JIMESE
Journal of Innovation Materials, Energy, and Sustainable Engineering

JIMESE 1(1): 50–69
ISSN 3025-0307

The potential of renewable energy sources in Java Island: a systematic literature review

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Received Date: May 22, 2023 Revised Date: July 31, 2023 Accepted Date: July 31, 2023

Cite This Article:
Kurniawan, F. ., Samsudin, A., Sriwati, E. & Coştu, B. .(2023). The potential of renewable energy sources in Java Island: a systematic literature review. *Journal of Innovation Materials, Energy, and Sustainable Engineering, 1*(1). 50-69.
https://doi.org/10.61511/jimese.v1i1.2023.101

Abstract
This study aims to reveal the various renewable energy sources that have the potential to be developed on the island of Java, Indonesia. Because it is cheap and easy to reach, non-renewable energy is widely used as a source of energy for people's lives. The negative side of non-renewable energy sources forces local governments to look for alternative energy sources that are more environmentally friendly. Environmentally friendly alternative energy is rarely studied, specifically on the island of Java, through literature studies. Therefore, this study used a research method: a literature study on 28 Scopus, WoS, and Sinta-indexed articles. This literature study yields the information that 10 types of renewable energy sources have the potential to be developed in Java. These renewable energy sources can be further developed using technology according to their potential in each province. Thus, this research has succeeded in linking various renewable energy sources that have the potential to be developed on the island of Java.
Keywords: Indonesia's ruen; Java Island; literature review; renewable energy sources

1. Introduction

Indonesia has various energy resources that can be utilized for the lives of its people. These energy resources are non-renewable and renewable energy (Adebayo et al, 2022; Kurniawan et al, 2020; Ordonez et al, 2022). Many renewable energies have been developed in Indonesia, such as geothermal, hydropower, and biomass (Hasan et al, 2012; Kashem et al, 2021; Lee et al, 2023; Nabila et al, 2023; Tang et al, 2019). However, dependence on the use of non-renewable energy is still quite high in Indonesia. One of Indonesia's main oil consumers among its numerous economic sectors is the country's road transportation industry. Huge energy demand from fuel has resulted in an annual consumption growth rate of roughly 4% due to the dominance of private vehicles, especially cars a,nd motorcycles, in the Indonesian transport modal mix (Dartanto, 2013; Pujiati et al, 2022; Setiawan, 2021; Widyaparaga et al, 2020). In addition, the transportation industry consumed over 64% of

Indonesia's total oil in 2014 and produced 23% of the nation's emissions (Government of Indonesia, 2017). In addition to consuming a lot of oil, Indonesia's transportation sector also faces a number of issues. Inadequate road transport infrastructure, particularly with regard to urban public transportation like bus rapid transit (BRT), feeder buses, and walking; severe daily gridlocks in urban mobility are a few of these. They include long-neglected policy and institutional reforms, under-utilized deployment of rail public transport modes (i.e., limited and outdated networks, rolling stock and headways, and a lack of urban rails), and limited and outdated networks for rail public transport modes. In addition to oil, coal and gas made up the majority of Indonesia's energy mix (Baskoro et al, 2021; Hasan et al, 2012; Hartono et al, 2020; Kurniawan et al, 2020; Rahman et al, 2021; Yana et al, 2022). The amount of oil in Indonesia's energy mix has been steadily decreasing because of coal, which has increased at an average annual rate of 1.9% over the past ten years. The power sector likewise exhibits a heavy reliance on fossil fuels, particularly coal; in 2014, coal accounted for 52.8% of the electricity produced. Indonesia has started the Power Fast Track program to increase the power generation capacity with the goal of reaching 100% electrification by 2020 and guaranteeing the security of the energy supply. The coal-fired power plant is the only source of energy used in the program's first stages (Kurniawan & Managi, 2018). In addition, a number of significant coal mining firms in Indonesia have grown into integrated energy firms that use their own coal for electricity production.

