Renewable Energy Studies in Indonesia and Malaysia: a state-of-the-art

Zakiyyan Zain Alkaf
Department of Mechanical and Industrial Engineering
Faculty of Engineering
Universitas Gadjah Mada (UGM), Yogyakarta, Indonesia
zakiyyan.zain.alkaf@mail.ugm.ac.id

Budi Hartono
Department of Mechanical and Industrial Engineering
Faculty of Engineering
Universitas Gadjah Mada (UGM), Yogyakarta, Indonesia
boed@gadjahmada.edu

Abstract

This paper elaborates on recent studies on renewable energy (solar, bamboo, general RE) in both Indonesia and Malaysia. A series of pertinent studies are identified, and findings and approaches of past publications are reported in this study. The studies are then classified according to the context/theme and focus/approach to form a literature matrix. For the focus/approach, three groups of studies are observed, namely: empirical/experimental study (focusing on technology development), exploratory study (focusing on drivers and impediments), and explanatory study (focusing on demand/supply/impact). The matrix indicates that: research on renewable energy in Indonesia and Malaysia is still limited. The implementation of renewable energy technology needs to be studied in order to be carried out effectively. The direction of further research proposed by the researcher is expected to broaden the understanding of renewable energy in Indonesia and Malaysia.

Keywords
Renewable Energy, Indonesia, Malaysia, Research and Literature Review.

1. Introduction
Energy generated from renewable sources supply 14% of the total world energy demand (UNDP, 2000). ASEAN is a regional organization composed of ten countries in Southeast Asia: Indonesia, Malaysia, Thailand, Philippines, Vietnam, Singapore, Laos, Cambodia and Brunei. ASEAN aims to accelerate economic growth, social progress and cultural development and to promote regional peace and stability (H. C. Lau et al., 2022). The member countries of the Southeast Asia region have rich renewable energy sources such as wind energy, biomass and sun (Erdiwansyah et al., 2019). Energy from solar power and biomass (especially bamboo) can be developed in the future as a potential in ASEAN countries, particularly Indonesia and Malaysia (Shah et al., 2021).

Indonesia is a large archipelago with 17,504 islands (Winarno dkk., 2017). A total population of 270.20 million people with a productive age (15-64 years) features a portion of 70.72%; Indonesia is undoubtedly a large country (Badan Pusat Statistik, 2021). Indonesia possesses renewable energy such as wind energy, solar energy, water energy, and waste energy. However, Indonesia's number of renewable energy users is minimal (Udin, 2020). With so much renewable energy potential in Indonesia, it may be necessary for the public to be aware of the importance of sustainable energy. Awareness is essential for the sustainability of the next generation of the nation. Indonesia, especially in the energy sector, faces several challenges in terms of sustainable development. The industry still relies on conventional energy, although the potential for renewable or alternative energy is enormous. In 2014, Indonesia's total fossil fuel consumption reached 1.358 billion SBM, equivalent to 96% of full primary energy use (National Energy Council, 2015). Energy use subsidies also cause problems in the country's finances; in 2014, the Indonesian government

provided large sums (more than $25 billion) to subsidize energy, with some used for electric power (National Energy Council, 2015).

Malaysia has a population of about 27.73 million and covers an area of 329,750 sq-km, according to the last census of 2008. Malaysia's GDP has grown at an average rate of more than 5.7% over the past six years. Therefore, as the country develops rapidly, electricity needs are expected to increase and be on the same trend as GDP growth (Ong dkk., 2011). As an increasing economic power, Malaysia has invested heavily in energy security. Between 1990 and 2007, energy supplies grew by an average of 7% per year, of which 40% was derived from fossil fuels. However, the contribution of renewable energy at the time was still negligible. (Alam dkk., 2016). The energy crisis of the 1970s had a long-term impact on the global energy landscape and affected Malaysia. At about 87.9% in 1980, oil contributed significantly to the energy mix (Bujang dkk., 2016). Policymakers must evaluate the energy mix closely so that the energy crisis in the past is not repeated.

Renewable energy has had a steady increase in academic and practitioner discussion throughout the last decades. The research in renewable energy has also grown, both in scope and methods used. This paper is a literature review that aims to see the development of research related to renewable energy in Indonesia and Malaysia. This research is divided into four parts. The first part is related to the background of renewable energy in Southeast Asia, especially in Indonesia and Malaysia. The second part describes the methods used for conducting this research. In the third section, the author discusses empirical, exploratory, and explanatory research. The last section ends with implications for the direction of further research goals.

2. Methods

First, the researcher needs to decide what the research question will be. The purpose of this study is to determine the area of research in the field of renewable energy in Indonesia and Malaysia and research questions include:
1. What types of approach have been discussed renewable energy in Indonesia and Malaysia today?
2. What methods of research are used?
3. How is the scientific research carried out?

