CHEMICAL ENGINEERING TRANSACTIONS
VOL. 106, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Peck Loo Kiew, Hon Huin Chin

ISBN 979-12-81206-05-2; **ISSN** 2283-9216
DOI: 10.3303/CET23106025

What Policy is Effective to Enlarge the Geothermal Power Capacity in Indonesia?

Abigail Hasyanita*, Koji Shimada

Graduate School of Economics, Ritsumeikan University, Japan
gr0548if@ed.ritsumei.ac.jp

As a ring of fire nation, Indonesia possesses a plethora of geothermal resources spread across the country. Out of 29 GW of potential capacities, less than 10 % is utilized as power plants. As part of effort to increase renewable energy generation, the government plans to push more utilization of geothermal power plants, by stipulating policies to achieve the target of 17 GW of used potential by 2050. To reach this goal, the potential factors that influence geothermal development should be examined, especially when such factors are influenced by various decision-makers. This study aims to identify the most significant factors influencing geothermal development in Indonesia. First, the study adopts a cross-sectional time series national data on installed geothermal power plant capacity spanning 35 years with key policy factors such as tax allowance, direct funding, and Feed-in tariff (FiT). Second, the study control for regional specific characteristics, such as forest protection policies along with the protected forest area,social conflicts, and natural disasters, by examining the panel of geothermal capacities across 6 provinces with the most geothermal resources. The study applies the Autoregressive Distributed Lag (ARDL) to examine the determinants of geothermal development through cumulative installed capacity of geothermal. The result suggests that direct funding and tax allowance positively and significantly impact geothermal capacity. At the provincial level, the study finds that forest protection policy and the area of protected forest promotes geothermal capacity development which suggests that imposing forest protection does not hinder geothermal development while being supported with the significance of feed-in tariff.

1. Introduction

Renewable energy usage has gained an urgency to be developed in the energy consumption mix as the environmental problems and climate change have become more prominent. From the traditional energy provision, cultivating renewable energy will bring economic benefit beside creating sustainable energy resources, such as providing easier energy access for people who cannot benefit from modern energy services (REN21, 2015). To improve the utilization of renewable energy, research conducted in the field of renewable energy is crucial to make production of renewable energy more efficient and less damaging to the environment (REN21, 2019), that creates urgency for more research in renewable energy sources, such as geothermal. Despite geothermal energy's potential, research on geothermal power development still lags other sources of energy such as wind and solar. For example, globally, there were approximately 62,000 publications on wind energy and 46,000 publications on solar energy, but only 5,000 publications on geothermal energy over the past 16 y (Rosokhata, 2021). Significant progress has been made in renewable energy research overall. Advances in technology, such as improved technology in solar panels and more efficient wind turbines, have led to increased renewable energy generation and reduced costs (Fu et al. 2018). The widespread adoption of renewable energy has demonstrated its ability to mitigate climate change, reduce reliance on fossil fuels, and promote green energy (Aminuddin, et al., 2022)

Geothermal energy offers unique benefits that make it a promising renewable energy source. Unlike wind and solar, geothermal provides a stable and continuous power supply regardless of the weather conditions and the situation of the environment where the plant is located. This reliability makes geothermal energy well-suited for power generation, contributing to grid stability and meet the constant energy demand (Palomo-Torrejo, et al., 2021). Geothermal energy is a domestic resource that can enhance energy security (Sumari, et al., 2014). By

Paper Received: 31 May 2023; Revised: 27 July 2023; Accepted: 28 August 2023
Please cite this article as: Hasyanita A., Shimada K., 2023, What Policy is Effective to Enlarge the Geothermal Power Capacity in Indonesia?, Chemical Engineering Transactions, 106, 145-150 DOI:10.3303/CET23106025

utilizing its vast geothermal reserves, a country like Indonesia can decrease its dependence on fossil fuel imports and create a more sustainable and resilient energy system.