Non-renewable energy (non-RE) is easy and cheap to produce and consume, but the environmental impact of non-renewable energy consumption cannot be ignored. Research by Nathaniel & Iheonu (2019) states that consumption of non-RE significantly increases CO2 emissions by 2.466 units, 0.601 units, 3.475 units, and 0924 units in Botswana, the Congo Republic, Gabon, and Morocco, respectively. This phenomenon has also been found in other countries in Africa (Awodumi & Adewuyi, 2020; Adedoyin et al, 2021; Banday & Aneja, 2020; Namahoro et al, 2021; Udeagha & Ngepah, 2022; Vural, 2020). Not only in Africa, consumption of non-RE also significantly increases CO2 emissions in Asia (Akadiri & Adebayo, 2022; Hanif et al, 2019; Hasnisah et al, 2019; Le, 2022; Mohsin et al, 2021; Usman et al, 2021; Wen et al, 2021), Europe (Alola et al, 2019; Adeleye et al, 2023; Bekun et al, 2019a; Mert et al, 2019; Piłatowska & Geise, 2021; Rasheed et al, 2022), and Australia (Khan & Liu, 2023; Kuldasheva & Salahodjaev, 2022; Peng et al, 2023; Rahman & Alam, 2022). Increased CO2 emissions in various countries can threaten the ozone layer of the earth's atmosphere in maintaining the stability of the earth's climate and temperature. Excessive CO2 emissions can accelerate global climate change and the phenomenon of the greenhouse effect (Mikhaylov et al, 2020; Yoro & Daramola, 2020). As a result, the earth's temperature will increase to an extreme and uncomfortable for living things to live in.

In contrast to non-RE resources, Renewable Energy (RE) resources have a positive impact on the environment. They promote development (Apergis et al, 2018; Emir & Bekun, 2019), encourage environmental protection (Bekun et al, 2019b; Ellabban et al, 2014; Rafindadi & Ozturk, 2017; Wei et al, 2016), and reduce emissions (Balsalobre-Lorente et al, 2018; Budzianowski & Postawa, 2017; Steiner et al, 2017). The positive impacts provided by RE on the environment have made many countries switch to RE sources as alternative energy. Some of these countries are European Union countries (Potrč et al, 2021); Africa (Müller et al, 2021; Mutezo & Mulopo, 2021), Australia (Clean Energy Council, 2017), South Asia (Murshed & Tanha, 2021), and ASEAN countries including Indonesia (Reyseliani & Purwanto, 2021; Vakulchuk et al, 2023). Through the national energy plan (Rencana Umum Energi Nasional - RUEN), Indonesia has committed to the energy transition and set goals for the percentage of Renewable Energy Technologies (RET) in the energy mix to be at 23% by 2025 and 31% by 2050 (President of Republic Indonesia, 2017).

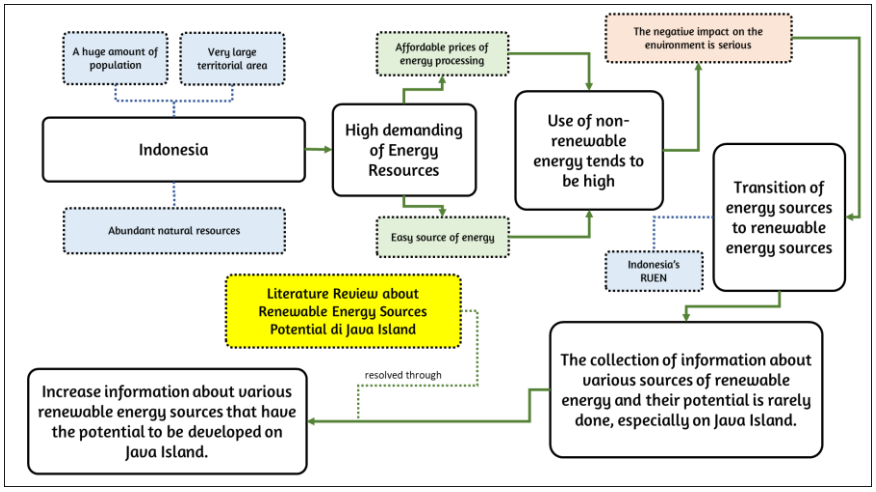

Figure 1. Conceptual Framework of Renewable Energy Research

To support RUEN, Indonesia needs to understand the potential resources of RE in its own country. There are a lot of RE resources that can be found in Indonesia (Hasan et al, 2012; Langer et al, 2021b). However, a review of the various potential sources of renewable energy, specifically on Java Island, is still rarely carried out. With more than 50% of Indonesia's 252 million people residing there, Java has the greatest population density out of the country's more than 17,500 islands (BPS, 2016). With the greatest industrial manufacturing facilities and the best-developed infrastructure, it is the country's economic and political hub (BPS, 2016). The density of people on Java Island has an impact on the need for high energy sources. So, knowledge about alternative energy resources that are environmentally friendly needs to be presented. Therefore, as shown in Figure 1, this research aims to provide information about the various potential sources of renewable energy in Java.