The study uses qualitative literature review analysis, and this review is based on explicit and detailed protocols for identifying articles and analyzing and discussing existing literature. The steps on this study follow and modify research by Glock and Hochrein (2011), as follows :
1. First, create a few relevant keywords that are specified. The keywords used in the study are listed in Table 1.: namely: "renewable," "solar," "bamboo," "Indonesia," and "Malaysia." Literature searches are filtered with limits for 2016-2021, and about 50 literature matches the review criteria for subsequent analysis.
2. The second step, the results of a search based on keywords in the previous step are checked based on relevance, checking is done by reading abstracts, results from research, and the entire article.
3. Step three, classifying several studies with similarities based on their focus and approach, as well as by context.
4. Step four, the search back and forth is carried out continuously until the most relevant publications are obtained.

Table 1. List of keywords as a literature search

	Indonesian Context	**Malaysian Context**	**General Context**
Keywords	“Renewable Energy” AND “Indonesia”	“Renewable Energy” AND “Malaysia”	“Renewable Energy”
	“Solar Energy” AND “Indonesia”	“Solar Energy” AND “Malaysia”	“Solar Energy”
	“Bamboo for Biomass Energy” AND “Indonesia”	“Bamboo for Biomass Energy” AND “Malaysia”	“Bamboo for Biomass Energy”

3. Results and Discussion

3.1 Classification Result

From reading the selected literature, patterns, similarities, and discrepancies among and between literature are observable. Past studies could be grouped into the focus/approach and the context/theme as depicted in Figures 1 and 2. In this study, the context is focused on Indonesia and Malaysia, with studies related to energy derived from bamboo, solar power, and renewable energy in general.

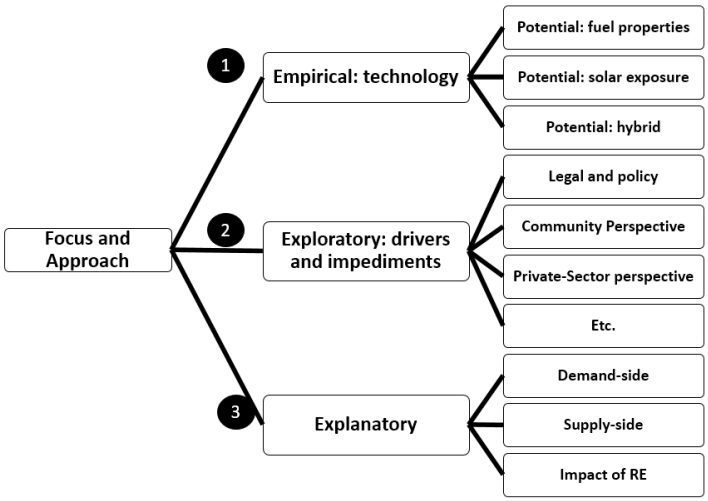

Figure 1. Literature classification based on focus and approach

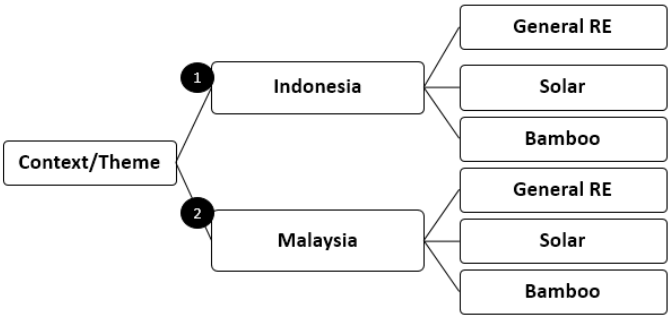

Figure 2. Literature classification based on context

3.2 Empirical: Technology

This section discusses the literature using an empirical approach. Table 2. shows a research map related to renewable energy in Malaysia and Indonesia with an empirical approach. Research on 'empirical: technology' focuses on identifying the potential of some renewable energy sources and the possible technologies used to harvest the energy. Studies in this group utilized empirical perspectives, such as surveys and experiments. For instance, Sucipta et al. (2017) identified the energy potential of specified bamboo species (Ampel) in Indonesia. The low ash, nitrogen, silica, and water content show that Ampel bamboo has promising potential as a fuel. In addition, Ampel bamboo is also environmentally friendly. A similar study was conducted by Park et al. (2019). He examined the energy potential of six bamboo species in Indonesia (Andong, Black, Tali, Kuning, Ampel, and Betung). The results were then compared to the most widely spread Bamboo in Asia, namely Moso Bamboo. It was found that the calorific values of the six bamboo species in Indonesia were comparable to this of Moso. Notably, Ampel bamboo has the highest calorific value level among the observed species. Ampel bamboo is also considered the most suitable bamboo for use as a charcoal making material with the most efficient heating/combustion temperature of 200 degrees. The research also showed that most bamboo species in Indonesia have good potential as biomass and can be used in a variety of manufacturing conditions. The possibility of other bamboo species in Indonesia is studied by Suluh et al. (2019) in the form of briquettes. It was found that Petung bamboo has the most calorific value, followed by Apus bamboo and then Wulung bamboo. From these studies, it can be concluded that most bamboo species in Indonesia have good potential as biomass.

Selected research from Malaysia focuses on the methods used to treat bamboos. Lam et al. (2019) and Saifuddin et al. (2016) with the microwave pyrolysis approach and Rahim et al. (2018) with ultrasonic probe approach on Ionic liquid.

