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Research article

Breaking barriers to low-carbon development in Indonesia: deployment of renewable energy

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ABSTRACT

The Indonesian government is incorporating Low-Carbon Development (LCD) into its National Medium-Term Development Plan 2020–2024. In the future, the energy sector will become the largest carbon emitter unless the government commits to dissolving barriers to renewable energy expansion. Literature studies indicate four barriers to LDC namely socio-cultural, economic, technology, and governance. This research aims to examine the barriers that hinder the implementation of LCD in Indonesia and to analyze which barriers are most significant. This study uses mixed methods. Qualitative and quantitative data were generated during fieldwork in DKI Jakarta, Bali, West Nusa Tenggara, and Bangka Belitung provinces. The Partial Least Square – Structural Equation Modeling (PLS-SEM) approach was used to measure the direction and strength of the relationship. The qualitative approach is useful for further deepening the provincial context that was not captured from the previous approach. This study indicates that among those four barriers, technological and governance barriers have negative significant and direct effects on LCD, and governance needs to be treated as the most critical barrier. This study emphasizes the importance of collaboration between central and local governments in implementing LCD. Shared vision, equal responsibilities, commensurate governance roles, development of fiscal instruments, can improve the coherence and continuity of renewable energy development programs and activities.

1. Introduction

Climate change is a major concern in both global and national contexts. International commitment to reduce greenhouse gas (GHG) emissions was codified in the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. Indonesia ratified the UNFCCC through Law No. 6 Year 1994. The convention was followed by the Kyoto Protocol in 1997, which was adopted ten years later in Indonesia through Law No. 17 Year 2004. The law notes that Indonesia can be one of the key players in overcoming the challenges posed by climate change due to its natural resource potential, including large forests that are vital for carbon sequestration.

In 2011, Indonesia targeted a 26% reduction in GHG emissions by 2030 compared to the baseline, as outlined in the Presidential Decree No. 61 Year 2011 on the National Action Plan for GHG Emission Reduction (known as RAN-GRK). By implementing a participatory approach, RAN-GRK requires each province in Indonesia including local governments and stakeholders to actively contribute to the Local Action Plan for GHG Emission Reduction (known as RAD-GRK). Then, in 2016, Indonesia signed the Paris Agreement and set up a new target on carbon reduction. Based on the Nationally Determined Contribution (NDC), its government committed to reducing emissions by 29% (on its own) or 41% (with international support) from the Business as Usual (BaU) scenario by 2030. Indonesia also initiated Low-Carbon Development (LCD) planning to integrate climate change mitigation policies into its national development program, as mandated by Article 3.4 of the UNFCCC.

The LCD policy has been integrated into the National Medium-Term Development Plan (RPJMN) 2020–2024 to emphasize commitment to the environment. RPJMN stated that by 2024, the Indonesian government aims to reduce GHG emissions by 27.3% compared to the baseline and increase the share of new and renewable energy by about 20%. The Indonesian government has drafted a long-term strategy on low carbon and climate resilience 2050, and with an ambitious target Indonesian plan to reach net-zero emission by 2060 or sooner.

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According to, the largest source of emissions by 2030 is predicted to come from the energy sector, which will generate about 1,669 MTon CO_2 under the BaU scenario in 2030. However, by pursuing the national LCD strategy, emissions from the energy sector can be decreased by 11% of total BaU in 2030. This includes policies promoting efficiency in energy consumption, implementation of clean coal technology for power generators, the utilizing of new and renewable energy in power generators, the utilizing of biofuel in the transportation sector, extending gas networks, and developing gas stations.

The aim of LCD is not only to reduce emissions following the Paris Agreement but also to increase economic growth and reduce poverty. The Indonesian government has mentioned LCD in the National Medium Development Plan 2020–2024. This covered three main programs such as renewable energy, energy efficiency, and fuels substitution from oil to biofuel. A study by predicts that reducing emissions by 43% (high-LCD scenario) in 2030 will allow the Indonesian economy to grow by 6% per year while simultaneously preventing a loss of 16 million ha in forests, improving air quality and living standards, and reducing mortality rates by up to 40,000 deaths per year between 2019 and 2045. However, this outcome depends on total commitment to reduce the consumption of fossil fuels. Increasing fossil fuel consumption would be costly in terms of air pollution, CO_2 emissions, government subsidies, and public health.

Although LCD is expected to eliminate the trade-off between development and lowering emissions, Jin et al. (2020) highlight the term 'weak decoupling' and the empirical studies have not provided strong confirmation for this conclusion. This indicates that the impact of LCD on the economy cannot be generalized, each country has a different economic structure, even for the analysis within the country, the results may differ. On the other hand, Belaïd et al. (2020) showed positive causation between income inequality and environmental degradation. They argued that there is a trade-off between environmental policies and policies that aims to reduce income inequality. They arguments implied that policy to reduce income inequality should not lead to an increase in carbon emissions, except in the case of low-income countries, a trade-off is absent. In the case of Indonesia, Setyadharma et al. (2020), said that efforts to reduce poverty have an impact on decreasing environmental quality. Likewise, Kusumawardani & Dewi (2020), said income inequality needs to be part of policy formulation to encourage economic growth, and reduce carbon emissions. Thus, it appears that in the case of Indonesia, there is a trade-off.

Omri and Belaïd (2021) argued that renewable energy has great potential to rebalance environmental, social, and economic goals. The Indonesian government has committed to increase the share of renewable energy in energy mixed. The share of new and renewable energy to the primary energy supply was about 22.55% in 2020 (excluding biomass), while in 2010 the share was about 10.8%. With the same data, in case of the electricity sector, total installed capacity for conventional (fossil-based) energy remains dominant, and the share has been stagnant since 2010 at about 85.5% of installed capacity. Indonesia needs to continue to push for a bigger role of renewable energy. This is because based on the climate economics index ranking, of the 48 sample countries analyzed, Indonesia's position is in the 48th, meaning that Indonesia is the country most vulnerable to the impacts of climate change (Guo et al., 2021). This condition, of course, further encourages the need for awareness to actively participate in promoting low-carbon development. Consequently, it is important to analyze the barriers to implementing LCD in the renewable energy sector.

Scholars have mentioned some barriers to promote renewable energy, such as Seetharaman et al. (2019) find that social barriers to renewable energy include lack of public awareness, limited information, lack of skilled labor, and rejection by local communities. Cultural barriers to renewable energy development must also be considered, as demonstrated in a study by Sovacool (2009). Financing difficulties play a major role in economic barriers to the implementation of renewable energy (Adenle et al., 2017; Eleftheriadis and Anagnostopoulou, 2015; Yildiz, 2014). Weak adoption of technology has also been a barrier to LCD implementation, as Simarmata et al. (2014) have noted. Adenle et al. (2017) highlight that the most dominant barrier to developing renewable energy development in Africa has been limited institutional capacity, as compared to other factors affecting the implementation of LCD.

