging many electronic devices used in places where plug-in electricity is not available (Kannan & Vakeesan, 2016).

Remote Electricity Supply and Micro-Scale Applications

Integrated micro power generation solutions will eliminate the problem of needing to connect low-power systems to an AC power source for primary electrical power or for recharging or replacing and disposing of batteries (Devabhaktuni et al., 2013). PV integration for Reverse Osmosis (RO) is used in salt desalination where PV panels supply electricity to the desalination plant (Kershman et al., 2002). Examines efforts to optimize energy consumption with DHT22 and LDR (Light Dependent Resistor) sensors as a smart energy management system on fans by controlling lighting and cooling automatically based on environmental conditions. The use of this sensor helps in more efficient and automatic energy management, such as turning on or off the fan based on the room temperature. The results of the application of DHT22 and LDR sensors show that the system can reduce energy consumption according to the calculated needs (Akmal 2024).

Progress Solar Power Systems in Indonesia

Government Regulation PP No 79 of 2014 about Konsentrasi Energi Nasional (KEN) provides direction regarding national energy management in order to realize Energy Independence and National Energy Resilience to support sustainable national development. One type of renewable energy is solar energy. The main advantage of developing solar energy in Indonesia is of course its excellent potential, namely an average of 4.8 kWh/m2 (Samsurizal et al., 2020). The potential for solar energy in Indonesia reaches 207.8 Gigawatts with the distribution of radiation for the western region of Indonesia amounting to 4.5 kWh/m2.day. Monthly variations are about 10%. For the eastern region of Indonesia, it is 5.1 kWh/m2.day with a monthly variation of 9% (Bayu & Windarta, 2021). Indonesia plans that in 2015 the capacity of electricity generation sourced from solar energy will reach 296 Gigawatts (Al Hakim, 2020).

Solar Energy Stove

Designing a portable solar energy stove with a parabolic collector for the Papua region that has cooking power results that meet the standards with the highest temperature produced at 85 ^{O}C (Dwicaksono & Rangkuti, 2018). Usage aluminum foil as a reflector with a parabolic collector obtained maximum furnace efficiency on a solar stove of 66.7%, where heat loss was caused by convective heat transfer from the pot to the surrounding air (Wullur et al., 2020). The creation of a box-type solar cooker for boiling water in a pot in Bone Bolango, Gorontalo, and found significant variations in performance that occurred due to factors such as changes in weather conditions or the position of the cooker. (Ahmadi et al., 2023). Comparison of reflectors that are also collectors for solar energy cookers made of zinc (aluminum and galvanized) AL-Zn and mirror glass back ground black paint, it was found that mirror glass material back ground black paint is better to use compared to AL-Zn zinc plate. Reflector raw materials and reflector materials with black paint back ground mirror glass material produce better efficiency (Napitupulu et al., 2022). The best reflector shape is a parabolic reflector to produce optimal solar cooker performance and research results that show the efficiency of parabolic solar cookers with mirror reflectors that reach 76.30% (Sari et al.,2024).

Solar Energy Power Plant

Data collected on the potential of solar radiation in 34 provinces in Indonesia that the installation of solar power plants is feasible / can be implemented in all provinces in Indonesia, this is because the results showed that the city of Banda Aceh is a province with the lowest potential solar radiation has a potential of 4.12 kwh / m2 /day, which is 3.12 kwh / m2 /day greater than the Standard Test Condition (STC) value of solar modules conducted in the laboratory (Hutajulu et al., 2022). Furthermore, research on the potential of solar power plants in Indonesia integrated with the grid interconnection system by taking into account the peak load and load of each province, obtained the highest results in South Sulawesi Province with a potential solar power plant capacity of 435 MW, while the lowest generating capacity in Bali Province is 0.29 MW (Fathoni et al., 2014). The solar power plant built in Toalang Hamlet is a centralized solar power plant which is an Off Grid system with a capacity of 21.84 kWp, a load of 55,758 Wh/day and has a peak solar radiation that meets the required standards, namely 4 hours/day so that the area is suitable for use. construction of a Solar Power Plant (Samsurizal et al., 2020). The battery capacity of 24.875 Ah with charging carried out from 10:00 WIB to 16:00 WIB on the application of solar energy to drive a DC motor on a rice thresher system in Medan found that this tool is able to produce a capacity of up to 100 kg / hour, which is twice as much as compared to traditional rice threshers so that this solution is feasible as an effort to increase agricultural productivity in Indonesia (Sitepu et al., 2021)