2. Methods

This study used a research method in the form of a literature review. This literature review procedure follows the procedure initiated by Randolph (2009). This procedure has been implemented by Putri et al (2022) in their review of the literature. The steps of this procedure are: 1) problem formation; 2) data collection; 3) data evaluation; 4) analysis; and 5) interpretation. Descriptions for implementing these steps are presented as follows:

Problem Formation

The first step in problem development is to create the research review's guiding questions. Providing information about the various potential sources of renewable energy in Java is the research aim of this study. As a result, the questions below were created to guide the literature study:

1) What kind of renewable energy is available on Java Island?
2) How potential is renewable energy can be developed?
3) From the existing literature, what are the recommendations for the future research?

Data Collection

The study review was put together by the authors using two major sources. First, the first author manually searches all articles that have been published since 2013 in journals of energy, natural environment, and renewable energy. We selected the Web of Science, Scopus, and Sinta-indexed publishers, including Elsevier (ELSEVIER), MDPI (MDPI), Univ.

Indonesia ( ), Int Journal Renewable Energy Research ( ), AIP Publishing ( ), and others. Sinta (Science and Technology Index) is an Indonesian journal indexing machine that compiles journals in Indonesia (Ahmadi, 2019). The phrases "renewable energy potential in Indonesia", "potensi energi terbarukan di Indonesia", "renewable energy potential in Java", or "potensial energi terbarukan di Jawa" were used. Second, the references for the research that were found to be relevant. There were found to be hundreds of papers. However, only 28 articles met our requirements, as will be stated in the section below.

Data Evaluation

The first author examined the titles and abstracts of the research before sifting through hundreds of search results to discover possibly pertinent articles. Several studies were then carefully examined for their relevance. Studies in the area of renewable energy and the potentials are our two main criteria for choosing which articles to examine. As a result, only 50 studies were used to collect the data. Results omitted topics not conducted in Java Island (e.g., Abdullah *et al*, 2016) and studies that just identified renewable energy ideas without determining the potentials in Java (e.g., Langer *et al*, 2021a; Parinduri & Parinduri, 2020).

To make this review manageable, data from relevant research was compiled into a computerized database. This includes details on each study's author, the publication date, the title of the journal, the author's region, the research methodology, the research place, the findings, the limitations, and suggestions for further research. The authors looked for commonalities in such renewable energies to identify gaps in the body of current knowledge.

3. Results and Discussion

Analysis Data and Interpretation

This study's review process lasted seven weeks, from May 8 to May 15, 2023. The initial author reported to other academics on the review activities of 7 publications every day from Tuesday through Friday. In the previous two weeks, we consolidated the reviewed literature. At this point, the authors were still able to point to a few modest theoretical and methodological breakthroughs. The following four assertions, all of which were confirmed by the review's results, are: 1) Indonesia has begun the transition from non-RE to RE; 2) there are so many RE resources that can be found on Java Island; and 3) RE has a lot of potential to be developed on Java Island.

Characteristics of Literature (author, the publication date, the author's region)

This research took articles from various journals. From the hundreds of journals that have been examined, only a few journals have articles that meet the criteria of this study (as listed in Appendix 1). The distribution of journals used in this review is presented in Table 1.

Table 1. Characteristics of Literature based on Journal

Name of Journal	Publishers	Author	Year Published	Indexed By	f
Renewable Energy		Ribal et al	2019	Scopus (Q1) and WoS (SCIE)	1
		Nasruddin et al	2016	Scopus (Q1) and WoS (SCIE)	2

Name of Journal	Publishers	Author	Year Published	Indexed By	f
Renewable and Sustainable Energy Reviews		Pratama et al	2017		
Energies		Isa et al	2021	Scopus (Q2) and WoS (SCIE)	1
International Journal of Technology		Günther	2018	Scopus (Q2), WoS (ESCI), and Sinta (S1)	1
International Journal of Renewable Energy Research		Sumotarto	2018	Scopus (Q3) and WoS (ESCI)	3
		Widodo et al	2019		
		Ma'arif et al	2019		
Journal of Renewable and Sustainable Energy		Mahiru Rizal et al	2019	Scopus (Q3) and WoS (SCIE)	1
Other Journal				Sinta (S2-S5)	19
Total					28

Table 1 shows that articles about renewable energy in Indonesia, especially in Java, are mostly published in articles indexed by Sinta. This is because the majority of practitioners who carry out activities related to renewable energy come from Indonesia itself. The development of articles on the potential for renewable energy in Indonesia from year to year is presented in Figure 2.