Indonesia is home to some of the world's largest geothermal reserves, with an estimated potential capacity of almost 29 GW (Yudha, 2022). Despite this potential, the country has only utilized a fraction of its geothermal resources with an installed capacity of approximately 2.1 GW (MEMR, 2021). The slow development of geothermal energy in Indonesia is attributed to various challenges, including regulatory barriers (Pambudi, 2018). Other challenges include the lengthy and uncertain permitting process, social and environmental issues related to land use and indigenous rights, and the lack of a clear regulatory framework and supportive policies (Boediono, 2019). To address these challenges, the Indonesian government has implemented several initiatives and policies to promote geothermal development in the country. In 2003, the government established the Law No. 27 about geothermal to accommodate the legal basis for geothermal developments and to expand regional authorities to support sustainable energy alternatives. Another key policy to promote renewable energy development in Indonesia is the Feed-in Tariff (FiT) program, which provides a guaranteed payment rate for electricity generated from renewable sources (Setiawan et al., 2022). Tax allowance, grants, and capacity building programs are included in the policy initiatives from the government to promote Indonesia's geothermal development (REN, 2017). Given that Indonesia has the second largest geothermal resource in the world and is an emerging economy with a rapidly growing population (National Statistics Bureau Indonesia, 2022), further research on geothermal energy in Indonesia is warranted. The government has set a target of 7 GW geothermal power plant installed capacity by 2025 and is expected to reach 17 GW by 2050 (Ministry of Energy and Mineral Resources, 2021), creating the urgency to accelerate the development of geothermal resources in Indonesia. This study aims to identify the most significant factors influencing geothermal development in Indonesia and to assess the effectiveness of various government policies in promoting geothermal energy production. By providing insights into the drivers of geothermal energy development in Indonesia, this study can inform policy makers and energy stakeholders in their efforts to increase the share of renewable energy in the country's energy mix.

2. Methodology and data

2.1 Methodology

In the context of the research on geothermal development in Indonesia, the application of the Auto-Regressive Distributed Lag (ARDL) model provided a robust analytical framework to explore the factors driving geothermal development in the country on both national and regional scale. The study aims to understand the relationship between geothermal development and key policy variables at the national and regional level. By utilizing aggregated data, it can be examined how policy variables, such as the Feed-in tariff, tax allowance, and direct funding, influence the installed cumulative capacity of geothermal power plants from 1985 to 2019. Regional factors such as forest policy, social conflicts, and natural disasters can be examined.

In the first phase of the research, the ARDL model captured the dynamic interplay between the policy variables and geothermal development. The auto-regressive component of the model considered the lagged values of the policy variables and geothermal capacity, providing insights into the immediate impacts of the policy changes. By employing the ARDL model, the intricate relationship between policy variables and geothermal development in Indonesia can be examined. The model allows for a comprehensive understanding of how policy interventions have influenced the growth and expansion of geothermal power plants in the country and provides valuable insights for policymakers and stakeholders in the renewable energy sector, aiding in the formulation of effective strategies to foster sustainable geothermal development in Indonesia. Eq(1) shows the mathematical formulation of national regression where y_t is the value of the dependent variable (cumulative capacity of geothermal), γ_i is the coefficients of autoregressive lagged values of the dependent variable, $x_{(k,t-j)}$ is the k-element column vectors of current and distributed lagged values of independent variables and $\beta_{(k,j)}$ is a column vector with k coefficients. μ is a usual constant and ε_t is a white noise term.

$$y_t = \mu + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=0}^{r} \beta_{k,j} x_{k,t-j} + \varepsilon_t \quad (1)$$

In the second phase of the research, the focus shifted to analysing the regional drivers of geothermal development in Indonesia. This phase specifically examines six provinces—West Java, Lampung, East Nusa Tenggara, North Sulawesi, South Sumatera, and North Sumatera—which have been identified as having the most significant geothermal reserves (Matoka, 2021). These provinces were chosen strategically due to their rich geothermal potential and the fact that they already house a substantial number of geothermal power plants. Including these provinces allows for a more targeted and focused analysis of the regional drivers of geothermal development.