The realization of solar power plants in 2020 reached 0.15 GWp of the total solar energy potential in Indonesia, namely 207.8 GWp (Faisal & Martin, 2022), until the end of 2021 the installed capacity of Indonesia's solar power plants has only reached 200.1 Mega Watt (MW) and as many as 31 companies have declared to build solar power plants with a total capacity of 2.3 GW in 2022 and 2023, as well as plans to build a supporting component factory for solar power plants in Indonesia (Abdila, 2022). The existence of new policies and/or regulations related to the development of new renewable energy power plants is very necessary to provide a friendlier investment climate for potential investors. This is so that the development of solar power plants in Indonesia runs according to target and is able to compete with plants that use fossil primary energy sources as fuel (Bayu & Windarta, 2021).

Hybrid Solar Energy

The results of designing a hybrid power plant (Solar-Wind) as a source of abundant electrical energy in the coastal area of Jepara whose existence is proven to save electricity costs (Safrizal et al, 2022). Calculation of energy costs obtained from the 74.8kWp Hybrid power plant on the island of Kawaluso Island, North Sulawesi, obtained a positive Net Present Value NPV value then with a hybrid solar power plant with a capacity of 84.3kWp NPV is positive so that the project is feasible to run. Payback period for 74.8 KWP hybrid solar power plant takes 3 years 2 months and 8 years 1 month for 84.3 KWP capacity solar power plant (Amba & Dalimi, 2023). Calculation of investment feasibility and economic studies on solar power plant and hybrid solar power plant using HOMER software in Dosay Village, West Sentani District, Jayapura Regency, Papua found that the data in the field can meet the needs of electrical energy in achieving the Electrification Ratio (RE) and towards the Energy Independent Village (DME). However, the assumptions of investment feasibility and economic studies using the Net Present Value (NPV), Profitability Index (PI) and Discounted Payback period (DPP) methods for Microhydro Power Plants are acceptable, but for solar power plants are not acceptable (Putra et al., 2023). Results from research studies indicate that renewable energy, such as solar energy and wind energy, will play an important role in the supply system of major energy sources to meet the needs of the growing world economy in the future (N.S. et al., 2022).

The Other Side of Solar Energy

There are several obstacles such as weather dependency, high initial costs, and issues related to efficiency and material disposal in the application of renewable energy sources. The fundamental challenges faced are cost, manufacturing, testing procedures, and waste products. Electricity generation using solar energy sources is weather-dependent and generation trends cannot be fully predicted. Therefore, solar energy sources should be operated together in a hybrid way. Indirect impact on the environment. For example, there are some toxic materials and chemicals, as well as various solvents and alcohols used in the manufacturing process of PV cells. In addition, large solar thermal power plants can disrupt environmental ecosystems if not managed properly. Birds and insects can be killed if they fly into the intense sunlight. CSP also uses potentially hazardous fluids (to transfer heat) that require proper handling and disposal. Water pollution can occur from water sis to clean concentrators and receivers regularly and for cooling the turbine-generators (Devabhaktuni et al., 2013). The obstacles faced in implementing solar power plant in Indonesia are the high investment costs, the main solar power plant equipment, namely photovoltaic modules, are still imported from other countries and the efficiency of photovoltaic modules is only 16%, which causes the price of solar power plant per kW to still be very high (Soelistio, 2016). The costs are still considered very expensive, so it is necessary for the world of education to continue to carry out research and collaborate with the industrial world so that solar cell and wind turbine parts can be produced that are affordable for the public (Safrizal et al., 2022). The use of renewable energy sources should be adapted to the potential of existing resources in a region with a system for calculating costs and environmental impacts in order to obtain a high level of efficiency. The LEAP (Long-range Energy Alternatives Planning System) model is a system used to model and analyze energy demand and the impacts of energy policy. It combines accounting and simulation approaches to create an energy framework model that considers costs and environmental impacts. LEAP can be used to evaluate various energy scenarios and their impact on the energy system, costs, and social effects arising from specific energy choices.(Nugraha & Irwanto, 2022)

