

Analysis of Renewable Energy Potential in South Sulawesi, Indonesia

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ABSTRACT

South Sulawesi, a province of Indonesia faces challenges in electricity distribution due to its geographic diversity. To mitigate this, the local government currently relies on diesel power plants, which are both non-renewable. This study investigates the feasibility of renewable energy sources as alternatives to meet the region's electricity needs. Data collection from previous articles on renewable energy potential in South Sulawesi forms the basis of analysis. The study focuses on solar thermal, photovoltaic (PV), wind power, biomass, and hydropower systems, assessing their potentials. Solar thermal and PV systems exhibit promising electricity generation capacities due to the region's high irradiation levels. Wind power and biomass systems demonstrate moderate potential, while hydropower offers significant generation capabilities. The study concludes that transitioning to renewable energy is essential for combating pollution and improving public health, though financial incentives favoring non-renewable sources pose a challenge.

ABSTRAK

Sulawesi Selatan, sebuah provinsi di Indonesia menghadapi tantangan dalam distribusi listrik karena keberagaman geografisnya. Untuk mengatasi hal ini, pemerintah lokal saat ini mengandalkan pembangkit listrik tenaga diesel, yang bersifat tidak terbarukan. Studi ini menyelidiki kelayakan sumber energi terbarukan sebagai alternatif untuk memenuhi kebutuhan listrik di wilayah tersebut. Pengumpulan data dari artikel-artikel sebelumnya mengenai potensi energi terbarukan di Sulawesi Selatan menjadi dasar analisis. Studi ini berfokus pada sistem termal surya, fotovoltaik (PV), tenaga angin, biomassa, dan hidroenergi, menilai potensinya. Sistem termal surya dan PV menunjukkan kapasitas pembangkitan listrik yang menjanjikan karena tingkat radiasi yang tinggi di wilayah tersebut. Sistem tenaga angin dan biomassa menunjukkan potensi sedang, sementara hidroenergi menawarkan kemampuan pembangkitan yang signifikan. Studi ini menyimpulkan bahwa beralih ke energi terbarukan penting untuk mengatasi polusi dan meningkatkan kesehatan masyarakat, meskipun insentif keuangan yang mendukung sumber-sumber tidak terbarukan menjadi tantangan.

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INTRODUCTION

Energy, at its core, is a currency used by a certain body to exert work. Sources of these currencies could originate from various sources, starting from food for the human body to process, to the industrial usage of fossil fuels. In terms of industrial and commonplace energy utilization, most people would know and realize that fossil fuels are the main energy resources used. A large percentage of global primary energy consumption came from fossil fuels, around 84% to be exact as shown in Figure 1 (Ritchie & Rosado, 2020).

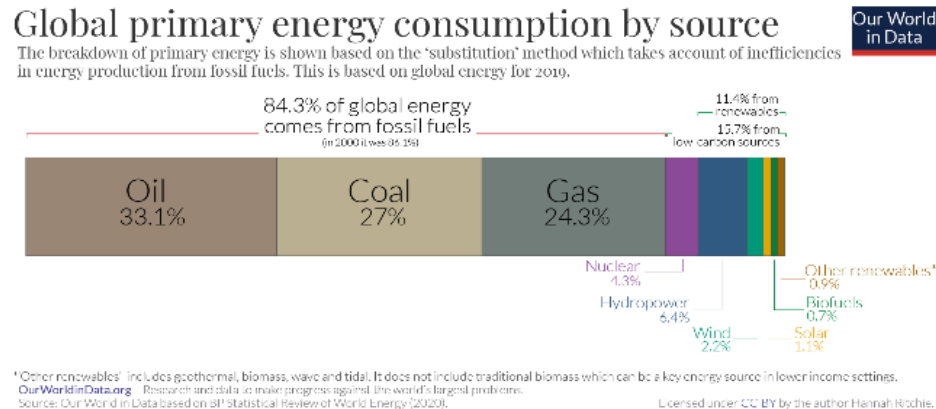


Figure 1. Annual CO₂ Emissions (Ritchie & Rosado, 2020)

While currently still having a certain sizable amount, fossil fuels would not be able to handle the gradually increasing global energy demand, as their regeneration process would take a very long time. Another issue regarding fossil fuel usage is how high their pollution rate is, especially from their CO₂ emissions (Wijaya & Saputri, 2024) as seen in Figure 2, which shows the annual CO₂ emissions from fossil fuels and industry.