An interactive web has been developed to collect data and offer up-to-date information on the potential solar energy of various countries (Korfiati et al., 2016). Moreover, some studies (Annandale et al., 2002) (Tanaka et al., 2006) develop models to estimate solar energy potential. The models measured radiation potential with differences hourly

and monthly. Meanwhile, the reported distribution of solar power on the island of Java, particularly East Java, has a higher energy potential and is more stable than in eastern Indonesia (Wahyuono and Julian, 2018).

Table 2. Research Map (Empirical Research)

RESULT (1)			CONTEXT / THEME					
			INDONESIA			MALAYSIA		
			Renewable Energy (General)	Solar Energy	Bamboo For Biomass Energy	Renewable Energy (General)	Solar Energy	Bamboo For Biomass Energy
FOCUS & APPROACH	EMPIRICAL STUDIES ON PROSPECTIVE TECHNOLOGY	Potential: fuel properties & material characterization			(Park et al., 2019; Purbasari et al., 2016; Sucipta et al., 2017; Suluh et al., 2019)			(Lam et al., 2019; Rahim et al., 2018; Saifuddin et al., 2016)
		Potential: Solar Radiation		(Budiyanto, 2017; Korfiati et al., 2016; Tiandho et al., 2019)			(Markos & Sentian, 2016; Mohammad et al., 2020)	
		Potential: Estimation Of Hydro And Solar Energy Output		(Agung Wahyuono & Magenika Julian, 2018)				
		Hybrid Configuration Simulation (Homer Software)	(Shezan et al., 2018)	(Syahputra & Soesanti, 2020)		(Haidar et al., 2011)	(Das et al., 2017)	

3.3 Exploratory: Drivers & impediments

This section discusses the literature using an exploratory approach. Table 3. shows a research map related to renewable energy in Malaysia and Indonesia with an exploratory approach. Exploratory research discusses the possible supporting factors and obstacles of planning and implementation of renewable energy projects. Such studies were often carried out by using exploratory approach. Indonesia and Malaysia have solar energy potential because they are located on the equator (Sigalingging et al., 2016; Soonmin et al., 2019; Wahid et al., 2017). The prospect of bamboo as renewable energy has also been discussed for Indonesia and Malaysia (Chin et al., 2017; Kaur et al., 2019; Samsul Rizal et al., 2018; Sharma et al., 2018).

Hermawati and Rosaira (2017) explained that renewable energy projects could be effectively carried out due to various drivers, namely project planning, community participation, active communication and beneficiaries, project and institutional management, support from local governments and stakeholders, and network development. Nugroho et al. (2017) asserted that financial challenges about renewable energy projects in the countryside should be addressed with the community and the private sector. In addition, some renewable energy can be combined into one with conventional generators. Another essential factor for a succesful RE project is policy, which should be developed collectively by stakeholders. Policymaking should incorporate government with the community and stakeholders. Environmental concerns are a major contributing factor to the adoption of photovoltaic technology, while the biggest inhibitory factor is the cost of project investment. Cost reduction also does not necessarily make people want to use photovoltaic technology, it is because people have different behaviors and preferences (Nurwidiana et al., 2021). The vital role of the Malaysian government has been explained by Vaka et al. (2020). The Malaysian government's policy is to implement a reduction in tax costs on renewable energy users. The Malaysian government is also targeting a significant investment in renewable energy projects of 5 billion ringgit or 1.1 billion dollars for 2020.

From a policy and legal perspective, the Government of Indonesia has developed a plan to implement renewable energy for 2025 in five provinces in Indonesia. The planning step was kept generic to accommodate unique variations. (Winarno et al., 2017). Policymaking can ideally ensure that power generation technology can compete and has included external costs (Burke et al., 2019). From a community perspective, it can be seen that the community level has a significant role in the results of renewable energy projects. Success in renewable energy projects in communities can occur if forces inside and outside the community can be put to good use. There needs to be a bridge between internal and external parties; there is an Ibeka foundation (Guerreiro and Botetzagias, 2018). Maulidia et al. (2019) discussed from a private sector perspective that the difficulty of renewable energy development is due to bureaucracy, especially on licensing, and the quality of developers who are still not good. Another difficulty is the monopoly factor

of existing power generation companies. Several factors can affect the supply chain system based on bamboo renewable energy like biomass, including program objectives, program needs, community sectors, constraints, possible changes, and related agencies (Wahono et al., 2018). Udin (2020) discusses renewable energy from a human resource perspective. Indonesia considers the importance of renewable energy and human resources so that infrastructure and human resource development can run together to create a better future. Other problems that need to be solved according to Yah et al. (2017) include energy tariffs, financial levels and subsidies for fossil fuel producers; and deficiencies in program design, resistance and regulatory failures.