Figure 1: Selected provinces on the regional scale

The inclusion of regional-specific characteristics in the analysis provides valuable insights into the factors that influence geothermal power development in each of these provinces. These characteristics include forest policy, social conflicts related to indigenous communities, and the impact of natural disasters. Forest policy plays a crucial role as it affects land availability and permits geothermal exploration and development. Social conflicts related to indigenous communities can impact the social acceptance and cooperation necessary for successful geothermal projects. Moreover, the vulnerability of geothermal plants to natural disasters, such as earthquakes, can significantly affect their operational capacity and development potential. By incorporating these regional-specific characteristics alongside the control variables from the first phase, the research aims to better understand how these factors interact with geothermal power development in each province. The Panel ARDL model enables a comprehensive analysis of the immediate impacts and long-term equilibrium relationship between the variables. The findings from this phase will contribute to a deeper understanding of the regional drivers and challenges in geothermal power development, providing valuable insights for policymakers, stakeholders, and industry players involved in sustainable energy planning and decision-making at both regional and national levels. Eq(1) can be derived and parameterized to obtain Eq(2) of Panel ARDL where the new subscript i stands for the region and t will be defined as the time.

$$y_{it} = \alpha' + \lambda_i y_{it-1} + \beta' x_{it} + \varepsilon_t \qquad (2)$$

2.2 Data

The data for these studies are mainly collected from secondary research, through the directories from the Ministry of Environment, Ministry of Energy, National Statistics Bureau, and the directories from the local government and the state-owned oil and gas enterprise. Other resources include primary resources through interviews and a workshop with the Ministry of Energy and Natural resources. Table 1 shows the specification of the data for both national and regional respectively.

Table 1: Variable description and sources

Variables	Details	Sources
lncumcap	Natural log of installed cumulative geothermal power capacity (MW)	Ministry of Energy (Primary)
lnforest	Natural log of area of protected forest (Ha)	National Statistics Bureau
taxall	Tax Allowance, dummy variable	Ministry of Energy (Primary)
incentive	Direct Funding, dummy variable	Ministry of Energy (Primary)
lnfit	Natural log of Feed in Tariff (USD/ kWh)	Ministry of Energy (Secondary)
lngdp	Natural log of GDP (Constant 2017 USD)	WDI (Secondary)
lnoil	Natural log of oil price (USD/barrel)	Pertamina (Indonesia's Oil and Gas SoE – Primary)
forestpol	Forest protection policy	Ministry of Environment
disast	Natural disaster, dummy variable	Ministry of Energy
conflict	Social conflict, dummy variable	Local Government Directory
lngdrp	Natural log of GDRP (Constant Bn IDR)	National Statistics Bureau

Dummy variable (1-exist, 0-otherwise)

3. Empirical results

3.1 National Level Result

The estimation results indicate that several factors are statistically significant in influencing geothermal development. Specifically, tax allowance, direct funding, GDP, and oil price exhibit significant coefficients. When the magnitude of each variable is being examined, it can be understood that when the tax allowance policy is imposed, it significantly decreases the geothermal power capacity by 9 % in the short run, and when the direct incentive is given by the government, it can lead to an increment of 29 % in the short run and 45 % in the long run. It can also be seen that in the long run, a 1 % increase in feed-in tariff can affect the geothermal power capacity by 0.357 %. This implies that policies focused on providing direct financial support are effective in promoting the growth of geothermal power development by providing funding directly to geothermal projects The negative relationship between tax allowance and geothermal development suggests that tax-based incentives may have unintended consequences. It appears that tax allowance policies may not effectively stimulate geothermal development, potentially due to the high upfront costs associated with geothermal energy projects. These costs, which encompass exploration and plant installation, might deter investors and lead to delays in investment decisions. The positive relationship between GDP and geothermal development highlights the importance of economic growth in the context of renewable energy. As Indonesia's GDP increases, there is a greater demand for energy consumption, and geothermal energy emerges as a crucial factor in meeting this demand. The positive correlation suggests that economic growth plays a significant role in fostering the development and utilization of geothermal resources. The negative relationship between oil prices and renewable energy consumption implies that renewable energy, including geothermal, serves as a substitute for fossil fuels. As oil prices rise, renewable energy becomes more competitive, leading to an increased adoption of renewable energy sources. This relationship indicates that higher oil prices can drive the transition towards renewable energy, including geothermal power.

Table 2: Result of Regression on National Level data (dependent variable: cumulative capacity)

Variables	ARDL Short Run	ARDL Long Run
Taxall	-.0926***	-.140
	(.052)	(.076)
Incentive	.296***	.450***
	(.060)	(.088)
Lnfit	.155	.357***
	(.174)	(.174)
Lngdp	1.050***	1.59***
	(.152)	(.179)
Lnoil	-.080***	-.122***
	(.028)	(.042)

Note: Standard errors in parentheses. *, **, and *** mean significance with a confidence interval of 90 %, 95 %, and 99 %.