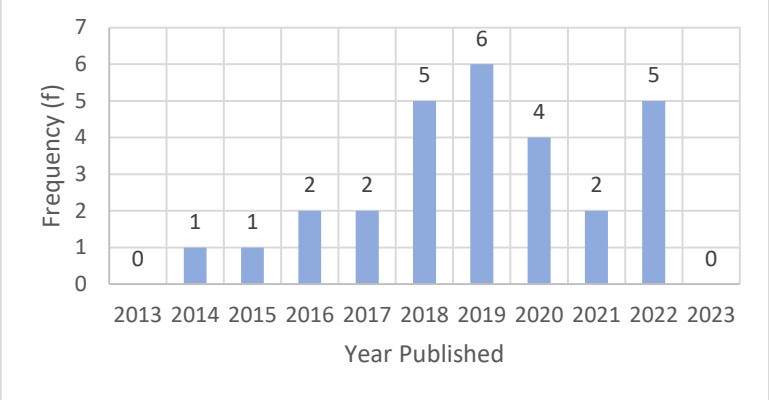

Figure 2. Frequency of Articles based on Year Published

Figure 2 shows that the number of articles that meet the criteria fluctuates. The increase occurred from 2013 to 2019, while the decrease occurred from 2019 to 2021. After that, the number of articles increased again in 2022.

The Research Methodology (Approach, research place)

The articles reviewed in this study have various approaches and research locations. Various research approaches in the article are presented in Figure 3.

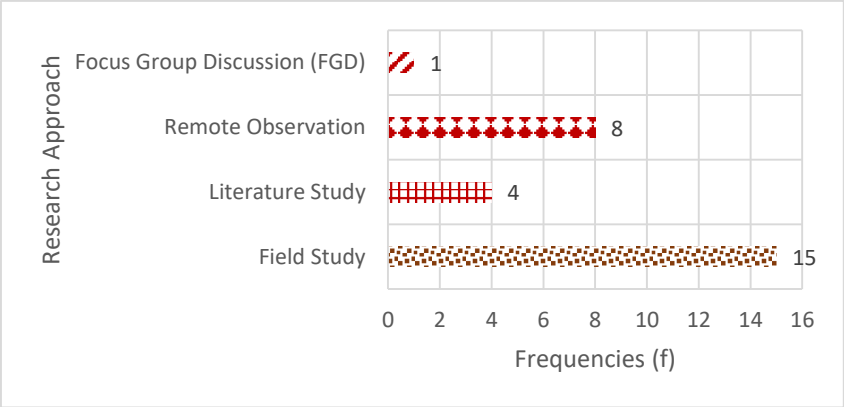

Figure 3. Frequency of Articles based on Research Approach

Based on Figure 3, research that reveals the potential for renewable energy in Java tends to be carried out using field studies. The social, cultural, physical, and environmental background of a region is typically studied in depth using this methodology (Bogdan & Biklen, 2018; Creswell, 2014). The specific areas covered by these articles will be presented along with the potential for renewable energy in those areas in the Findings section.

The Findings (Findings and limitations)

Based on the analysis of the literature review that has been carried out, the various potentials found in Java Island are shown in Table 2.

Table 2. Variety of Renewable Energy Found

Renewable Energy Sources	Studied by	Place	Potential	
			Value	Quantity
Ocean Wave	Ribal et al (2020)	Java Island	20.00-30.00 kW/m	Intensity
	Mahiru Rizal et al (2019)	Pandeglang, West Java	27.58 kW/m	Intensity
		Sukabumi, West Java	26.74 kW/m	
		Cianjur, West Java	24.47 kW/m	
		Pangandaran, West Java	26.91 kW/m	
		Cilacap, Central Java	46.62 kW/m	
		Kebumen, Central Java	28.30 kW/m	
		Yogyakarta, Special Region of Yogyakarta (DIY)	40.16 kW/m	
		Trenggalek, East Java	27.59 kW/m	
		Malang, East Java	27.01 kW/m	
		Jember, East Java	47.78 kW/m	
		Alas Purwo, East Java	34.55 kW/m	
	Pratama et al (2017)	South Coast of Java Island	162,167.00 W/m2	Intensity
	Purba (2014)	Sukabumi, West Java	1.0-3.10 m	Height
		Pangandaran, West Java		
		Cianjur, West Java		
		Garut, West Java		
		Tasikmalaya, West Java		