Things that can be done from a marketing/economic standpoint to raise interest in renewable energy projects include: Increasing the Institute of Sciences' and the Indonesian Ministry of Research and Technology's engagement and funding in research into the location of alternative energy potential in Indonesia, as well as the technology that best meets Indonesia's geographical characteristics; Establish laws for alternative energy power plants and provide tax incentives for them; Alternative energy plant development and operation are more accessible than fossil energy generation; Facilitate rules to include electric vehicles in comparison to traditional cars, hence increasing demand for electric power and attracting investors to invest in Indonesia; Setting a purchase price for alternative energy from the government or PLN, Indonesia's state-owned electric power management company, that is more expensive or at least comparable to the cost of fossil energy promotes investor interest; Pertamina gas stations building electric vehicles gas stations (Arafah et al., 2018). Another study discussing marketing/economy by Tabassum et al. (2017) ensures that solar energy is feasible in Malaysia and may beat alternative energy. The most suitable technology applied is photovoltaic. Wei and Saad (2020), on a case study in Malaysia, carried out two observations. The first scheme calculates payback periods with FiT and NEM systems. The second scheme calculates payback periods and Return on Investment (ROI) with FiT and NEM systems. It was found that the fastest payback period of the first PV project scheme was 8.7 years, for the second scheme was 8.2 years. ROI is 155.03% for FiT, 203.65% for NEM.

Table 3. Research Map (Exploratory Research)

RESULT [2]			CONTEXT / THEME					
			INDONESIA			MALAYSIA		
			Renewable Energy (General)	Solar Energy	Bamboo For Biomass Energy	Renewable Energy (General)	Solar Energy	Bamboo For Biomass Energy
FOCUS & APPROACH	EXPLORATORY STUDIES ON DRIVERS & IMPEDIMENTS	General	(Hermawati & Rosaira, 2017; Nugroho et al., 2017)	(Nurwidiana et al., 2021; Sigalingging et al., 2016; Soonmin et al., 2019)	(Sharma et al., 2018)	(Chien Bong et al., 2017; Sovacool & Drupady, 2011; Yah et al., 2017)	(Vaka et al., 2020; Wahid et al., 2017)	(Chin et al., 2017; Kaur et al., 2019; Samsul Rizal et al., 2018)
		Policy & Legal Perspectives	(Winarno et al., 2017)	(Burke et al., 2019)				
		Community Perspective	(Guerreiro & Botetzagias, 2018; Nugroho et al., 2017)					
		Private Sector Perspective	(Maulidia et al., 2019; Nugroho et al., 2017)					
		Supply Chain Partnership Perspective	(Mustikaningsih et al., 2019)		(WAHONO et al., 2018)			
		Human Resource Perspective	(Udin, 2020)					
		Marketing/Economy Perspectives	(Arafah et al., 2018)				(Tabassum et al., 2017; Wei & Saad, 2020)	

3.4 Explanatory

This section discusses the literature using an explanatory approach. Table 4. shows a research map related to renewable energy in Malaysia and Indonesia with an explanatory approach. A study by Malik and Ayop (2020) in Malaysia utilized the Technology Acceptance Model and found that people support government initiatives to increase their income through solar energy technology. Kardooni et al. (2016) explained that the high cost influenced the community's renewable energy intention. Price affects users' motivation to use renewable energy indirectly. The Indonesian government has the challenge to find effective ways that solar energy can be adopted quickly to meet renewable energy goals (Setyawati, 2020). Research by Lau et al. (2020) also found that the cost factor is the most

influential thing for the community before using PV technology. Knowledge and social influences can also affect PV installations; consumers with high knowledge can more influence their environment to use the technology. Solar PV technology companies should take advantage of these observations by increasing their marketing efforts and including existing users in their promotional efforts. A study by Teoh et al. (2020) found that while communities knew renewable energy, they did not qualify second, with respondents exhibiting somewhat disappointing levels of energy-efficient behavior. In addition, despite having the desire to install PV panels, respondents were hesitant to realize the desire because of the cost. The use of wood and bamboo fuels that do not have rules can create environmental damage, and this is because Indonesian people have a significant role in ecological conditions, especially forests. Government intervention does not make forest conditions improve. In areas that have used wood and bamboo as their primary fuel, governments should create alternative energy policies and programs instead (Lee et al., 2015).

Malaysia has managed to diversify the fuel mix for power generation from oil to natural gas in the Malaysian context in terms of supply. However, the share of renewable sources is minimal, and electricity demand in Malaysia will likely increase in the future. The potential of renewable energy has also been measured, that solar and biomass energy is potential energy in Malaysia and needs to be further developed. Adopting multicriteria tools is essential for policymakers and planners to perform detailed analysis from a multi-perspective and get optimal solutions (Ahmad and Tahar, 2014). The Supply chain partnership perspective discussed in research by Mustikaningsih et al. (2019) explained that supply chain performance and dynamic capabilities impact business performance in Indonesia. Supply chain performance is influenced by the quality of relationships, while supplier resources have the most role in improving business performance.