3.2 Provincial Level Result

In this section, a Panel Autoregressive Distributed Lag (ARDL) model to analyze the regional factors affecting geothermal energy development is utilized. The variables such as forest protection policy, natural disasters, and social conflicts are examined. The results of the regression analysis are presented in Table 2. The findings reveal that forest protection policy has a significant and positive impact on geothermal power development. More importantly, forest protected area that is located in the geothermal provinces show significance in promoting the geothermal power development, with 1 % increment in the forest protected areas affecting 0.06 % increment in the short run and 0.02 % increment in the geothermal power development simultaneously. Contrary to the common belief that forest policies may hinder geothermal power development, the research demonstrates that well-implemented forest protection measures contribute to the development and utilization of geothermal power, influencing the geothermal power capacity 17 % in the short run and 37 % in the long run. The presence of a strong forest policy is crucial in encouraging geothermal energy development. Forest protection measures likely contribute to preserving the natural environment and promoting the sustainable use of renewable energy resources. Investors in geothermal projects are more confident to invest in geothermal projects when there is a strong forest policy as a good governance principle (Darsono, et al., 2022).

In contrast to the national-scale results, tax allowance does not exhibit a significant impact on geothermal development at the provincial level. This suggests that the effectiveness of tax allowance policies may vary depending on the geographical context. It is important for policymakers to consider regional characteristics and tailor their policy approaches accordingly to achieve the desired outcomes in promoting geothermal energy development. Interestingly, the analysis indicates that Feed-in-Tariffs (FiTs) have a more significant impact on geothermal development at the regional level compared to tax allowance and direct funding policies. FiTs are policies that provide long-term contracts and guaranteed electricity prices for renewable energy producers. This finding highlights the importance of implementing appropriate incentive mechanisms, such as FiTs, to stimulate geothermal development in specific regions. Policymakers should consider incorporating FiTs or similar supportive mechanisms to attract investments and foster the growth of geothermal projects at the regional level. Despite the variations observed across regional and national scales, direct funding maintains a positive and significant relationship with geothermal development in the regional context. This reaffirms the effectiveness of direct financial support in promoting the deployment of geothermal energy projects at the provincial level. Policymakers should continue to allocate resources and provide direct funding to support geothermal initiatives to drive regional renewable energy development.

There seems to be a reversed causality between tax allowance and geothermal development, which is proven with the significance of p-value in Granger causality test of 0.001. The instrumental variable approach is used to control endogeneity concerns. Table 4 reflects the results of instrumental variable regression methodology. In choosing the instrumented variable, the lagged value of tax allowance was chosen. The magnitude of coefficients for most variables does change significantly and the significance of the variables is generally consistent. Although the effects of protected forest area are similar between ARDL short and IV, the effects of other policy variables such as forest policy, direct funding, and feed-in tariff in the IV model are smaller than those in ARDL short model. Considering the endogeneity bias, the estimated results by IV method would be more robust than ARDL short model.

Table 3: Result of Regression on Provincial Level (dependent variable: cumulative capacity)

Variables	ARDL Short Run	ARDL Long Run
Forestpol	.173**	.379**
	(.089)	(.786)
Lnforestarea	.060*	.020*
	(.056)	(.739)
Disast	.094	.837
	(.101)	(.846)
Conflict	.073	.590
	(.144)	(.178)
GDRP	.398	.242***
	(.336)	(.421)
Taxall	.083	.608
	(.151)	(.205)
Incentive	.295**	.482***
	(.147)	(.184)
Lnfit	.391**	.369***
	(.566)	(.852)
Lnoil	.016	-.149
	(.085)	(.941)

Note: Standard errors in parentheses.*, **, and *** mean significance with a confidence interval of 90 %, 95 %, and 99 %.

Table 4: Result of Instrumental Variable Regression (dependent variable: cumulative capacity)

Variables	Coefficient	Standard Error
Forestpol	.062**	.349
lnforest	.052*	.298
Disast	.655	.308
Conflict	-.714	.3493
GDRP	.480***	.029
Taxall	-.999	1.81
Incentive	-.0944002	1.134424
Lnfit	.2468823***	.1205076
Lnoil	-.0003945	.5447036

Note: *, **, and *** mean significance with a confidence interval of 90%, 95%, and 99%.