Indonesia's big ambitions will not be enough to reduce carbon emissions if the barriers to low-carbon development are not addressed immediately. This paper attempts to capture the views of stakeholders who have been involved in low-carbon development programs in the energy sector, where since 2011, the Indonesian government has implemented a series of actions both at the central and local levels to reduce carbon emissions such as in energy sector. In terms of methods, authors applied quantitative and qualitative approach, in contrast to Seetharaman et al. (2019) which uses a quantitative approach. The application of quantitative and qualitative research in low-carbon development studies has also been carried out by Okhariev and Trysnyuk (2019).

The objectives of this research are: (i) to examine barriers to implementing LCD in renewable energy in Indonesia; (ii) to examine the interconnections among these barriers; and (iii) to analyze which barriers are predominant and propose policy responses. This paper is organized into five sections. The introduction in section 1, developing state of the art including objectives and novelty, a review of previous studies and other published documents related to LCD barriers is provided. After that, the literature review in section 2 is not limited to Indonesia; it includes cases from other countries. Section 3 explains the methodology of this study, in which the path analysis conducted is described in more detail. Section 4 discusses research findings, and section 5 provides conclusions and policy recommendations that must be considered to successfully implement LCD.

2. Literature review

Wimbadi and Djalante (2020) provided a critical review on the terms decarbonization, low carbon development (LCD), and low carbon transition (LCT). They argued that by applying the systematic literature review (SLR) method, climate politics and major countries' interests have driven the conceptualization of the terms. They argued that decarbonization refers to an energy system that can be decoupling of CO_2 emissions and economic activities. This implies that CO_2 reduction will have a minimal or neutral impact on the economy. Then, they also said that LCT and LCD refer to the state or situation of development transition in pursuing net-zero CO_2 emissions. Finally, they argued that LCT puts pressure on long term process and demand for transforming or reconfigure the system, while LCD emphasized on a model of economic development that emit a minimum amount of CO_2 emissions.

Renewable energy has become a critical pillar for sustainable development. Tiba and Belaid (2020) provided a diagrammatic analysis that examines the relationship between renewable energy and the pillars of sustainable development consisting of environmental, economic, institutional, and social. They showed that the causality relationship is complex, and the main finding indicates that renewable energy is important for achieving a sustainable future. They also argued that renewable energy is a requisite condition for enhancing human well-being. However, the process of transformation and reconfiguration of development toward low emissions will have many obstacles. This paper focused on four major barriers such as socio-cultural, economic, technology and governance. Concerning governance barriers, it covers administrative, bureaucratic, actors' relations, and politics.

Sovacool (2009) showed that rejection of renewable energy in the United States from 2005 to 2008 has been linked to traditional values and attitudes surrounding consumption, freedom, control, and trust. His study indicates that these cultural barriers can further be explained in three ways. First, apathy and lack of understanding in the populace may

cause people to ignore the environmental costs incurred by continued reliance on fossil fuels. Second, perceptions of consumption and the abundance of energy resources may be associated with using energy-intensive devices and the attendant misconception that the energy supply will remain abundant, easily accessible, and affordable in the long term. These factors contribute to a lack of concern and awareness in society (also indicated by Adenle et al., 2017) around the urgency of developing and using renewable energy. Finally, psychological resistance can also encourage excessive energy consumption. People may be reluctant to sacrifice their comforts by switching to new energy products and may prefer to use fossil fuels that are considered to be cheaper, in terms of initial investment cost and price, than renewable energy.

Social barriers to renewable energy have been discussed by Seetharaman et al. (2019) in terms of "Not in My Backyard (NIMBY) syndrome". This indicates that people are fearful of losing sources of income. Locals often believe that renewable energy projects could threaten their livelihood, reflecting concern over opportunity costs. Meanwhile, the NIMBY syndrome exists when communal support is contingent on the renewable energy project not being located nearby. Furthermore, Lockwood (2013) notes that social barriers may also include producers or political elites prioritizing their short-term profits instead of sharing benefits with the local communities. For example, biofuel production can cause land conversion of rainforests or peat swamp forests and threaten the sustainability of the land originally worked by small farmers. This outcome would run contrary to the inclusive principle of LCD, which is concerned with the socio-economic interests of the poor.

In addition, economic barriers that can hinder the deployment of renewable energy include competition with fossil fuels and reliance on grants and subsidies from the government and a limited number of financial institutions, as well as high initial capital costs or intangible costs (Seetharaman et al., 2019). In the case of Indonesia, there are four issues recorded in the literature related to an electricity subsidy. First, electricity subsidy increases the financial fragility of electricity companies. Institute for Energy Economic and Financial Analysis (IEEFA) shows that PLN needs funding injection to strengthen the financial position without increasing electricity tariff. Second, providing more subsidies to existing customers can reduce financial resources to invest in the regions with low electrification for improving electricity access. Third, electricity subsidy under unequal electricity access does not only affect income inequality (in the context of geographic or location-based) but also at household levels. Finally, electricity subsidy may worsen the energy efficiency that had been realized due to tariff reform. Burke and Kurniawati (2018) found that since 2013, reform on electricity subsidy increased saving in annual electricity use by around 7% compared to pre-reform in 2015.

Technology has also been a barrier to LCD implementation. Challenges include limited technological infrastructure, the inability to operate and maintain technology, and the high costs of the technologies themselves (Adenle et al., 2017; Zhao et al., 2016). In addition, Nguyen et al. (2010) stated that major barriers to geothermal power technologies, particularly in Vietnam, include weak research and development (R&D) initiatives, lack of information, limited industrial capabilities, and poor policy frameworks. They also emphasized that obstacles to the penetration of renewable energy might also include poor policy frameworks, including procedures and mechanisms of renewable energy installation. Meanwhile, grid integration infrastructure poses one of the biggest problems for the development of renewable energy (Eleftheriadis and Anagnostopoulou, 2015; Seetharaman et al., 2019).

Several studies have correlated economic barriers with technological barriers. These include findings from Kennedy and Basu (2013) that substantial investment and financing may be associated with the widespread deployment of low-carbon technologies. Renewable energy technologies (RETs) usually feature higher power-specific upfront capital costs than do investments in conventional energy infrastructures. However, it is important to note, in the last ten years, rapid advances in technology and high demand for renewable energy, have made renewable energy's position slowly but surely compete with fossil energy. IRENA (2018) showed that in 2017, investment in renewable energy has outpaced investment in fossil fuel power plants. The report also stated that the largest increase was mostly in developing and emerging countries. IEA (2021) pointed out that renewable remains the success story of the COVID-19 era and most of the increase in electricity demand in 2021, will be supplied from renewable energy.