Table 4. Research Map (Explanatory Research)

RESULT [3]				CONTEXT / THEME					
				INDONESIA			MALAYSIA		
				Renewable Energy (General)	Solar Energy	Bamboo For Biomass Energy	Renewable Energy (General)	Solar Energy	Bamboo For Biomass Energy
FOCUS & APPROACH	EXPLANATORY STUDIES	Demand side	Technology Acceptance Model (Descriptive)					(Malik & Ayop, 2020)	
			Intention to use RE		(Setyawati, 2020)		(Kardooni et al., 2016)	(Lau et al., 2020)	
			Potential costomers' readiness, attitude, behavior					(Teoh et al., 2020)	
			Household energy pattern			(Lee et al., 2015)			
			Trade-off Preferences		Harjanto and Ambarsari (2020)			Harjanto and Ambarsari (2020)	
		Supply	Supply Chain performance	(Mustikaningsih et al., 2019)					
			Analytic Hierarchy Process				(Ahmad & Tahar, 2014)		
		Impact of RE	Impact of RE. ARIMA				(Aeknarajindawat et al., 2020)		
			Impact of RE: Environmental Kuznets Curve (Autoregressive Distributed Lag (ARDL))	(Sugiawan & Managi, 2016)			(Gill et al., 2018; Haseeb et al., 2019; Saudi et al., 2019)		

Aeknarajindawat et al. (2020) indicated that renewable energy has a positive impact on carbon dioxide emissions, i.e., as renewable energy in a country grows, carbon dioxide emissions decrease. Moreover, the influence of natural resources on carbon dioxide emissions is positive, i.e., when there is an increase in natural resources, there will be an increase in emissions. The effect of economic growth on carbon dioxide emissions is positive. In short, renewable energy may reduce carbon dioxide emissions, while economic development positively affects carbon dioxide emissions. Research by Sugiawan and Managi (2016) shows that the long-term impact/effects of energy consumption

when viewed from carbon dioxide emission levels are much higher than the short-term impact/effects. These findings suggest there is inefficient energy consumption/use that can then cause environmental damage. Other findings, the beneficial impact of electricity production using renewable energy with the aim to reduce carbon dioxide emissions shows that environmental sustainability can be achieved and maintained by increasing the demand of renewable energy. The findings are also consistent with Saudi et al. (2019), who found that consumption of renewable energy and technological advancements have a negative impact on carbon dioxide emissions, whereas consumption of non-renewable energy and economic growth have a positive impact. In the short and long term, the use of renewable energy has a positive impact on the economy. The use of renewable energy also has an encouraging effect on the economic sector in the short and long term (Haseeb et al., 2019).

The implementation of renewable energy technology needs to be studied in order to be carried out effectively (Hermawati and Rosaira, 2017; Sovacool and Drupady, 2011). From Tables 2,3, and 4, it can be seen that there are many empty spaces that can be filled by researchers related to renewable energy in Indonesia and Malaysia. The biggest empty space that can be filled is with an exploratory approach such as community perspective, policy & legal perspective, supply chain partnership, human resource perspective and economy perspective. Another empty space that can be filled is related to supply which can be filled with other perspectives (Ahmad and Tahar, 2014).

4. Conclusion and Recommendations

It can be concluded from the literature that renewable energy research in Indonesia and Malaysia is still limited. Suggestions for further research include follow-on in-depth case studies on implementing renewable energy technology in Indonesia and Malaysia. Another recommendation from an ecosystem perspective is to discuss regulations/policies, politics, economy, environment, and energy security. Future studies could elaborate on various factors, such as: 'social acceptance,' 'trust,' 'distributional justice', and 'emotional factors'. Studies on the supply side may discuss risk-based, system-wide feasibility analysis, LCA, and MCDA.

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References

Aeknarajindawat, N., Suteerachai, B., and Suksod, P. (2020). The impact of natural resources, renewable energy, economic growth on carbon dioxide emission in Malaysia. *International Journal of Energy Economics and Policy*, *10*(3), 211–218. https://doi.org/10.32479/ijeep.9180

Ahmad, S., and Tahar, R. M. (2014). Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. *Renewable Energy*, *63*, 458–466. https://doi.org/10.1016/j.renene.2013.10.001

Alam, S. S., Nor, N. F. M., Ahmad, M., and Hashim, N. H. N. (2016). A survey on renewable energy development in Malaysia: Current status, problems and prospects. *Rigas Tehniskas Universitates Zinatniskie Raksti*, *17*, 5.

Annandale, J., Jovanovic, N., Benade, N., and Allen, R. (2002). Software for missing data error analysis of Penman-Monteith reference evapotranspiration. *Irrigation Science*, *21*(2), 57–67.

Arafah, W., Nugroho, L., Takaya, R., and Soekapdjo, S. (2018). Marketing Strategy for Renewable Energy development In Indonesia Context Today. *International Journal of Energy Economics and Policy* |, *8*(5), 181–186. http:www.econjournals.com

Badan Pusat Statistik. (2021). *Hasil Sensus Penduduk 2020*.

