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The Potential of Carbon Trading and Carbon Tax Analysis to Enchance the Economic Feasibility of Geothermal Power Plant in Indonesia

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Abstract. Global climate change, driven by the increasing concentration of greenhouse gases in the atmosphere, has emerged as one of the most pressing challenges confronting humanity. The energy sector, particularly its continued reliance on fossil fuel combustion for electricity generation, is a major contributor to greenhouse gas emissions. In response to the urgent need to mitigate these negative impacts, various countries and international organizations have developed policies and mechanisms aimed at reducing carbon emissions. One such mechanism is the carbon trading system, a market-based instrument that enables countries or companies to buy and sell carbon emission allowances. Under this scheme, entities that successfully reduce emissions beyond their assigned targets may sell their surplus allowances to others who are unable to meet their reduction obligations. This approach fosters both efficiency and innovation in emissions reduction, with economic incentives serving as a primary driver. Geothermal Power Plants, as a renewable energy source, play a pivotal role in reducing dependence on fossil fuels. Compared to fossil power plants, Geothermal Power Plants generate significantly lower levels of carbon emissions. Therefore, analyzing the potential integration of Geothermal Power Plants into the carbon trading system could offer financial incentives and enhance the economic viability of geothermal energy. This mechanism has the potential to support the further development and expansion of geothermal power infrastructure.

Keywords: *carbon pricing; carbon trading; climate change; geothermal power plant; greenhouse gases.*

1 Introduction

Carbon emissions, if not properly managed, can lead to significant environmental consequences, most notably global warming. Indonesia is among the highest emitters of greenhouse gases globally. According to data published by the World Resources Institute (WRI), Indonesia ranks eighth among the top ten greenhouse gas-emitting countries, contributing approximately 965.3 million metric tons of CO_2 equivalent ($MtCO_2e$), which accounts for around 2% of global emissions.

The following chart illustrates the top ten countries with the highest greenhouse gas emissions as of 2018.

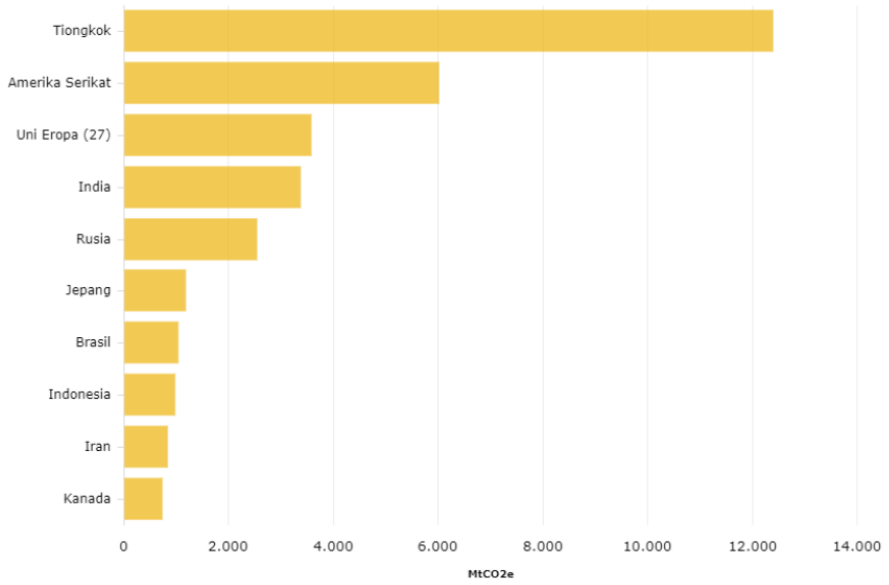

Figure 1 Large contributors to greenhouse gas emissions in 2018 (WRI, 2020)

Carbon trading is a market-based mechanism designed to reduce greenhouse gas (GHG) emissions. This system emerged in response to the global climate change crisis, with the aim of mitigating the harmful effects caused by excessive carbon emissions. The mechanism was initially implemented under the *cap and trade* principle, in which countries or entities with assigned emission limits are allowed to trade their surplus emission allowances with others that exceed their designated caps.

A pivotal development in the evolution of this system occurred with the adoption of the Kyoto Protocol in 1997, which enabled developed countries to meet part of their emission reduction targets through the *Clean Development Mechanism* (CDM). This mechanism allows investment in emission-reduction projects in developing countries. According to research conducted by Gillenwater and Seres in [1] carbon trading can be an effective tool for reducing the costs associated with emission mitigation, although its success is highly dependent on market design and policy frameworks.