Technology advancement can improve energy efficiency used but Colenbrander et al. (2015) revealed that energy efficiency may pose a dilemma due to 'rebound effects.' Instead of improving efficiency in the long term, individual energy savings from using renewable energy may be spent on buying energy-intensive products that consume much more electricity or fuel. This individual growth in consumption could increase energy demand significantly in a large-scale economy. Rebound effects could be reduced through the cost recovery mechanism to reduce ongoing energy demand as well as through policies of energy pricing or tradable permits. Similarly, Jia et al. (2018) argued that energy efficiency is not necessarily positively correlated with emissions reduction.

Technological capabilities will be a key success factor for LCD programs, and this is in line with Florini and Sovacool (2009) provide examples of how systems supporting innovation and the dissemination of new technologies for renewable energy development are among the governance innovations required to successfully address climate change. However, Mongo et al. (2021) indicate that the effect of environmental innovation on CO_2 emissions showed a mixed result between the short and medium-term. They argued that due to the rebound effect, in the short run, environmental innovation tends to increase CO_2 emissions, but in the long run, the innovation decreases the emissions. Then they said that government needs to conduct policy instruments beyond price that can limit the rebound effect in the short run.

Governance has become an important aspect in providing enabling environment for the development of renewable energy and it can cover several dimensions. Examining LCD requires a study of governance because it reflects two characteristics: issues surrounding public goods (or "collective consumption goods," as elucidated by Samuelson (1954)) and negative externalities (Florini and Sovacool, 2009). Good environmental is a public good, and government needs to design various program that aims to improve quality of the environment. On the other hand, weak governance will increase environmental damage and increase negative externalities both now and in the future. For example, a study by Lange et al. (2018) examining the transition to marine renewable energy in Ireland likewise highlighted governance barriers, including the lack of policy integration and the need to build trust from local communities to support government policies.

Through a qualitative study approach, Adenle et al. (2017), shows that the quality of the institution will determine the success of the global environment facility program. Experience from Africa shows that the establishment of a climate change mitigation institution is to overcome the quality of weak institutions. This institution is important for capacity building, research and development partnerships, and financing coordination.

Administrative and bureaucratic complexity, as well as a lack of standards and certifications, are considered regulatory barriers to the deployment of renewable energy, as explained by Seetharaman et al. (2019). However, instead of using the term 'regulatory,' this paper prefers to consider the 'governance' aspect to examine a broader array of variables. Governance is a process of interactions or a pattern of activities with applicable rules, through mechanisms or authorities both formal and informal that enables actors or organizations to achieve the expected common goals (Florini and Sovacool, 2009; Kooiman, 1993; Rosenau, 2009). The pattern of activities, according to Kooiman (1993), includes guidance, direction, control, and management.

Governance includes not only the government but also the government's interactions with other stakeholders, such as private companies, associations, non-governmental organizations (NGOs), and civil society organizations, in the context of the policy-making process and policy

implementation (Hidayat, 2018; Sangita, 2002). Other studies have also examined multilevel governance, which includes the local, regional, national, and international levels (Amundsen et al., 2010; Sangita, 2002; Smith, 2007). Furthermore, Lockwood (2013) uses a political economy approach emphasizing the interaction between political and economic power in understanding the LCD transition as a result of economic restructuring.

In conclusion, pursuing low carbon development is dealing with a complex set of barriers such as socio-cultural, economic, technology, and governance. They are interdependent barriers, and the big challenge is in determining the most critical barrier. Indonesia has an important position in expanding its potential of renewable energy, but to succeed, Indonesia needs strategy and priority for a better transition.

3. Methodology

This study uses a quantitative and qualitative method. Data were collected during fieldwork in DKI Jakarta, Bali, West Nusa Tenggara, and Bangka Belitung provinces in 2019. We selected the four provinces because the provinces pay great attention to the development of tourism. The development of the tourism sector requires attention to preserve the environment while DKI Jakarta was selected as it contains the central government offices. Tian et al. (2021) pointed out that the tourism sector has a connection with CO_2 emissions. They indicate that 1% increases in tourism decrease CO_2 emissions by 0.05% in the long run. However, they argued that the results cannot be generalized and the results both direction and magnitude may be different among countries.

Qualitative data was collected using Focus Group Discussion (FGD) techniques and in-depth interviews and this approach aims to achieve the first objective, while quantitative data was processed from the results of filling out the questionnaire. The quantitative approach is used to achieve objective two dan three. Participants who took part in the discussion focused on institutions at the provincial level that have a major role in low-carbon development included involvement and experience in the LCD or energy-climate sector programs, such as the Regional Development Planning Agency (Bappeda), the Environment and Forestry office, the Investment Office, the Transportation Agency, non-governmental organizations engaged in the environment, representatives from universities, and PT. PLN (State Electricity Company). Meanwhile, at the central government level, discussions were held with representatives of the National Development Planning Agency (Bappenas), the Fiscal Policy Agency (BKF), the Ministry of Energy and Mineral Resources (ESDM), and also Walhi (Non-Governmental Organization for environmental issues).

The substance of the discussion and in-depth interviews were directed to gain insight into the implementation of low-carbon development in the energy sector. FGD was conducted in each province, and approximately 10 participants were present. The process of filling out the online questionnaire was done flexibly, namely before the discussion started, or the resource persons and discussion participants were given the opportunity to fill out the questionnaire in their respective free time after the discussion. The questionnaire was designed to be completed in less than 10 min. To increase the number of respondents who filled out the questionnaire, the research team asked the discussion participants who were present to share the online survey link with their co-workers who had been involved in low-carbon development programs, especially in energy-related fields. This purposive sampling technique is quite effective in increasing the number of respondents and in getting a variety of respondents who have a good understanding of the study topic.

In the discussion and in-depth interview, there were four important issues. The first is the role that has been carried out by each institution in reducing carbon emissions, what impacts have been seen, and what obstacles they face. The second is the capability of local government in pursuing energy security without relying on coal or fossil energy. Third, how to build renewable energy without causing social conflict? Fourth, what are the policy steps that must be taken to invite the role of the private sector and the community for low-carbon development (renewable energy)?