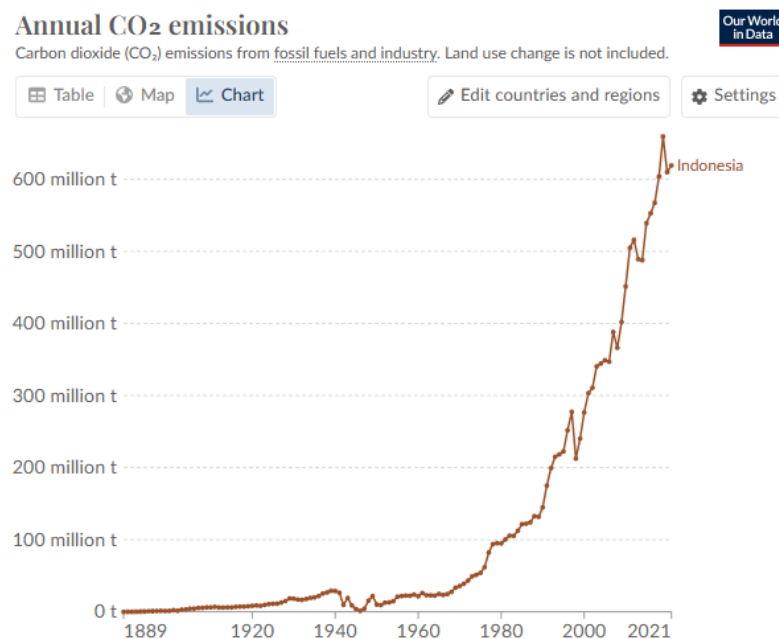


Figure 2. Annual CO₂ Emissions (Budget, 2023)

To prevent further environmental issues, other alternatives are used, such as renewable energy. Renewable energy is a form of energy source which, unlike fossil fuels and other non-renewable sources, could naturally regenerate over time at a higher rate than the rate they are being used. Examples of renewable energy sources include solar, water, wind, and geothermal power,

all of which can be found naturally from the sun and the environment. In short, the renewable energy potential of a certain location depends on the abundance of natural resources in its surroundings. Indonesia is a country with large renewable energy potential since it contains ample amounts of natural resources spread out in its various regions. This could be seen as Indonesia had an increase in their renewable energy starting from 2016, while also reducing their non-renewable energy sources (Indonesia, 2017). The renewable energy potential in Indonesia is considered high, while still only managing to utilize just a bit of it. Table 1 shows how Indonesia currently only utilized about 0.3% of the total renewable energy potential in 2021 (Wahyuni & Ardiansyah, 2022).

Table 1. Renewable Energy Potential in Indonesia

NRE Commodity	Total Potential 2021 (GW)	Power Plant Capacity (GW)	% Utilization
Tidal	17.9	-	-
Geothermal	23.9	2.3	9.6%
Bioenergy	56.9	2.3	4.0%
Wind	154.9	0.2	0.1%
Hydro	95.0	6.6	6.9%
Solar	3,294.4	0.2	0.01%
Total	3,643.0	11.6	0.3%

The global COVID-19 pandemic has brought about significant alterations in people's daily routines, affecting both their professional and leisure activities. Given the virus's potential for transmission through direct contact with infected individuals (Rinanda Saputri & Radithya, 2024), there has been a notable shift towards indoor-oriented lifestyles. This contrasts with previous habits of engaging in activities outside the home. Additionally, energy consumption patterns have also been impacted by the pandemic. Although the overall energy demand and its gross domestic product (GDP) decreased by around 6% from the year of 2019 to 2020, it was also found to vary between every region, with the USA having the highest varying rates and Europe being the lowest, almost having no variations (Agency, 2020).

South Sulawesi is one of the provinces of Sulawesi Island in Indonesia, however, it also consists of various small islands which caused uneven electricity distribution throughout the area. An alternative given by the local government to fulfill their electricity needs is by supplying a diesel power plant (Diesel-PP), which utilizes non-renewable energy and its usage is also time-limited (Kitta et al., 2021). In resolving these issues, renewable energy sources could potentially be used to fulfill the electricity needs of the people, regardless of time and location. Forms of renewable energy sources in South Sulawesi will be discussed and analyzed to find the best renewable energy source option in South Sulawesi. The purpose of this study is to investigate the feasibility of renewable energy sources as alternatives to meet the electricity needs in the South Sulawesi region, Indonesia. The method used is data collection from previous articles on the potential of renewable energy in South Sulawesi, which then serves as the basis of analysis in this research.