Conclusions

The demand for renewable energy sources is the main solution in meeting the world's energy requirements. One of the renewable energy sources that has promising prospects is solar energy. There have been many research results and activity reports related to the utilization of radiant energy, be it energy capture technology, absorber materials, storage systems to efficiency calculations to applications from the use of solar energy show that the progress of this technology continues to develop. The application of solar energy has been carried out a lot to prove that solar energy as an alternative energy to meet the supply needs of the main energy source to meet the needs of the growing world economy. Indonesia's area on the equator is the main advantage of solar energy as a promising alternative energy source. The high potential of solar energy in Indonesia needs to be processed and requires regulations that support the development of solar power plants as alternative energy. Challenges in the use of solar energy in Indonesia are manufacturing and start-up costs. The use of solar energy must be synchronized with the potential resources available in a region with a system of calculating costs and environmental impacts in order to obtain a high level of efficiency. Technically, solar photovoltaic energy has the potential to become an alternative energy source for the public in the future as a substitute for fossil energy and to provide electricity in remote areas of Indonesia.

References

Abdila, R. (2022). Potensi Energi Surya Indonesia Capai 207,8 Giga Watt, Kapasitas Terpasang Baru 200,1 Mega Watt. *Tribunnews.Com*.

Ahmadi, H., Made Hermanto, I., Samatowa, L., Rahman, I., Doholio, D. A., & Jau, S. (2023). Studi Eksperimental Penggunaan Kompor Surya Tipe Box Berbasis Energi Matahari Di Kabupaten Bone Bolango: Kinerja Dan Potensi Pemanfaatan Energi Terbarukan. *Jurnal Normalita*, *11*(3), 510–515.

Akmal, S., Meliala, S., Amani, Y., & Jalil, S. M. (2024). Solar Energy Management in Electricity Load Application of Household Room Based on IoT. *Journal of Renewable Energy, Electrical, and Computer Engineering*, *4*(1), 1–9. https://doi.org/10.29103/jreece.v4i1.13425

Al Hakim, R. (2020). Model Energi Indonesia, Tinjauan Potensi Energi Terbarukan Untuk Ketahanan Energi di Indonesia:Literature Review. *Andasih*, *1*(1), 1–11.

Ali, M., & Windarta, J. (2020). Pemanfaatan Energi Matahari Sebagai Energi Bersih yang Ramah Lingkungan. *Jurnal Energi Baru & Terbarukan*, *1*(2), 68–77.

Amba, M. I., & Dalimi, R. (2023). Economic Analysis of Hybrid Power Plant (Solar-Diesel) on Kawaluso Island, North Sulawesi. *Jurnal EECCIS*, *17*(1), 13–21.

Assiddiq, H., Dinahkandy, I., Jurusan,), Mesin, T., Kotabaru, P., Raya, J., Km, S., & Selatan, K. K. (2018). Studi Pemanfaatan Energi Matahari Sebagai Sumber Energi Alternatif Terbarukan Berbasis Sel Fotovoltaik Untuk Rumah Sederhana Di Daerah Terpencil. *Jurnal Teknik Mesin UNISKA*, *3*(2), 88–93.

Bayu, H., & Windarta, J. (2021). Tinjauan Kebijakan dan Regulasi Pengembangan PLTS di Indonesia. *Jurnal Energi Baru Dan Terbarukan*, *2*(3), 123–132.

Demirbas, M. F. (2007). Electricity Production Using Solar Energy. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *29*(6), 563–569.

Desideri, U., Zepparelli, F., Morettini, V., & Garroni, E. (2013). Comparative Analysis of Concentrating Solar Power and Photovoltaic Technologies: Technical and Environmental Evaluations. *Applied Energy*, *102*, 765–784.

Devabhaktuni, V., Alam, M., Shekara Sreenadh Reddy Depuru, S., Green, R. C., Nims, D., & Near, C. (2013). Solar Energy: Trends and Enabling Technologies. In *Renewable and Sustainable Energy Reviews, 19*, 555–564.

Dwicaksono, M. B., & Rangkuti, C. (2018). Perancangan, Pembuatan dan Pengujian Kompor Energi Matahari Potabel Tipe Parabola Kipas. *Jurnal Penelitian Dan Karya Ilmiah Lembaga Penelitian Universiats Trisakti*, *3*(2), 37–44.