In the online survey, the respondent is given statements that he/she needs to choose a single number. The questionnaire used the Likert scale with a five-point scale to capture how strongly the respondents agree/disagree on each statement related to LCD barriers[1]. Number 1 for does not strongly support and 5 for strongly support with the statement of low carbon development. Between 1 and 5 there are other options such as do not support (2), neutral (3), and support (4). The statement is defined following a design from Seetharaman et al. (2019), but we added new statements, such as for economic barrier, we added two statements that based on observation are relevant for Indonesia, for example: (1) financing for conventional industries is easier than renewable energy; (2) lack of incentives lead to the barrier of financial access from international agencies. In the case of the technology barrier, we added one statement 'development of spare part industries will have a patent problem'. Then instead of defining a regulatory barrier, we defined a governance barrier. We added new six statements, such as unclear regulation caused the problem on global financial access; dominant of sectoral ego across government agencies has become a barrier for utilization of renewable energy; active of government in promoting green energy diplomacy is still lack in; Indonesia needs help from developing countries to reach emissions reduction target; the role of donor agency is still dominant in determining low carbon program; attitude of some developed countries that withdraw from Paris Agreement has affected government in fully committed to promote low carbon development program. Then we also develop a new strategy for comparing among barriers. This strategy aims to measure consistency in determining the high priority barrier.

There were 92 respondents selected purposively and most of them were also participants in group discussions, either directly invited by the research team or representing their leaders and agencies as explained before. Authors provided terms of reference to discussion participants thus they have time to prepare the data and information. Thus, the respondents are those who have an understanding of the low carbon development programs. A small proportion of the respondents were those who were involved in in-depth interviews. Thus, although the number of respondents may be relatively small, they have been involved both directly and indirectly in low carbon development policies. Of the 92 respondents, 34% were from Bali, 23% were from West Nusa Tenggara, 17% were from Bangka Belitung, and 26% were from DKI Jakarta (Figure 1)[2]. In terms of professional engagement, the structure of respondents is as follows: the government or legislative institutions (66%), education and research sector (academics) or NGOs (24%), and business sectors or associations (10%) (Figure 1).

Then, the Partial Least Square – Structural Equation Modelling (PLS-SEM) was deployed to map barriers to implementing the LCD program and is analyzed through ADANCO 2.2 software. The PLS-SEM is a multivariate analysis technique that can "explain the relationships among multiple variables simultaneously" (Hair et al., 2019). This model includes a measurement (outer) model and a structural (inner) model. The structural model indicates the relationships between exogenous and endogenous variables, while the measurement model consists of indicators/observed variables (using data obtained from the questionnaire) representing unobserved/latent variables.

A research framework for breaking down the barriers to LCD implementation can be constructed (Figure 2), adapting an earlier study from Seetharaman et al. (2019). Seetharaman et al. examined four groups of major barriers to the deployment of renewable energy: social, economic, technological, and regulatory factors. In this paper, these four categories were modified to: (1) socio-cultural, (2) economic, (3) technological, and (4) governance barriers, for the reasons explained above. In this research framework, the thin arrows represent how economic barriers may be

[1] The questionnaire is provided in supplementary file – Questionnaire.
[2] Authors can share the data set by request.

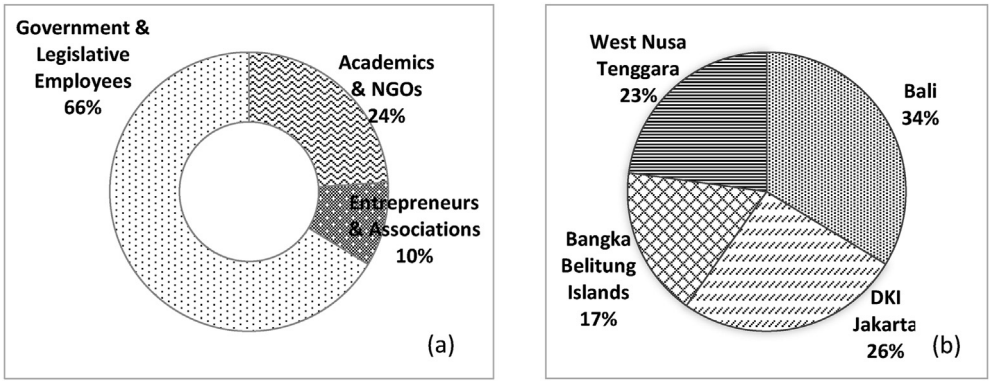

Figure 1. Profile of respondents classified by affiliation (a) and province (b).

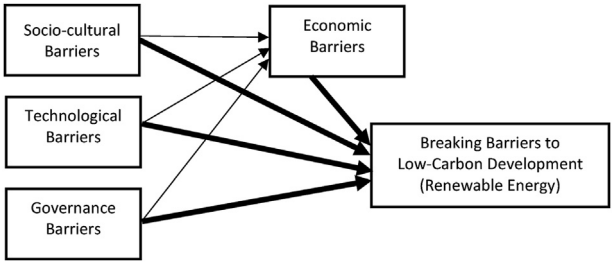

Figure 2. Research framework. Source: Adapted from Seetharaman et al. (2019).

interrelated with socio-cultural, technological, and governance barriers. The thick arrows reflect the possibilities for these four barriers to directly influence LCD. In contrast to Seetharaman et al., this study uses not only quantitative but also qualitative data analysis drawing from primary data, as explained in the following section.

As explained in section 2, the latent variables were adopted from those used in Seetharaman et al. (2019) and partially correspond to those of the literature reviewed above. This paper attempts to expand the variables of 'social' and 'regulatory' barriers to 'socio-cultural' and 'governance' barriers. Thus, the selected latent variables are as follows:

a) Exogenous Latent Variables:
   - Socio-cultural Barriers (SB)
   - Economic Barriers (EB) (also an intervening variable)
   - Technological Barriers (TB)
   - Governance Barriers (GB)

b) Endogenous Latent Variables:
   - Breaking Barriers to implementing the LCD in the renewable energy sector (BB)

The structural equation for the latent variables is:

$$\eta = \beta\eta + \gamma\xi + \zeta$$

where:

- Variables
  - η = endogenous latent variable.
  - ξ = exogenous latent variable
  - ζ = latent error
- Coefficient
  - β = coefficient matrix for the endogenous latent variable
  - γ = coefficient matrix for the exogenous latent variable

As explained by Hox and Bechger (1998), structural equation modeling combines factor analysis and regression or path analysis and is often visualized by a path diagram. In this study, PLS-SEM is used with latent variables that can summarize various indicators in the same group. The economic barriers, in particular, act not only as an exogenous variable but also as an intervening variable, thereby permitting an analysis of the indirect effect of the other three exogenous variables (SB, TB, GB) on the endogenous variable (BB). Thus, based on the research framework, the hypotheses used in this study are as follows:

H1. Socio-cultural barriers have a significant influence on the implementation of LCD.