RESEARCH METHODS

In this study, the method used is a literature review, involving data collection from previous articles discussing the potential of renewable energy in South Sulawesi, Indonesia. The primary sources of data are scientific literature and related reports previously published by other researchers. The collected data includes information on the potential of renewable energy sources such as solar thermal systems, photovoltaic (PV) systems, wind power, biomass, and hydropower in the region.

The data analysis technique employed in this study involves synthesizing and evaluating information obtained from relevant scientific literature. The data collected from various sources are then analyzed to evaluate the potential of each renewable energy source in meeting the

electricity needs in South Sulawesi. Based on the analysis of the data, conclusions are drawn regarding the feasibility and potential of using renewable energy as an alternative to meet the electricity needs in South Sulawesi. The conclusions to be drawn will be supported by the data and information gathered during the literature review process.

RESULT AND DISCUSSION

The discussion section plays a important core to provide a critical analysis of the research results. In this study, the investigation aimed to explore the feasibility of renewable energy sources in meeting the electricity needs of South Sulawesi, Indonesia. The method employed involved collecting data from previous articles and research studies on various renewable energy systems, including solar thermal, photovoltaic (PV), wind power, biomass, and hydropower.

Several types of renewable energy could be utilized in Indonesia, specifically in South Sulawesi. An example of a system used for utilizing renewable energy is the solar pond system (Ravi Kumar et al., 2021). The operating temperature for each solar thermal system could be classified into low, medium, and high-temperature systems. While industrial usage of these solar thermal systems would require them to operate on a much higher temperature, South Sulawesi being the focus of this discussion made solar pond the ideal choice for a solar thermal system, as it only requires a low operating temperature ranging between 30-150°C. Another research done in South Sulawesi showed how solar pond systems could be implemented in areas such as Jeneponto and Pangkep, as shown in the annual irradiation data in Table 2 (Fadliah Baso et al., 2018).

With considerably high irradiation and peak temperature, solar ponds as a solar thermal system could potentially be implemented in South Sulawesi for both daily household usage, as well as small-scale industrial usage.

The most well-known renewable energy system currently is the photovoltaic (PV) system, which only requires solar energy and converts it into electrical energy in its usage. There are different methods of implementing solar PV systems; one which implemented PV systems on the rooftop of every house of the residential sector with no other transmitting and distribution process, one which uses a centralized power plant at each district to generate electricity for the surrounding residential sector with certain distribution cost, and one which used centralized power plant to generate electricity for the whole region which would require both transmission and distribution cost. Research was done to figure out the best implementation method for the PV system in South Sulawesi, which showed how installing PV systems individually on the rooftops of the residential sector would be the best method when compared financially (Hermawan & Wahid, 2020).

Table 2. Annual Irradiation Data in Jeneponto and Pangkep, South Sulawesi

Month	Jeneponto Radiation (MJ/m ² /day)	Pangkep Radiation (MJ/m ² /day)
January	16.452	16.848
February	17.424	17.748
March	20.7	19.944
April	21.276	20.88
May	21.492	20.628
June	20.412	19.908
July	21.42	20.664
August	24.12	23.328
September	25.992	24.588
October	25.38	23.904
November	21.924	20.268
December	17.1	16.056
Annual	21.132	20.412

It could be noted how there are several factors in determining the best method of implementing PV systems other than from its financial perception. The characteristics or specifications of each PV panel could be analyzed, which is shown in research done by using the BP Solar PV panel in Table 3 (Sihotang & Okajima, 2017).

Table 3. PV Panel Specification

Manufacture	BP Solar
Type of PV module	Mono-Si
Model	BP 2150 S
Capacity per panel	185 W
PV efficiency	14.80%
Area per panel	1.24 m ²
Inverter efficiency	92%

The thing to note would be the angle of the PV systems installed, in which the research done in Makassar shows that the angle of the rooftop PV systems is limited only to be around 20°, following the rooftop design in Makassar. The azimuth of the panels would change from 0° to 180° with 20° intervals. The angle and azimuth of large-scale PV systems would differ, with the angle changing between 0° to 30° with 10° intervals, while the azimuth would change from 0° to 180° in 15° intervals. The angle and azimuth of the PV systems are set to obtain the most optimum annual power generation (Sihotang & Okajima, 2017).