	Akbar et al (2019)	Pangandaran, West Java	30.50 m/dt	Speed
Hydro	Pratama et al (2017)	Java-Madura-Bali	4,929.50 MW	Power
	Günther (2018)	Java-Bali	18.00 TWh	Energy
	Taufiqurrahman & Windarta (2020)	East Java	535.00 MW	Power
		Central Java	813.00 MW	
		West Java	2,861.00 MW	
Micro-hydro	Isa et al (2021)	Sukabumi, West Java	206.00 kW	Power
	Pranoto et al (2017)	Serayu-Opak River, Central Java to DIY	26.00 MW	Power
	Hanggara & Irvani (2017)	Malang, East Java	47.85 kW	Power
	Aspriadi et al (2019)	Batang, Central Java	4.25 GWh/year	Energy/year
	Taufiqurrahman & Windarta (2020)	East Java	1,142.00 MW	Power
		Central Java	1,044.00 MW	
		DIY	5.00 MW	
		West Java	647.00 MW	
Pico-hydro	Nakhoda et al (2018)	Jember, East Java	180.00-300.00 W	Power
Tidal Energy	Pratomo & Soebari (2020)	2 places in Banten	373,867.20-1,040,873.40 kW	Power
		10 places in West Java		
		3 places in Central Java		
		1 place DIY		
		3 places East Java		
Geothermal	Pratama et al (2017)	Java-Madura-Bali	10,013.00 MW	Power
	Nasruddin et al (2016)	Java Island	3,536.00 MW	
	Günther (2018)	Java-Bali	41.00 TWh	Energy
	Sumotarto (2018)	Arjuno-Welirang, East Java	200.00 MWe	Power
	Subekti & Harmoko (2020)	Dieng, Central Java	280.00 MW	Power
	Sidik & Harmoko (2022)	East Java	1,967.00 MWe	Power

Biomass	Pratama et al (2017)	Java-Madura-Bali	10,616.80 MW	Power
	Ma'arif et al (2019)	Giwangan Market, DIY	5.14 kW	Power
		West Banyuwangi, East Java	8,571.00 unit	Stem Bamboo
		North Banyuwangi, East Java	136,000.00 unit	
		Kediri, East Java	366.00 unit	
	Magelhaes (2018)	Jombang, East Java	89,289.51 m3	Volume (rice husk)
			73,217.00 m3/day	Volume (livestock manure)
			180.00 ton/day	Mass (Organic Trash)
			38.00 m3/day	Volume (Human feces)
			100,000.00 MWH	Power (Bagasse)
			1.65 ton/Ha	Mass/area (cassava)
Biogas	Santoso et al (2020)	Blitar, East Java	6,513.00 kkal/m2	Calori/area
Solar	Pratama et al (2017)	Java-Madura-Bali	79,201.30 MW	Power
	Günther (2018)	Java-Bali	574.00 TWh	Energy
	Widodo et al (2022)	Semarang, Central Java	5.63 kWh/m2/day	Energy/area
	Diniardi et al (2022)	Purwakarta, West Java	187.00 MW	Power
		Cianjur, West Java	145.00 MW	
		Sumedang, West Java	145.00 MW	
		Bandung Barat, West Java	90.00 MW	
		Bogor, West Java	75.00 MW	
		Kuningan, West Java	17.00 MW	
	Rizkasari et al (2020)	Yogyakarta, DIY	107,571.70 kWh/year	Energy
	Akbar et al (2019)	Pangandaran, West Java	4.60 kWh/m2/day	Energy/area
Wind	Pratama et al (2017)	Java-Madura-Bali	2,450.60 MW	Power
	Purba (2014)	Sukabumi, West Java	5.30-12.60 m/s	Speed
		Pangandaran, West Java		
		Cianjur, West Java		

	Garut, West Java		
	Tasikmalaya, West Java		
Dewi & Handini (2022)	Banten	1.97 m/s	Speed
	DKI Jakarta	3.07 m/s	
	West Java	2.93 m/s	
	Central Java	7.92 m/s	
	DIY	1.35 m/s	
	East Java	10.18 m/s	
Murniati & Sudarti (2021)	Banyuwangi, East Java	1.34 W/m2	Power/area
Akbar et al (2019)	Jember, East Java	3,025.00 W	Power
	Pangandaran, West Java	4.42 m/s	Speed