H2. Socio-cultural barriers have a significant influence on economic barriers.

H3. Economic barriers have a significant influence on the implementation of LCD.

H4. Technological barriers have a significant influence on the implementation of LCD.

H5. Technological barriers have a significant influence on economic barriers.

H6. Governance barriers have a significant influence on the implementation of LCD.

H7. Governance barriers have a significant influence on economic barriers.

4. Results and discussion

The analysis in this section is divided into two parts. First, we examine descriptive statistics on the answers given by respondents related to the four obstacles in the development of renewable energy, namely socio-cultural, economic, technology, and governance barriers, and the analysis of the PLS-SEM model. In section two, we discuss the four barriers.

4.1. Descriptive and PLS-SEM results

It is necessary to highlight the dominant issues associated with each group of stakeholders (Table 1). This was conducted by looking at the highest mean value for indicators of each group of barriers classified by each set of stakeholders, based on descriptive statistics obtained in this model. Respondents to this survey generally indicated that the most dominant barriers to developing renewable energy or implementing LCD in Indonesia were governance barriers. This finding is consistent with the primary concerns of academics, NGOs, entrepreneurs, and associations. The other set of barriers pinpointed by academics and NGOs is defined as technological barriers. Government and legislative employees, meanwhile, consider the main issues to be economic barriers. More details on the dominant parameters of these barriers are explained in Table 1 below.

Table 1. Major barriers to implementing LCD, as classified by stakeholders.

Actor/Barriers	*Most Dominant Aspect* [a]	Socio-Cultural	Economic	Technological	Governance
Government and Legislative Employees	*Economic Barriers*	Lack of skilled workers in renewable energy projects	Lack of investors in renewable energy projects	Lack of Smart Grid integrating conventional and renewable energy sources	Complex bureaucratic procedures & Sectoral ego among government institutions
Academics and NGOs	*Technological $ Governance Barriers*		Difficulties in renewable energy funding		Complex bureaucratic procedures
Entrepreneurs and Associations	*Governance Barriers*		Difficulties in renewable energy funding & Lack of incentives to attract international funding	Limited role of R&D in energy storage technologies	Sectoral ego among government institutions
Most Dominant Barriers[b]	***Governance Barriers***	***Lack of skilled workers***	***Lack of investors***	***Lack of Smart Grid infrastructure***	***Sectoral ego***

Source: Author's analysis results, 2019

Note:

[a] "Most dominant aspect" refers to the most dominant aspect of barriers for each actor.

[b] "Most dominant barriers" refers to the aggregate assessment from all actors.

Table 2. Reliability test.

Construct	Jöreskog's rho (ρ_c)
SB	0.7273
EB	0.7779
TB	0.7479
GB	0.8242
BB	0.8558

Table 3. Validity test: Fornell-Larcker criterion.

	SB	EB	TB	GB	BB
SB	0.4017				
EB	0.0601	0.3719			
TB	0.1280	0.1526	0.3776		
GB	0.0835	0.2615	0.1978	0.4059	
BB	0.0152	0.0342	0.0898	0.0949	0.5975

In terms of socio-cultural barriers, all groups of stakeholders in this survey believe that the foremost issue is the lack of skilled and experienced workers in renewable energy projects. The lack of skilled workers may also be associated with ineffective job rotation of local government officials, causing communication constraints and knowledge gaps[3]. In terms of economic barriers, the greatest concern is the lower number of investors in the renewable energy sector compared to the conventional energy industry.

Regarding technological barriers, most respondents, especially among government employees and academics, consider smart grid infrastructure integrating conventional energy and renewable energy to be the greatest barrier. Respondents from the entrepreneurs and associations group stated that the role of R&D in energy storage technologies is still limited. Finally, in the case of governance barriers, many respondents, especially those working in government, legislative, and academic institutions, as well as NGOs, believe that complex bureaucratic procedures are a major barrier to implementing LCD. Most respondents generally consider sectoral ego among government institutions to be the most dominant barrier in terms of governance.

This study also applies stages of PLS-SEM analysis. The model, based on the research framework in section 2, uses reliability and validity assessments. The composite reliability represented by Jöreskog's rho (ρ_c) values for all constructs is more than 0.7 (Table 2). The validity test, using the Fornell-Larcker criterion, shows that the Average Variance Extracted (AVE) of each construct (in diagonal) is greater than the squared inter-construct correlation in the model (Table 3).

This study also follows the structural model assessment. The collinearity of exogenous constructs is assessed, resulting in Variance Inflation Factors (VIF) less than 3. Moreover, Table 4 shows that three hypotheses (H1, H2, and H3) are not accepted based on the bootstrap results of significance testing. The results are also illustrated in a path diagram (Figure 3). Thus, the parameters of socio-cultural barriers used in this study may not have adequate explanatory power either for the economic barriers or for breaking barriers to implementing LCD in renewable energy. The examined latent variable of economic barriers also does not have a direct effect on the LCD. However, technological and governance barriers have significant effects both on the economic barriers and on the outcomes of breaking down the renewable energy or LCD barriers. Cohen's f^2 values also confirm the effects of technological and governance barriers as exogenous constructs in this model (Hair et al., 2019).

The results of the PLS-SEM analysis show that H1 is not supported by our sample data. Testing of H2 indicates the effect of socio-cultural barriers on economic barrier parameters is not significant. H3 is supported by this study. Testing of H4 supports the significant and direct effects of technological barriers on LCD. Testing of H5 indicates that technological barriers significantly impact economic barriers. Testing of H6 confirms significant and direct effects of governance barriers on LCD implementation. Testing of H7 shows that governance barriers significantly influence economic barriers.

4.2. Narrative of the four barriers

A summary of answers to the questionnaire and the results of the PLS-SEM have not been able to deeply reveal the views of the actors who have been involved in the LCD program. Likewise, the findings of PLS-SEM, do not show that all barriers have a significant impact on LCD. The quantitative approach has not been able to reveal the barrier of the LCD program. Therefore, it is important to analyze more deeply the views of the informants obtained from the results of the FGD and in-depth interviews.

4.2.1. Socio-cultural barriers

The qualitative approach indicates that the local socio-cultural conditions give a different response. This may be due to differences in attitudes among the people in increasing the role of renewable energy in the four study locations. Socio-cultural values of the local community may not strong enough to generate a common social commitment to support (or oppose) LCD. This finding is in line with researchers' findings during field research. Locals in the Bangka Belitung Islands have a value known as '*dak kawa nyusah*': they do not concern themselves with renewable

[3] Comments from focus group discussion and in-depth interview.

Table 4. Results of the hypothesis and significance testing.