Faisal, A., & Martin, A. (2022). Tinjauan Potensi dan Kebijakan Energi Surya di Indonesia. *Jurnal Engine: Energi, Manufaktur, Dan Material* , *6*(1), 43–52.

Fathoni, A. M., Utama, N. A., & Kristianto, M. A. (2014). A Technical and Economic Potential of Solar Energy Application with Feed-in Tariff Policy in Indonesia. *Procedia Environmental Sciences*, *20*, 89–96.

Ford, D. H., Rand, J. A., Delledonne, E. J., Ingram, A. E., Bisaillon, J. C., Feyock, B. W., Mauk, M. G., Hall, R. B., & Barnett, A. M. (1999). Briefs High Current, Thin Silicon-on-Ceramic Solar Cell. In *IEEE TRANSACTIONS ON ELECTRON DEVICES*, 46(10), 2162-2164.

Green, M. A. (2002). Photovoltaic Principles. *Physica E*, *14*, 11–17.

Gultom, T. T. (2015). Pemanfaatan Photovoltaik Sebagai Pembangkit Listrik Tenaga Surya. *Jurnal Mundira Indure*, *1*(3), 33–42.

Helwa, N. H., Bahgat, A. B. G., El Shafee, A. M. R., & El Shenawy, E. T. (2000). Maximum Collectable Solar Energy by Different Solar Tracking Systems. *Energy Sources*, *22*(1), 23–34.

Hutajulu, O. Y., Siregar, B. M., & Mendoza, M. D. (2022). Studi Kelayakan Potensi Penyinaran Matahari 34 Propinsi di Indonesia Untuk Pembangkit Listrik Skala Rumah Tangga. *Jurnal Insinyur Profesional*, *2*(1), 9–15.

Jäger-Waldau, A. (2006). European Photovoltaics in World Wide Comparison. *Journal of Non-Crystalline Solids*, *352*, 1922–1927.

Kannan, N., & Vakeesan, D. (2016). Solar Energy for Future World: - A Review. *Renewable and Sustainable Energy Reviews*, *62*, 1092–1105.

Kershman, S. A., Rheinlander, J., & Gabler, H. (2002). Seawater Reverse Osmosis Powered Tom Renewable Energy Sources-Hybrid Wind/Photovoltaic/Grid Power Supply for Small-Scale Desalination in Libya. *DESALINATION* , *153*, 17–23.

Khan, F. A., Pal, N., & Saeed, S. H. (2018). Review of Solar Photovoltaic and Wind Hybrid Energy Systems For Sizing Strategies Optimization Techniques and Cost Analysis Methodologies. In *Renewable and Sustainable Energy Reviews* , *92*, 937–947.

Kholiq, I. (2015). Pemanfaatan energi Alternatif Sebagai Energi Terbarukan Untuk Mendukung Substitusi BBM. *Jurnal IPTEK*, *19*(2), 75–91.

Kumar, R., & Rosen, M. A. (2011). A Critical Review of Photovoltaic-Thermal Solar Collectors for Air Heating. In *Applied Energy*, *88* (11), 3603–3614.

Lambert, D. W. H., Holland, R., & Crawley, K. (2000). Appropriate battery technology for a new, rechargeable, micro-solar lantern. *Journal of Power Sources*, *88*, 108–114.

Li, K., Liu, C., Jiang, S., & Chen, Y. (2019). Review on Hybrid Geothermal and Solar Power Systems. *Journal of Cleaner Production*, *19*.

Mekhilef, S., Saidur, R., & Safari, A. (2011). A Review on Solar Energy Use in Industries. In *Renewable and Sustainable Energy Reviews*, *15*(4), 1777–1790.

Mills, D. (2004). Advances In Solar Thermal Electricity Technology. *Solar Energy*, *76*, 19–31.

N.S., M., N.A., G., & G.A., A. (2022). Role of Renewable Energy Sources in the World. *Journal of Renewable Energy, Electrical, and Computer Engineering*, *2*(2), 63. https://doi.org/10.29103/jreece.v2i2.8779

Napitupulu, R. A. M., Manurung, C. S. P., & Naibaho, W. (2022). Pengaruh Material Reflektor Terhadap Kinerja Kompor Energi Surya. *Jurnal Of Mechanical Engginering*, *3*(2), 94–105.