Table 2 shows that the island of Java has considerable renewable energy potential. The large number of renewable energy processing efforts that have been carried out on the island of Java are the result of the government's commitment to transitioning energy sources to renewable energy. Based on Table 2, ten types of renewable energy have the potential to be developed in Java. Each province has renewable energy potential in different quantities and quality. Therefore, the selection process related to the development of renewable energy needs to pay attention to the potential of each energy source. Energy sources that have the highest potential can be prioritized for further development. This potential can be developed and maximized by using technologies that have been developed by researchers, for example, triboelectric nanogenerators for ocean waves (Huang et al, 2020; Rodrigues et al, 2020; Zhang et al, 2019), piezoelectric systems for hydro, micro-hydo, pico-hydro (Bao et al, 2019; Mahajan et al, 2021; Wu et al, 2021); tidal-current turbine for tidal energy (Mutsuda et al, 2019; Li & Zhu, 2023; Qin et al, 2022), binary cycle power plant for geothermal (Eskandari, 2023; Hekim & Çetin, 2021; Wu & Wang, 2022), biorefinery for biomass (Kosamia et al, 2022; Saravanan et al, 2023; Siddiki et al, 2022), anaerobic digestion for biogas (Kannah et al, 2021; Vargas-Estrada et al, 2021; Wu et al, 2021), hybrid photovoltaic for solar (Gupta et al, 2021; Tang et al, 2023; Wu et al, 2021), and triboelectric nanogenerator for wind (He et al, 2022; Li et al, 2021; Ren et al, 2022). The rapid pace of technology is increasingly enabling humans to process renewable energy effectively.

However, each type of renewable energy has not been studied equally in every province. The distribution of the number of studies conducted in certain provinces based on renewable energy is shown in Figure 4.

Figure 4. Distribution of Renewable Energy by Research Place in the Articles

Figure 4 shows that not all types of renewable energy have been studied in every province. Moreover, there are types of renewable energy that have only been studied in one province, namely pico-hydro and biogas. These rare or unstudied areas can be an opportunity for researchers to conduct research related to renewable energy. Thus, residents and local governments can find out the energy potential that exists in their area.

Suggestions for further research

Based on the articles that have been reviewed, several suggestions can be made by further researchers for developing renewable energy on the island of Java. Some of these suggestions are:

1. Some research still use a lot of limited measurement technology methods and tools (Dewi & Handini, 2022; Murniati & Sudarti, 2021; Pratama et al, 2017; Subekti & Harmoko, 2020), so it is suggested that further researchers be able to develop previous methods of

measurement, using more recent technology, or using another method. By using a variety of measurement methods, the results obtained in the field will be more accurate and factual.
2. The need for sustainability in building a culture of managing renewable energy means that collaboration between researchers, residents, stakeholders, and local governments needs to be strengthened again (Purba et al, 2014; Günther, 2018; Isa et al, 2021; Rizkasari et al, 2020; Widodo et al, 2022). Thus, it is suggested that future researchers can work more closely with residents, stakeholders, and local governments to obtain more sustainable developments.
3. It is necessary to expand the scope of research both in the region and the type of renewable energy studied (Sumotarto, 2018; Pranoto et al, 2017; Mahiru Rizal et al, 2019). By analyzing a wider scope, the information obtained can be more holistic.

4. Conclusions

This study has revealed the variety of renewable energy sources on Java Island. It shows that Java Island has a lot of renewable energy potential. Renewable energy sources that can be found on Java Island and its surroundings are ocean waves, hydro, micro-hydro, pico-hydro, tidal energy, biomass, biogas, solar, and wind. However, only several provinces researched in Java have these complete renewable energy sources. Each province has its own renewable energy potential to be developed. Based on its own potential, each province can develop its own renewable energy by using a technology-based system. Besides, there are some recommendations to the next researchers, such as: using more varied methods and techniques to study the renewable energy sources in Java Island; cooperating with local residents, stakeholders, and the government to make sustainable development of renewable energy in each province in Java Island; and widening the scope of place and renewable energy in Java Island.

Acknowledgement:
Acknowledgment is given to reviewer and IASSSF team for the support of this paper.

Author Contribution:
F.K. (conceptualization, investigation, formal analysis, data curation, validation, and methodology), A.S. (conceptualization, formal analysis, project administration, and resources), E.S. (supervision, funding acquisition, conceptualization, methodology, and writing), B.C. (conceptualization, review, editing, and validation). All authors have read and agreed to the published version of the manuscript.

Funding:
This research received no external funding

Ethical Review Board Statement:
Not applicable

Informed Consent Statement:
Not applicable

Data Availability Statement:
No new data

Conflicts of Interest:
The authors declare no conflict of interest

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