Hypotheses	Structural Relationships	Original Coefficient	Cohen's f^2	Standard Bootstrap Results		Accepted
				t-value	p-value (1-sided)	
H1	SB - > BB	-0.3041	0.0993	-1.5780	0.0574	No
H2	SB - > EB	0.0596	0.0043	0.3982	0.3453	No
H3	EB - > BB	0.0136	0.0002	0.0902	0.4641	No
H4	TB - > BB	0.2897	0.0747	1.9567	0.0253*	Yes
H5	TB - > EB	0.1864	0.0369	1.7147	0.0434*	Yes
H6	GB - > BB	0.2672	0.0568	2.4013	0.0083**	Yes
H7	GB - > EB	0.4112	0.1885	3.5628	0.0002**	Yes

Note:
* significant at **α** 5%.
** significant at **α** 1%.

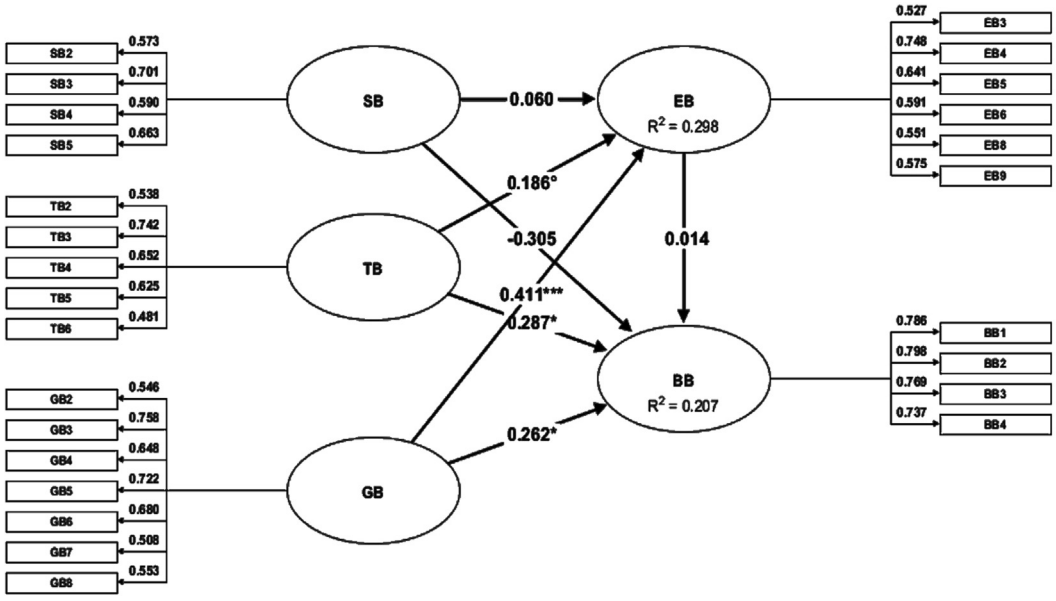

Figure 3. Path diagram for the structural model.

energy and LCD projects, believing that these issues are the government's responsibility.

Locals in other research sites, such as DKI Jakarta and West Nusa Tenggara, also do not exhibit major opposition to LCD programs. This may be due to the heterogeneity of metropolitan society in DKI Jakarta. Moreover, the two largest Muslim organizations in West Nusa Tenggara, known as Muhammadiyah and Nadhatul Ulama, do not take actions or hold values that would threaten the renewable energy or LCD program. As they begin to increase their share in international tourism, locals in West Nusa Tenggara have become frequently open to new changes, including the LCD paradigm.

Locals in Bali, on the other hand, may have relatively strong socio-cultural values that conflict with LCD projects. One example is the case of a geothermal project in Bedugul that was delayed due to local communities' beliefs that Bedugul is the focal point of the sacred island and that the geothermal power plant would rapidly deplete the lake's water supply (FGD, 26 April 2019). However, such local resistance is not always encountered in Bali. Unlike the geothermal project in Bedugul, which was strongly rejected, the construction of hotels for tourism activities is often permitted by locals, even though hotel activities draw from water resources.

Thus, it appears that Not in My Backyard (NIMBY) syndrome occurs in four provincial cases. This indicates that the community is more concerned about current conditions and the impacts of developing renewable energy that they will feel. The potential risks, costs, and benefits of developing renewable energy, are seen in the current conditions. This indicates that in the context of the Sovacool's study (2009), the lack of knowledge and position in the comfort zone is more relevant to describe the conditions in the four provinces.

Further, under the socio-cultural barriers, most of the respondents selected the unavailability of skilled manpower in the field of renewable energy. This can happen because job rotation is likely too frequent, making it difficult for employees to achieve a deep engagement and understanding in specific renewable energy projects[4]. Transfer of knowledge likewise cannot be properly maintained between the previous and current employees assigned in RAD-GRK. This type of issue was expressed by some stakeholders interviewed in Bali (BI, 22 April 2019; KW, 23 April 2019; IW, 26 April 2019). However, this problem is not necessarily encountered in all regions or institutions. For example, according to one interviewee (12 November 2019), there has been an official (equivalent to the head of sub-division) in the Environmental Agency (*Dinas Lingkungan Hidup*) of DKI Jakarta Province dealing with LCD for about ten years. In other words, there do exist employees with long-term experience and competence in the renewable energy field who could share their knowledge with other stakeholders. The informant said

[4] Conclusion from discussion and in-depth interview.

that considering the importance of LCD, the number of employees in this field needs to be increased as well as their competence.

Because the PLS-SEM showed that socio-cultural barriers do not have a significant influence on the implementation of LCD, then it can be estimated that socio-cultural barriers also do not have a significant impact on economic barriers. Although the lack of skilled workers was indicated by descriptive statistics to be the highest-concern parameter for respondents, it is not strong enough to allow this barrier category to have a direct effect in this PLS-SEM analysis. However, the qualitative approach helps to explain that in the case of Bali province, it seems that socio-cultural has become a substantial barrier to geothermal investment. Then, research finding from DKI Jakarta Province emphasizes the importance of having competent human resources in this field. This may be related to the strong possibility of overcoming the skilled-worker problem in the short term through many approaches (El Fadel et al., 2013).

4.2.2. Economic barriers

In terms of economic barriers, the greatest concern is the lower number of investors in the renewable energy sector compared to the conventional energy industry. This may be associated with a common assumption among investors that renewable energy projects are too high-risk, potentially result in their unwillingness to invest in this field (Ohunakin et al., 2014). They argued that this obstacle, may cause difficulty obtaining renewable energy funding, a problem emphasized by entrepreneurs, associations, academics, and NGO respondents. Additionally, entrepreneurs and associations noted the lack of incentives that can likewise hinder international funding potential. This result is also in line with an earlier study from Colenbrander et al. (2015) emphasizing that the main obstacles to climate change mitigation in cities within developing countries are related not to economic issues, but rather to political and institutional issues.