Nozik, A. J. (2003). Photoelectrochemistry Applications to Solar Energy Conversion. *Annual Review of Physical Chemistry*, *29*(1), 189–222.

Nugraha, Y. T., & Irwanto, M. (2022). Modelling Demand for Energy Sources as Alternative Energy in the Province of North Sumatra. *Journal of Renewable Energy, Electrical, and Computer Engineering*, *2*(2), 84. https://doi.org/10.29103/jreece.v2i2.9278

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in environmental protection: A review. In *Renewable and Sustainable Energy Reviews*, *15*(3), 1513–1524.

Parida, B., Iniyan, S., & Goic, R. (2011). A review of solar photovoltaic technologies. In *Renewable and Sustainable Energy Reviews, 15*(3), 1625–1636.

Powell, K. M., Rashid, K., Ellingwood, K., Tuttle, J., Iverson, B. D., Powell, K. M., Rashid, K., Iverson, &, Powell, K. M. ;, Rashid, K. ;, Ellingwood, K. ;, Tuttle, J. ;, & Hybrid, ". (2017). Hybrid Concentrated Solar Thermal Power Systems: A Review. *BYU ScholarsArchive*, *80*, 215–237.

Putra, B. R., Kariongan, J., Aryo, J., Bay, P. B., Liga, M., Sinaga, A. S., Wuri, D. T., Disetujui, ;, & Abstrak, P. B. B. (2023). Perancangan Pembangkit Listrik Tenaga Hybrid (Photovoltaic-Mikrohidro) Menuju Desa Mandiri Energi Di Kampung Dosay, Distrik Sentani Barat, Kabupaten Jayapura, Papua. *Teletronic*, *1*(1), 1–11.

Safrizal, Muhammad, G., Azizah, N., Darmoto, Ariyanto, D., & Amelia, V. R. (2022). Program Kemitraan Masyarakat Inovasi Reserve Energy Hybrid (Wind Turbine, Solar Cell Dan Generator) Di Pemerintah Desa Tegal Sambi Kabupaten Jepara. *Indonsian Collaboration Journal of Community Servises*, *2*(3), 187–192.

Samsurizal, Christiono, & Husada, H. (2020). Studi Kalayakan Pemanfaatan Energi Matahari... *Jurnal Ilmiah Setrum*, *9*(1), 75–83.

Sari, L. K., Munawwir, Z., & Umamah, C. (2024). Efficiency of Solar Cookers with Different Geometric Shapes Over the Last Decade: A Comprehensive Review. *Journal of Renewable Energy, Electrical, and Computer Engineering*, *4*(1), 32–41. https://doi.org/10.29103/jreece.v4i1.13764

Sawle, Y., Gupta, S. C., & Bohre, A. K. (2016). PV-Wind Hybrid System: A Review with Case Study. *Cogent Engineering*, *3*(1), 1–31.

Shafiee, S., & Topal, E. (2009). When will fossil fuel reserves be diminished? *Energy Policy*, *37*(1), 181–189.

Sibarani, E. S., Maizana, D., Mungkin, M., Isa, M., & Pandey, G. P. (2022). Design and development of 10 WP Solar panel tracking system based on RTC and Arduino. *Journal of Renewable Energy, Electrical, and Computer Engineering*, *2*(2), 55. https://doi.org/10.29103/jreece.v2i2.8568

Sitepu, T., Malau, A. T., Cholish, & Abdullah. (2021). Design and Build Solar Panels as Source Rice Thresher Motor Energy.

Journal of Renewable Energy, Electrical, and Computer Engineering, *1*(2), 58. https://doi.org/10.29103/jreece.v1i2.5233
Soelistio, A. T. (2016). *Paper Pembangkit Listrik Tenaga Surya (PLTS)*.
Solar Energy Technologies Office. (n.d.). *Concentrating Solar-Thermal Power Basics*. U.S. DEPARTEMENT OF ENERGY. Retrieved 2 March 2024, from https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics
Wullur, C. W., Sahupala, P., & Pareden, D. (2020). Penggunaan Kompor Energi Matahari Untuk Rumah Tangga. *MUSTEK ANIM HA*, *9*(1), 1–6.