Bujang, A. S., Bern, C. J., and Brumm, T. J. (2016). Summary of energy demand and renewable energy policies in Malaysia. *Renewable and Sustainable Energy Reviews*, *53*, 1459–1467. https://doi.org/https://doi.org/10.1016/j.rser.2015.09.047

Burke, P. J., Widnyana, J., Anjum, Z., Aisbett, E., Resosudarmo, B., and Baldwin, K. G. H. (2019). Overcoming barriers to solar and wind energy adoption in two Asian giants: India and Indonesia. *Energy Policy*, *132*(April), 1216–1228. https://doi.org/10.1016/j.enpol.2019.05.055

Chin, K. L., Ibrahim, S., Hakeem, K. R., H'ng, P. S., Lee, S. H., and Mohd Lila, M. A. (2017). Bioenergy production from Bamboo: Potential source from Malaysia's perspective. *BioResources*, *12*(3), 6844–6867. https://doi.org/10.15376/biores.12.3.6844-6867

Erdiwansyah, Mahidin, Mamat, R., Sani, M. S. M., Khoerunnisa, F., and Kadarohman, A. (2019). Target and demand for renewable energy across 10 ASEAN countries by 2040. *The Electricity Journal*, *32*(10), 106670.

https://doi.org/https://doi.org/10.1016/j.tej.2019.106670

Glock, C. H., and Hochrein, S. (2011). Purchasing Organization and Design: a literature review. *Business Research*, *4*(2), 149–191.

Guerreiro, S., and Botetzagias, I. (2018). Empowering communities–the role of intermediary organisations in community renewable energy projects in Indonesia. *Local Environment*, *23*(2), 158–177. https://doi.org/10.1080/13549839.2017.1394830

Haseeb, M., Abidin, I. S. Z., Hye, Q. M. A., and Hartani, N. H. (2019). The impact of renewable energy on economic well-being of Malaysia: Fresh evidence from auto regressive distributed lag bound testing approach. *International Journal of Energy Economics and Policy*, *9*(1), 269–275. https://doi.org/10.32479/ijeep.7229

Hermawati, W., and Rosaira, I. (2017). Key Success Factors of Renewable Energy Projects Implementation in Rural Areas of Indonesia. *STI Policy and Management Journal*, *2*(2), 111. https://doi.org/10.14203/stipm.2017.122

Kardooni, R., Yusoff, S. B., and Kari, F. B. (2016). Renewable energy technology acceptance in Peninsular Malaysia. *Energy Policy*, *88*(2016), 1–10. https://doi.org/10.1016/j.enpol.2015.10.005

Kaur, P. J., Pant, K. K., and Kaushik, G. (2019). Properties and Importance of Various Bamboo Species for Multi-Utility Applications. In *Sustainable Agriculture, Forest and Environmental Management*. https://doi.org/10.1007/978-981-13-6830-1_8

Korfiati, A., Gkonos, C., Veronesi, F., Gaki, A., Grassi, S., Schenkel, R., Volkwein, S., Raubal, M., and Hurni, L. (2016). Estimation of the global solar energy potential and photovoltaic cost with the use of open data. *International Journal of Sustainable Energy Planning and Management*, *9*, 17–29. https://doi.org/10.5278/ijsepm.2016.9.3

Lam, S. S., Azwar, E., Peng, W., Tsang, Y. F., Ma, N. L., Liu, Z., Park, Y. K., and Kwon, E. E. (2019). Cleaner conversion of bamboo into carbon fibre with favourable physicochemical and capacitive properties via microwave pyrolysis combining with solvent extraction and chemical impregnation. *Journal of Cleaner Production*, *236*, 1–11. https://doi.org/10.1016/j.jclepro.2019.117692

Lau, H. C., Zhang, K., Bokka, H. K., and Ramakrishna, S. (2022). A Review of the Status of Fossil and Renewable Energies in Southeast Asia and Its Implications on the Decarbonization of ASEAN. *Energies*, *15*(6). https://doi.org/10.3390/en15062152

Lau, L. S., Choong, Y. O., Wei, C. Y., Seow, A. N., Choong, C. K., Senadjki, A., and Ching, S. L. (2020). Investigating nonusers' behavioural intention towards solar photovoltaic technology in Malaysia: The role of knowledge transmission and price value. *Energy Policy*, *144*(May), 111651. https://doi.org/10.1016/j.enpol.2020.111651

Lee, S. M., Kim, Y. S., Jaung, W., Latifah, S., Afifi, M., and Fisher, L. A. (2015). Forests, fuelwood and livelihoods-energy transition patterns in eastern Indonesia. *Energy Policy*, *85*, 61–70. https://doi.org/10.1016/j.enpol.2015.04.030

Malik, S. A., and Ayop, A. R. (2020). Solar energy technology: Knowledge, awareness, and acceptance of B40 households in one district of Malaysia towards government initiatives. *Technology in Society*, *63*(May), 101416. https://doi.org/10.1016/j.techsoc.2020.101416

Maulidia, M., Dargusch, P., Ashworth, P., and Ardiansyah, F. (2019). Rethinking renewable energy targets and electricity sector reform in Indonesia: A private sector perspective. *Renewable and Sustainable Energy Reviews*, *101*(October 2018), 231–247. https://doi.org/10.1016/j.rser.2018.11.005

Mustikaningsih, D., Cahyandito, M. F., Kaltum, U., and Sarjana, S. (2019). Building business performance through partnership strategy model: Evidence from renewable energy industry in Indonesia. *International Journal of Energy Economics and Policy*, *9*(5), 297–307. https://doi.org/10.32479/ijeep.7780

National Energy Council. (2015). Executive Reference Data: National Energy Management. In *Booklet*. DEN Jakarta.