Incentive and disincentive schemes should be implemented to encourage the energy industry to better align with the LCD perspective. If external costs are integrated—for example, if emissions or environmental taxes are imposed—business players may consider the environmentally friendly projects cheaper due to their lower emissions. Hahn and Stavins (1992) explain that incentive policy is a market approach that offers the flexibility for individual polluters to determine the degree to which they can meet environmental goals, based on their abilities. However, provincial governments are limited in their capacity to provide incentives. As confirmed by the Environmental Agency of DKI Jakarta Province in an in-depth interview (12 November 2019), the province has been passing regulations granting land and tax relief for buildings that meet green building requirements. On the other hand, Bali's provincial government struggles to allocate its budget and obtain the financial resources to pay the tipping fee for a waste-to-energy plant project in Suwung, Bali (FGD in Bali, 26 April 2019). The differences in regional fiscal capacity mean that provinces cannot perform equally in terms of implementing the incentive policy. Meanwhile, in the provinces of West Nusa Tenggara and Bangka Belitung, there were lack of incentives provided by the local government to encourage the use of renewable energy by the private sector. Thus, policy supports from the central government and development partners becomes important for the regions.

The Indonesian government's budget allocation for climate action remains limited. The Indonesian government has also agreed to develop funding sources using several green financing instruments, such as green sukuk[5], and government just implemented carbon trading, and carbon taxes policies. Carbon trading has been achieved through several mechanisms, such as the Clean Development Mechanism (CDM), the Joint Credit Mechanism (JCM), and the Nusantara Carbon Scheme. However, the short-term gains can be achieved if government consistently reduces fossil energy subsidies and reallocates these subsidies for strengthening energy infrastructures, such as smart grids and a feed-in tariff for renewable energy.

4.2.3. Technology barriers

Seetharaman et al. (2019) and Dulal et al. (2013), emphasizing that the penetration of renewable energy requires advanced technology, especially in developing countries; however, the procurement cost is often too high. The importance of technological improvement is also confirmed by empirical findings in various locations. Information collected from field research in Bali (April 2019) indicates that a solar PV of 1 MW in Kayubihi Village, Bangli Regency, sustained damage causing a 50% reduction in productivity. Components used in this power plant are mostly imported from high-tech countries. Lack of technology is also an issue in the waste-to-energy power plant in Bali, resulting in extra costs to sort organic and inorganic waste. In addition, technological upgrades are widely needed, such as in the case of the diesel power plant (PLTD) in Pilang, Belitung Regency, Province of Bangka Belitung Islands (June 2019). Although the diesel engine currently in use is capable of using B30 biodiesel, its efficiency may decrease, especially as the engines age. The technological barriers in this case may also include the limited compatibility of biodiesel and diesel power plant specifications.

This may be seen in the cases of the technical issues mentioned above, which result in inefficiencies and/or higher cost burdens for renewable energy projects. In addition, since the payment from PLN was below the generating cost of solar power, business activities of solar PV in Kayubihi tend to ignore maintenance procedures that can reduce the technical age of solar power[6]. Consequently, solar PV in Kayubihi saw almost no profit from the electricity traded to PLN. The electricity sales are only sufficient to cover operational costs and sustain the power plant without profit[7]. Renewable energy investments may also be perceived as less attractive due to operational inefficiencies, including the more complex maintenance procedures required for producing renewable energies as opposed to fossil fuel energy. Additional costs are also an issue in biodiesel when adapting storage mechanisms from diesel to biodiesel since the storage mechanism can be easily damaged if it contains water.

In DKI Jakarta Province, almost no problems related to technology are found, in fact many people have used renewable energy, such as solar panels at houses and offices. Meanwhile, in West Nusa Tenggara Province, the community has utilized the biogas program. However, many biogas reactors are not utilized due to a shortage of biogas raw materials, and many damaged reactors are found.

Regarding technological barriers, most respondents, especially among government employees and academics, consider lack of smart grid infrastructure integrating conventional energy and renewable energy to be the greatest barrier. Seetharaman et al. (2019) note that a lack of grid integration discourages the adoption of renewable energy. Industries that consume large quantities of electricity require specific transmission integration infrastructures, such as renewable energy from independent sources and diesel power plants from the State Electricity Company (PLN). Low grid capacity could inhibit the diffusion of wind and Photovoltaic (PV) solar power (Eleftheriadis and Anagnostopoulou, 2015). The importance of R&D (Nguyen et al., 2010) which connects to issues of RET investment (Del Río, 2007; Masini and Menichetti, 2012; Ringel, 2003), can also be associated with the lack of technological infrastructure. Respondents from the entrepreneurs and associations group stated that the role of R&D in energy storage technologies is still limited. In short, more R&D breakthroughs and RET investments are needed to improve smart grid infrastructure and energy storage technologies.

[5] Green sukuk is a bond that upholds sharia principles employed for green projects, such as public transport improvement, national park establishment, flood and control management, and drainage projects.

[6] Summary of interview.

[7] Summary of interview.

4.2.4. Governance barriers

Colenbrander et al. (2015) and Simarmata et al. (2014) demonstrate that major obstacles to climate change mitigation are highly related to deficiencies in institutional capacity and capability, government commitment or awareness, and political will. Their studies also describe the generally poor performance of local governments in designing urban planning systems, including spatial planning and collecting data required to achieve LCD targets. This may be reflected in the case of Bangka Belitung province (FGD, 21 June 2019). Most of the provincial government agencies have officially set out some programs' priorities for reducing carbon emissions. However, the proposed programs and activities tend to be partial, and tend to represent each provincial government agency's mission, as opposed to an integrated program to support RAD-GRK.

A similar but more detailed explanation of the obstacles faced in the implementation of the RAD-GRK was provided by MY, an official in Bangka Belitung Province (Interview, 20 June 2019). According to MY, there are at least five fundamental issues as to why the RAD-GRK has not yet been implemented properly. First, the RAD-GRK concept remains too abstract; it is not clear what parameters are used to define the specifics of its implementation. Second, central and regional government administrators do not have a common perspective towards the LCD program. As a result, sectoral egos predominate. As a corollary to this attribute, the integration of programs among parties involved has proven difficult to realize on a day-to-day basis. Each ministry at the central level, and each local government agency within the regions, tend to function independently. Third, there have been unclear incentives for private parties and communities involved in the implementation of RAD-GRK. Fourth, the construction of governance in the implementation of RAN and RAD-GRK has been highly reliant on the role of the state (state-center). Meanwhile, the role of society has received less attention. Fifth, both the concept and the implementation of RAN-GRK and RAD-GRK tend to ignore the pivotal cultural features of the affected areas. In fact, the success or failure of policy implementation is, among other factors, determined by the extent to which cultural values in the affected areas are accommodated and adapted.