4. Conclusion

The research highlights the importance of direct funding as a key policy factor in driving geothermal power development, which has been demonstrated by the consistency of significance in both national and regional in the short and long term. This implies that the assistance of geothermal funding is crucial to encourage geothermal power development, as it will incentivize developers and attract more organizations, such as multilateral banks, to invest in geothermal projects in Indonesia. The study emphasizes the significance of implementing proper feed-in tariff policy, which shows consistency in significance in national and regional scale. The feed-in tariff guarantees a stable and profitable price for geothermal energy, which can incentivize developers and ensure the viability of geothermal projects, as it will provide stability and predictability for stakeholders involved. In terms of national policy intervention, incentive-based policy such as direct funding and the feed-in tariff are more effective in encouraging geothermal power development, instead of fiscal-based policy that has been examined in this study through the variable of tax allowance. The forest protection policy and how it overlaps with forest protected areas may not be hampering geothermal power development, but rather incentivizes the geothermal projects because it can bring good governance for developers, which ensures investors to invest in geothermal projects as a sustainability principal. The study also suggests that variables that differ on the regional scale such as social conflict and natural disaster, are not significant in hampering geothermal power development and that most policy interventions can be done on a national scale. To capture more policy dynamic, further study can incorporate the actual value of the direct funding and tax allowance instead of dummy variable.

Acknowledgement

This work was supported by JSPS KAKENHI Grant Number 20K12308. Gratitude is also given to Prof. Mai Seki and Dr. Joseph Jr. Aduba for their comments and suggestions.

Reference

Aminuddin N.A.M., Foo D.C.Y., Lam H.L., 2022, Improving the Framework for Energy Policy to Harness Renewable Energy Resources for Sustainable Development in Developing Countries, Chemical Engineering Transactions, 94, 1147-1152.

Boediono L. ,2019, Indonesia: Scaling Up Geothermal Energy by Reducing Exploration Risks <http://documents.worldbank.org> accessed 31.05.2023.

Darsono S., Wong W., Ha N., Jati H., Dewanti D., 2022, Good Governance and Sustainable Investment: The Effects of Governance Indicators on Stock Market Returns, Advances in Decision Sciences, 26, 1-33.

Fu, R., Feldman, D. J., Margolis, R. M., 2018, US Solar Photovoltaic System Cost Benchmark Q1 2018 (No. NREL/TP-6A20-72399), National Renewable of the US Department of Energy, Colorado, United States of America.

Ministry of Energy and Mineral Resources Indonesia, 2021, Rencana Usaha Penyediaan Tenaga Listrik 2021-2030, Kementerian Energi dan Sumber Daya Mineral, Jakarta, Indonesia (In Indonesian).

National Statistics Burreau Indonesia, 2023, Statistik Indonesia 2022, Badan Pusat Statistik Indonesia, Jakarta, Indonesia (In Indonesian).

Palomo-Torrejón, E.,,Colmenar-Santos, A., Rosales-Asensio, E., Mur-Pérez, F., 2021, Economic and environmental benefits of geothermal energy in industrial processes, Renewable Energy, 174, 2021, 134-146.

Pambudi, Nugroho Agung, 2018, Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy, Renewable and Sustainable Energy Reviews, 81(P2), 2893-2901.

Rosokhata, A .,Minchenko, M.,Khomenko, L.,Chygryn, O., 2021, Renewable energy: a bibliometric analysis. E3S Web of Conference, 250(2001), 03002.

Setiawan, Andri, Marmelia P. Dewi, Bramka Arga Jafino, Akhmad Hidayatno, 2022, Evaluating feed-in tariff policies on enhancing geothermal development in Indonesia, Energy Policy, 168,113164.

Sumari, A., S. Mariani and R. G. Dewi, 2014, Promoting geothermal for energy security (A case of Indonesia), 2nd International Conference on Technology, Informatics, Management, Engineering & Environment, Bandung, Indonesia, 2014, 281-287.

Yudha SW, Tjahjono B, Longhurst P., 2022, Unearthing the Dynamics of Indonesia’s Geothermal Energy Development, Energies, 15(14), 5009.