Wind power systems have been in use for a long time and supplied around 6% of global electricity demand in 2021, with China as its frontrunner with around 206 GW of electricity generated. In Southeast Asia, Vietnam is the frontrunner generating around 25 GW of electricity, with Indonesia in third place generating around 10 GW of electricity from wind power. The equatorial location of Indonesia caused the average wind speed to be lower than other countries, with only around 3-6 m/s when compared to other countries with average wind speeds higher than 8 m/s. With this range of wind speed, the wind power potential that could be reached is about 60.6 GW, while only about 0.15 GW of wind power is used in 2020. RUEN mentioned South Sulawesi as having a wind power potential of up to 4.19 GW of electricity, while the current largest wind power plant in Indonesia is also located in South Sulawesi with only about 75 MW wind power generation capacity (Ardiansyah & Eka Dewi, n.d.).

The design of the wind turbine could be differentiated into the vertical axis wind turbine (VAWT) and the horizontal wind turbine (HAWT) (Kamran & Fazal, 2021). Due to the low wind speed conditions in Indonesia, the VAWT is considered to be more suitable, however, the produced amount would also be lower. Furthermore, the VAWT could be differentiated from the Savonius rotors and the Darrieus rotors VAWT, which can be modified to obtain a better result. The two types differ in how aerodynamic their overall performances are, as well as their self-starting ability. Hybrid Savonius-Darrieus rotors could be used instead, to ensure the self-starting ability, but also with the excellent aerodynamic performance of the rotors (Ardiansyah & Eka Dewi, n.d.).

As mentioned previously, the largest wind power plant in Indonesia is located in Sidrap, South Sulawesi, which consists of 30 turbines and can provide up to 75 MW of electricity. Research showed the wind speed around Sidrap to be between 7.0-7.5 m/s at an altitude of 100 meters, with the average wind speed ranging from 5.0-7.5 m/s in 2004-2015. The average wind speed in South Sulawesi of 7.7 m/s could still be considered acceptable to be utilized for wind power generation (Lisapaly, 2021).

Another form of renewable energy includes biomass energy, which in Indonesia was estimated to reach up to 33 GW in 2013. In 2020, biomass energy was only around 10% of the global primary energy produced, although biomass energy is considered to be versatile, as its materials could vary. In terms of its electricity production, South Sulawesi did not have a high potential, however it could still produce a significant amount of electricity. South Sulawesi

contained various biomass potentials, with the highest being rice husk, which had around 700 MW of potential power generated (Primadita et al., 2020).

When utilizing rice husks as a biomass energy source, the fluidized bed combustion (FBC) technology is used, as it could convert various materials directly. The FBC system operates at a temperature between 800-900°C, and when compared to another conventional combustion system, the FBC system is much more efficient as the heat transfer happening inside it is done equally (Yusran & Aprusmin, 2017).

One of the highest renewable energy potentials comes from the utilization of hydropower energy. South Sulawesi has a lot of water potential as there are many bodies of water around the province and surrounding it. While there are still some islands in the province that experienced a lack of electricity, these bodies of water could be the alternative in fulfilling their electricity needs, rather than utilizing Diesel-PP which could pose danger for the environment. Research is done in South and West Sulawesi which shows that hydropower plants only supplied around 25% of electricity in the area (Astuty & Haryono, 2014).

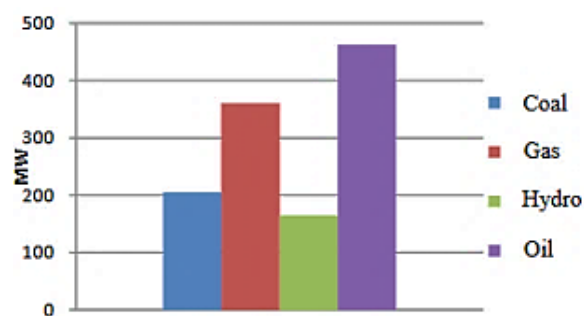


Figure 3. Power Generation in South and West Sulawesi

Currently, there are three hydropower plants in South Sulawesi; Karebbe with 160 MW capacity, Balambano with 130 MW, and Bakaru with 126 MW. Since large-scale hydro power plants cannot possibly be run everywhere, there are other alternatives such as the implementation of micro-hydropower plants in the residential sector, which had already been implemented in South Sulawesi in North Luwu with its installed capacity of around 40 kW. Another type of water-utilizing plant is the pumped storage hydroelectricity (PSH) plants which contain water reservoirs at different elevations. The electricity production from PSH plants could be set following the electricity demand, as the PSH system would use the difference in elevations to pump the water to the reservoir above for storage and to let the water flow down through a turbine to generate power later (Ardiansyah, 2022).