Meanwhile, the FGD in West Nusa Tenggara province (23 July 2019) indicates that local government agencies at the provincial level have all arranged their own efforts through programs and activities to support RAD-GRK. Those programs and activities included in the local action plan to reduce GHG emissions are necessary to achieve West Nusa Tenggara's Green, Sustainable, and Zero Waste goals. However, almost all of those provincial programs seem to have either stalled at the conceptual level or simply not yet progressed to the implementation stage due to, amongst others, an unstable political condition. This is in line with the case mentioned by Seetharaman et al. (2019) regarding ineffective government policies. Business players and investors, however, require stable and conducive conditions.

Thus, the implementation of RAD-GRK in Bangka Belitung and West Nusa Tenggara provinces has several challenges. To name but a few: a) There is not yet a common awareness among stakeholders, especially regional government officials, of the RAD-GRK concept, mainly because RAD-GRK itself is still very theoretical and not yet operational; b) Government policies have been inconsistent, as leadership changes usually result in policy changes; c) No clear budget scheme has been presented; d) There are horizontal and vertical authority conflicts (Provincial vs District Governments and Provincial vs Central Governments); e) Incentive schemes for local government, the private sector, and communities in the execution of RAD-GRK are unclear; and f) Communities have low awareness of their role in supporting low carbon programs.

In the context of regulatory preparation of low carbon development in the DKI Jakarta Province is relatively running well. The DKI Jakarta Government has formed a Climate Disaster Mitigation and Adaptation Working Team in 2020. Even long before this work team was formed, the DKI Jakarta Government was relatively fast in following up on the issuance of the RAN-GRK by making the Governor Regulation Number 131 of 2012 concerning the RAD-GRK. Recently, the DKI Jakarta Government has provided incentives for exemption from the transfer of title tax for electric vehicles, through the Decree of the Governor of DKI Jakarta Number 3 of 2020 concerning the tax incentive for the transfer of the name of motorized vehicles on battery-based electric motorized vehicles. This policy is in line with Shin (2018), who recommends the need for performance-based compensation in promoting environmental policies. However, there are still many things that need attention from local governments, for example in accelerating the implementation of green building, providing infrastructure for electric vehicles, as well as improving municipal waste and waste management.

The governance barriers elaborated on above may also produce high transaction costs, in effect a form of market failure. From the institutional perspective, these issues could complicate financial incentives and reflect the lack of reliable or professional institutions (Painuly, 2001). Bureaucratic obstacles, which result in a complex and time-consuming process of obtaining permits, may result in higher investment costs. As mentioned by Lockwood (2013), political power influences economic restructuring, and the degree of political interest may affect financial institutions or actors' performances on renewable energy projects. Moreover, the commitment of stakeholders is crucial to developing and utilizing the incentive schemes required to support more effective LCD programs.

Regarding governance barriers, many respondents, especially those working in government, legislative, and academic institutions, as well as NGOs, believe that complex bureaucratic procedures are a major barrier to implementing LCD. Although various bureaucratic reforms to the institutions that handle energy sector affairs have been implemented in Indonesia, past political influence and limited coordination are lingering issues (Halimanjaya, 2019). This category of problems also includes the complex licensing procedures required for several government levels and institutions in different locations, with a lack of communication and knowledge gaps among relevant stakeholders (Jupesta et al., 2011), a state of affairs that aptly characterizes the case of biogas installations in Bali (Bößner et al., 2019). As the state-owned enterprise and holding authority for managing electricity transmission, PLN must follow mandates from various ministries in Indonesia, potentially leading to regulatory conflicts. Thus, integrating more efficient bureaucracy and transparency into LCD policies should be a top priority (Maulidia et al., 2019).

5. Conclusion and policy implications

Low-carbon development has become a mainstream model of economic development in the world including Indonesia. It has been argued that promoting renewable energy is important for sustainable development, but many challenges need to be considered. Previous studies have shown four main barriers, such as socio-cultural, economic, technology, and governance. This paper aims to estimate how the four barriers are connected and its connection to breaking barriers in the deployment of renewable energy. While Seetharaman et al. (2019) applying the PLS-SEM analysis, this study combined it with qualitative analysis by conducting focus group discussions and in-depth interviews with selected experts. By combining the two methods, a better understanding of the complex problems of renewable development can be explored. Indonesia has diversity in social and cultural context, and fieldwork was focused on four provinces that have been known as tourist destinations such as DKI Jakarta, Bali, West Nusa Tenggara, and Bangka Belitung. The PLS-SEM estimates were based on the questionnaire that was filled out by 92 respondents who were selected purposively from the 4 provinces.

A statistics descriptive method revealed that governance is the most dominant barriers to developing renewable energy in Indonesia. Then, the PLS-SEM has three major results. First, economic, technology, and governance barriers have significant influence on the implementation of LCD respectively. Second, technology and governance have significant influence on economic barriers respectively. Finally, the quantitative approach also indicated that governance has not only become an

important barrier for developing renewable energy in Indonesia, but also it influenced the economic barrier.

Qualitative analysis indicated that policymakers, including local governments, have not fully integrated climate change adaptation and mitigation actions into their regional development planning with support from other stakeholders. local governments and local communities lack a sense of ownership over the LCD program initiated by the central government. Likewise, program sustainability is often hampered by differences in priorities in development when there is a change of leadership. This also has an impact on employee transfers without regard to competency standards for the intended field. As a result, the sustainability of the program is experiencing problems and inadequate competence and capacity of personnel.

There are three policy implications of this study. First, the provincial government plays an important role in implementing LCD. It is therefore important to ensure that both the central and local governments share the same passion for commensurate governance. Second, because the central government still plays an important role in allocating fiscal resources to local governments, this instrument can serve as an incentive basis for local governments in advancing the role of renewable energy. Third, it is important to maintain the coherence and continuity of renewable energy development programs and activities for anyone who becomes a leader at the central and regional levels. Finally, mutual benefits and trust will bind the cooperation between the central and local governments and other stakeholders to continue to collaborate in advancing the role of renewable energy.

Declarations

Author contribution statement

Maxensius Tri Sambodo, Chitra Indah Yuliana, Syarif Hidayat, Felix Wisnu Handoyo, Ika Inayah: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Rio Novandra, Alan Ray Farandy: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Putri Irma Yuniarti: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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