Geothermal Power Plants are a form of renewable energy technology that utilizes geothermal heat to generate electricity. Geothermal Power Plants produce significantly lower levels of greenhouse gas emissions compared to fossil fuel-

based power plants, positioning them as an environmentally friendly alternative in the energy sector. According to research by Dissanayake, et.al in [2] found that Geothermal Power Plants have significant potential to contribute to carbon emission reductions, particularly in developing countries with abundant geothermal resources. The operation of Geothermal Power Plants directly reduces reliance on fossil fuels, which are the primary source of carbon emissions. According to Liu et.al in [3] transitioning from fossil fuel-based power plants to geothermal systems can reduce carbon emissions by up to 90%, playing a crucial role in achieving global emission reduction targets.

The potential of carbon trading in the development of Geothermal Power Plants offers an opportunity for countries or companies operating such facilities to gain additional revenue or incentives through carbon credits generated from emission reductions. According to research by Bertani in [4] Geothermal Power Plants projects in many developing countries often qualify for *Certified Emission Reductions* (CERs), which can be traded on global carbon markets, such as through the *Clean Development Mechanism* (CDM) under the Kyoto Protocol.

Within the carbon trading system, two key terms are commonly used: *carbon trading* and *carbon credits*. Carbon trading refers to a market-based mechanism that facilitates the buying and selling of carbon credits or CO_2 emission allowances. One of its main objectives is to ensure that companies or institutions ful fill their obligations to reduce carbon emissions, thereby supporting the development of green energy. Moreover, participation in such initiatives can improve a company's environmental credentials, including eligibility for awards such as the "Gold Proper" rating in certain regulatory frameworks. On the other hand, a carbon credit represents a unit equivalent to the reduction or avoidance of one metric ton of CO_2 emissions and serves as formal proof that a company, institution, or individual has reduced emissions by that amount.

The most widely implemented carbon trading scheme is the *cap-and-trade* system, which is based on emission limits and tradable allowances. Under this mechanism, a regulatory authority sets a total cap on greenhouse gas emissions, and entities that emit less than their allocated quota may sell their surplus allowances to those exceeding their limits. This creates economic incentives for efficiency and innovation in emission reduction efforts.

The main objectives of the carbon market to encourage companies and countries to invest in low carbon technologies or renewable energy sources in order to reduce their emissions more efficiently and economically. The issue addressed in this study is that carbon taxes within the carbon trading system have not yet been fully utilized to support the development of power generation units in geothermal power plants. By applying this mechanism, it becomes possible to compare the

development of a geothermal power plants unit without revenue from carbon tax sales to that of a geothermal power plants unit built with revenue generated from carbon tax sales. This comparison aims to assess the effectiveness and efficiency of carbon tax revenue in supporting the construction of power generation units in geothermal power plants.

2 Methodology

The research method employed is a systematic literature review to examine the utilization of carbon markets, particularly the implementation of carbon taxes, in supporting the development of power generation units at geothermal power plants in Indonesia. This approach aims to understand the role of carbon trading in facilitating the transition to a low-carbon energy system and to assess the effectiveness and efficiency of using carbon tax revenues in renewable energy projects.

2.1 Identification of Literature

The literature was obtained from various scientific databases, with sources collected from both national and international peer reviewed journals focusing on carbon trading and carbon taxation in geothermal power systems. These sources were selected to provide a conceptual analysis of applicable carbon tax implementation schemes for geothermal power plants. The literature search was focused on the period from 2014 to 2025 to ensure coverage of the most recent developments in carbon market mechanisms.

2.2 Selection and Analysis

The literature used in this study was selected based on several criteria:

1. Relevance to the research topic, specifically the relationship between carbon trading, carbon taxation, and the development of applicable geothermal power plants.
2. Source credibility, with priority given to peer-reviewed scientific articles and reports from reputable institutions.
3. Availability of data and information supporting comparative analysis of geothermal power plants development with and without carbon tax revenue.

Following the initial selection phase, content analysis was conducted on the selected literature to identify patterns and comparisons across sources. The analysis involved categorizing the literature based on key issues such as carbon market policies, carbon tax policies, mechanisms and benefits of carbon tax

implementation, and case studies of geothermal power plant projects in various regions.

2.3 Literature Validity

The validity of the literature used in this study is ensured by relying on official sources, such as indexed journals and reports from government institutions. However, a limitation of this approach is the lack of empirical data specifically evaluating the direct impact of carbon taxation on geothermal power plant projects. Therefore, further approaches such as case studies or applicable financial modeling are needed to complement the analysis.