As a result of the COVID-19 pandemic, the world has gone through changes in their lifestyle, which also affected their overall energy usage (Novianto et al., 2022; Rouleau & Gosselin, 2021). Although the overall energy usage was seemingly going down, it did not take too long before the pandemic ended and people went back to their previous habits for their energy usage to drastically increase. It could even be felt and seen directly, in various regions of Indonesia, how their pollution rate continuously increases which affects the health and comfort of the people. Remembering how fossil fuel usage caused several environmental and health issues, the implementation of these renewable energy systems might be the key to a much healthier and cleaner source of energy. Although not entirely clean and healthy in its production process, implementations of renewable energy systems in various areas would help in reducing issues such as high pollution rates, and even help in combating global warming. Technologies and facilities are just tools to help realize the future 'green' environment with renewable energy as its main currency. It, however, would not be able to be utilized optimally when there is no awareness and knowledge regarding these things planted in the minds of the people. In the case of Indonesia as a developing country, the people mainly focus on the financial side of things without even contemplating about the effects occurring locally and globally. Renewable energy is currently still

considered to be a new and developing subject, which in turn would require a much higher expenditure to use. In the current global situation, considering the environment and the health of the people, the utilization of renewable energy sources is much needed.

The findings revealed several important insights regarding the potential of each renewable energy source in South Sulawesi. Solar thermal systems, particularly utilizing solar ponds, emerged as a promising option due to the region's high irradiation levels and the relatively low operating temperatures required. Similarly, PV systems showed significant potential, especially when installed individually on the rooftops of residential sectors. Wind power systems, although viable, faced challenges due to the region's lower average wind speeds, necessitating the use of specialized rotor designs for optimal performance. Biomass energy, particularly from rice husks, demonstrated considerable potential, albeit with variations in electricity production capacity. Additionally, hydropower emerged as one of the highest renewable energy potentials in South Sulawesi, given the abundance of water resources in the region.

Overall, the findings underscore the importance of diversifying the energy mix in South Sulawesi to reduce dependence on fossil fuels, mitigate environmental impacts, and enhance energy security. By harnessing the abundant renewable energy resources available in the region and implementing appropriate technologies and policies, South Sulawesi can move towards a cleaner, more sustainable energy future.

CONCLUSION

South Sulawesi is a region full of renewable energy potential to be utilized, and to replace fossil fuels as primary energy sources. This paper focuses on five kinds of renewable energy systems; solar thermal, photovoltaic (PV), wind power, biomass, and hydropower systems, and their potentials in South Sulawesi. Implementation of a solar thermal system could potentially produce a large amount of power, considering the usage of the solar pond as well as the irradiation amount in South Sulawesi. Similar to solar thermal systems, the high irradiation amount in South Sulawesi would also affect the productivity of PV systems, which in this case would cause the electricity generation for PV systems to be higher as well. On the other hand, wind power systems do not seem to work as well as the previous two systems, since the wind speed in South Sulawesi is considered small and would produce little amount of electricity, even with the utilization of the hybrid Savonius-Darrieus rotors. Similarly, biomass energy potential in South Sulawesi is considered useable and could still generate significant power, higher than its wind power potential. South Sulawesi had already implemented hydropower plants in various places, some had considerable installed capacity. While using the micro-hydropower plants might be more fitting for residential sectors, the use of pumped storage hydroelectricity (PSH) plants would yield a much higher power generation.

The effects and the aftermath of the pandemic could be felt and seen directly in various regions of Indonesia, with how their pollution rate continuously increases which affects the health and comfort of the people. One of the many reasons for these issues is the increasing usage of transportation, both public and private, that uses fossil fuels as their energy sources. With that in mind, the plans to change their energy sources from non-renewable fossil fuels to a cleaner and healthier alternative in renewable energy sources would be easily implemented. However, most people would not be able to consider the effects of non-renewable energy sources and would still decide their usage, since it is more rewarding financially. The awareness and knowledge of the people would need to be geared towards the future of the world, rather than the present. The investment cost given for renewable energy systems would help in creating a better, cleaner, and healthier place for us all to live in.

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