Nugroho, H., Fei-Lu, S., and Firmansyah. (2017). Developing renewable energy in developing countries: A lesson from Indonesia. *Energy Sources, Part B: Economics, Planning and Policy*, *12*(4), 318–325. https://doi.org/10.1080/15567249.2015.1072599

Nurwidiana, N., Sopha, B. M., and Widyaparaga, A. (2021). Modelling photovoltaic system adoption for households: A systematic literature review. *Evergreen*, *8*(1), 69–81. https://doi.org/10.5109/4372262

Ong, H. C., Mahlia, T. M. I., and Masjuki, H. H. (2011). A review on energy scenario and sustainable energy in Malaysia. *Renewable and Sustainable Energy Reviews*, *15*(1), 639–647. https://doi.org/https://doi.org/10.1016/j.rser.2010.09.043

Park, S. H., Jang, J. H., Wistara, N. J., Febrianto, F., and Lee, M. (2019). Fuel properties of Indonesian Bamboo Carbonized at different temperatures. *BioResources*, *14*(2), 4224–4235. https://doi.org/10.15376/biores.14.2.4224-4235

Rahim, A. H. A., Yunus, N. M., Man, Z., Sarwono, A., Hamzah, W. S. W., and Wilfred, C. D. (2018). Ultrasonic assisted dissolution of bamboo biomass using ether-functionalized ionic liquid. *AIP Conference Proceedings*,

2016, 1–6. https://doi.org/10.1063/1.5055412

Saifuddin, N., Priatharsini, P., and Hakim, S. B. (2016). Microwave-assisted co-pyrolysis of Bamboo biomass with plastic waste for hydrogen-rich syngas production. *American Journal of Applied Sciences*, *13*(5), 511–521. https://doi.org/10.3844/ajassp.2016.511.521

Samsul Rizal, A. K. H. . S., Samsul Rizal, A. K. H. . S., Ikramullah, Irshad Ul Haq Bhat, S. H., Ikramullah, Irshad Ul Haq Bhat, S. H., Sulaiman Thalib, A. M. and, Sulaiman Thalib, A. M. and, and Saurabh, C. K. (2018). Recent Advancement in Physico-Mechanical and Thermal Studies of Bamboo and Its Fibers. *Web of Science*, *9*, 145–164.

Saudi, M. H. M., Sinaga, O., and Jabarullah, N. H. (2019). The role of renewable, non-renewable energy consumption and technology innovation in testing environmental Kuznets curve in Malaysia. *International Journal of Energy Economics and Policy*, *9*(1), 299–307. https://doi.org/10.32479/ijeep.7327

Setyawati, D. (2020). Analysis of perceptions towards the rooftop photovoltaic solar system policy in Indonesia. *Energy Policy*, *144*(May), 111569. https://doi.org/10.1016/j.enpol.2020.111569

Shah, K. N. A. K. A., Yusop, M. Z. M., Rohani, J. M., Fadil, N. A., Hasan, M. F., Yasin, M. F. M., Kamaruzaman, N., Bakar, E. M. N. E. A., Samion, S., Yahya, M. Y., Manaf, N. A., Hartono, B., Tuyen, N. D., Masaki, T., Ahmad, A. S., and Ramli, A. (2021). Solar and biomass potential of renewable energy in selected ASEAN countries and Japan. *Journal of Physics: Conference Series*, *2053*(1). https://doi.org/10.1088/1742-6596/2053/1/012018

Sharma, R., Wahono, J., and Baral, H. (2018). Bamboo as an alternative bioenergy crop and powerful ally for land restoration in Indonesia. *Sustainability (Switzerland)*, *10*(12), 1–10. https://doi.org/10.3390/su10124367

Sigalingging, R., Sigalingging, J. W. C., and Herák, D. (2016). Solar energy opportunities for Indonesia agricultural systems. *TAE 2016 - Proceedings of 6th International Conference on Trends in Agricultural Engineering 2016*, *2016-Septe*(September), 583–587.

Soonmin, H., Lomi, A., Okoroigwe, E. C., and Urrego, L. R. (2019). Investigation of solar energy: The case study in Malaysia, Indonesia, Colombia and Nigeria. *International Journal of Renewable Energy Research*, *9*(1), 86–95.

Sovacool, B. K., and Drupady, I. M. (2011). Examining the Small Renewable Energy Power (SREP) Program in Malaysia. *Energy Policy*, *39*, 7244–7256. https://doi.org/https://doi.org/10.1016/j.enpol.2011.08.045

Sucipta, M., Putra Negara, D. N. K., Tirta Nindhia, T. G., and Surata, I. W. (2017). Characteristics of Ampel bamboo as a biomass energy source potential in Bali. *IOP Conference Series: Materials Science and Engineering*, *201*(1). https://doi.org/10.1088/1757-899X/201/1/012032

Sugiawan, Y., and Managi, S. (2016). The environmental Kuznets curve in Indonesia: Exploring the potential of renewable energy. *Energy Policy*, *98*, 187–198. https://doi.org/10.1016/j.enpol.2016.08.029

Suluh, S., Sampelawang, P., and Sirande, N. (2019). An Analysis of the Use of Local Bamboo as an Alternative Energy Source. *IOP Conference Series: Materials Science and Engineering*, *619*(1). https://doi.org/10.1088/1757-899X/619/1/012006

Tabassum, M., Bin, S., and Kashem, A. (2017). *Feasibility of Using Photovoltaic (PV) Technology to Generate Solar Energy in Sarawak*. 11–16.

Tanaka, S., Takeda, H., Tsuchiya, T., Iwata, T., Michijin, T., Akimoto, and T. (2006). *Latest architectural environment engineering* (4th editio). Inoue Shoin.

Teoh, A. N., Go, Y. I., and Yap, T. C. (2020). Is Malaysia Ready for Sustainable Energy? Exploring the Attitudes toward Solar Energy and Energy Behaviors in Malaysia. *World*, *1*(2), 90–103. https://doi.org/10.3390/world1020008

Udin, U. (2020). Renewable energy and human resource development: Challenges and opportunities in Indonesia. *International Journal of Energy Economics and Policy*, *10*(2), 233–237. https://doi.org/10.32479/ijeep.8782

UNDP, U. (2000). WEC–"World Energy Assessment–Energy and the Challenge of Sustainability"–UNDP. *New York, NY, USA*.

Vaka, M., Walvekar, R., Rasheed, A. K., and Khalid, M. (2020). A review on Malaysia's solar energy pathway towards carbon-neutral Malaysia beyond Covid'19 pandemic. *Journal of Cleaner Production*, *273*, 122834. https://doi.org/10.1016/j.jclepro.2020.122834

Wahid, S. S. A., Ramli, M. S., Noorden, Z. A., Hassan, K. K., and Azli, S. A. (2017). A review on highlights and feasibility studies on solar energy utilization in Malaysia. *AIP Conference Proceedings*, *1875*. https://doi.org/10.1063/1.4998385

Wahono, J. W., Wijanarko, B. D., Sumarwan, U., Arifin, B., and Purnomo, H. (2018). Sustainable Supply Chain in the Development of Renewable Energy Base on Bamboo Forest Biomass (Development Solution for Underdeveloped Areas in Indonesia). *Journal of Business Studies and Mangement Review*, *1*(2), 79–88. https://doi.org/10.22437/jb.v1i2.5356

Wahyuono, R. A., and Julian, M. M. (2018). Revisiting Renewable Energy Map in Indonesia: Seasonal Hydro and Solar Energy Potential for Rural Off-Grid Electrification (Provincial Level). *MATEC Web of Conferences*, *164*, 1–11. https://doi.org/10.1051/matecconf/201816401040

Wei, C. K., and Saad, A. Y. (2020). The Potential of Solar Energy for Domestic and Commercial Buildings in Malaysia. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *75*(3), 91–98. https://doi.org/10.37934/arfmts.75.3.9198

Winarno, O. T., Alwendra, Y., and Mujiyanto, S. (2017). Policies and strategies for renewable energy development in Indonesia. *2016 IEEE International Conference on Renewable Energy Research and Applications, ICRERA 2016*, *5*, 270–272. https://doi.org/10.1109/ICRERA.2016.7884550

Yah, N. F., Oumer, A. N., and Idris, M. S. (2017). Small scale hydro-power as a source of renewable energy in Malaysia: A review. *Renewable and Sustainable Energy Reviews*, *72*(January), 228–239. https://doi.org/10.1016/j.rser.2017.01.068

Biographies

Zakiyyan Zain Alkaf was born in Banyumas, November 4, 1997, having completed the Bachelor program in Industrial Engineering at the Faculty of Industrial Technology, Universitas Islam Indonesia in 2019. Currently, he continues his studies in the Graduate Program in Industrial Engineering (S-2) at the Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta. Interest in studies from the field of industrial engineering that he has been in until now in the Master Program in Industrial Engineering, namely Project Management and Lean Manufacturing. The focus of interest in previous undergraduate levels is on Lean Manufacturing. While the current master's study focuses more on project management. In addition to studying in college, he also participated in research programs/projects to develop his experience and knowledge. In the program, his research is related to one of the areas of study that he is interested in, namely Project Management. The research discusses renewable energy projects, especially in Indonesia. The author can be reached by email: zakiyyan.zain.alkaf@mail.ugm.ac.id

Budi Hartono earned his bachelor's degree in 1999 from the Mechanical Engineering Department, Institut Teknologi Bandung, Indonesia. He earned his Master of Project Management degree in 2004 from the University of Queensland (UQ), Australia. He earned his Ph.D. in 2012 from the National University of Singapore (NUS). He is a professor of Industrial Engineering, Mechanical and Industrial Engineering Department, Universitas Gadjah Mada, Indonesia. His research interests include project management, risk analysis and complexity and systems approaches. He was a former Director of Project Management Institute, Indonesia Chapter, Yogyakarta Branch. The author can be reached by email: boed@gadjahmada.edu