3. Carbon Credit Mechanism Originating from Geothermal Power Plants

Within the carbon trading system, Geothermal Power Plants have the potential to earn carbon credits by achieving emission reductions, particularly when compared to conventional fossil fuel-based power generation. As Geothermal Power Plants generate cleaner, renewable energy and avoid the release of carbon dioxide (CO_2) into the atmosphere, they may qualify for carbon certificates that are tradable on carbon markets. The verification and certification of these credits are overseen by regulatory bodies such as the *Clean Development Mechanism* (CDM), which ensures that each carbon credit issued corresponds to a measurable, verifiable, and real reduction in greenhouse gas emissions.

4. The Impact of Carbon trading on Geothermal Power Plant Development

The carbon trading mechanism provides economic incentives for countries and companies investing in Geothermal Power Plant projects by enabling the production of cleaner energy while generating additional revenue through the sale of carbon credits. According to Schmidt et.al in [5] the renewable energy sector stands to benefit significantly from the rapidly expanding carbon market, as elevated carbon prices serve as a strong motivator for shifting away from fossil fuels toward cleaner energy alternatives. According to Kamandika and Dhakal in [6] Geothermal Power Plant with their relatively low operating costs and minimal carbon emissions, offer a competitive source of energy within the framework of carbon trading. Beyond economic benefits, Geothermal Power Plant also play a role in advancing sustainability objectives within the energy sector. The carbon credits generated from Geothermal Power Plant can assist countries in achieving their Nationally Determined Contributions (NDCs) under the Paris Agreement, which obligates signatory nations to reduce greenhouse gas emissions, including carbon dioxide.

5. Challenges of Geothermal Power Plant Carbon Trading

Geothermal Power Plants hold significant potential in generating carbon credits. However, the implementation of carbon trading mechanisms in these projects faces several challenges. One of the primary obstacles is the high upfront capital requirement for geothermal development. According to Xiaojun and Hakam study in [7] the construction cost of a geothermal power plant ranges from $1,870 to $5,050 per kW, and this substantial initial investment poses a major barrier to large-scale financing. In addition, the standardization of emission verification procedures presents another challenge, given the complexity of accurately measuring emission reductions from geothermal power plants compared to fossil fuel-based power generation. According to research by Chen and Lin in [8] the measurement of greenhouse gas emissions from geothermal power plants is highly complex, particularly due to the presence of non-condensable gases such as CO_2. This complexity poses a significant challenge in developing robust verification procedures, potentially hindering the integration of geothermal projects into carbon trading schemes relative to fossil fuel power plants. Although the prospects for carbon trading in geothermal projects are promising, regulatory uncertainty and inconsistent policy frameworks remain critical issues that can affect the stability of the carbon market. According to Winters in [9] geothermal energy utilization in Indonesia remains low despite its vast potential. This is largely attributed to weak regulatory capacity at the local government level and the lack of clarity in national policies, which contributes to uncertainty among investors seeking to develop the sector.

Policy changes and carbon price fluctuations can directly affect the feasibility of Geothermal Power Plant projects that rely on carbon credit sales as a primary revenue source. According to research conducted by Heryana and Sudrajad in [10] the implementation of a carbon pricing mechanism can significantly influence the financial metrics of a geothermal power plant project with a certain capacity. The study found that carbon pricing led to a 13.58% increase in net present value, along with a shortened payback period from 8.37 years to 7.67 years. These findings indicate that carbon price volatility and the presence of clear and consistent carbon pricing regulations can have a substantial impact on the overall feasibility of geothermal projects.

6. Analysis of Potential and Challenges of Carbon Tax Implementation

The carbon tax is designed as a policy instrument to reduce carbon emissions while supporting the transition toward the development of renewable energy sources. According to Alikhan in [11] if implemented in Indonesia, a carbon tax

not only contributes to the reduction of greenhouse gas emissions but also holds the potential to strengthen the national economy and improve public welfare.

One of the main advantages of a carbon tax scheme lies in its price stability, which helps avoid issues related to emission price volatility. This stability provides greater certainty for investors when making decisions regarding project development, including those related to Geothermal Power Plant projects. Additionally, the carbon tax can serve as a source of additional state revenue and reduce the fiscal burden associated with emission reduction efforts.

The Indonesian government has expressed its commitment to adopting a carbon tax under a cap and tax scheme. As highlighted by Hadijjah and Rachmad in [12] the officially approved rate is IDR 30.00 per kilogram of carbon dioxide equivalent, with the expectation that this relatively affordable rate will enhance public acceptance.

In terms of emission measurement, Indonesia utilizes emission factors to determine the volume of greenhouse gas emissions produced by each sector. The table below explains greenhouse gas emissions based on sector.

Table 1 Greenhouse gas emissions by sector (NDC, 2021)

Sector	GHG Emission Level 2010* (MTon CO_2e)	GHG Emission Level 2030 MTon CO_2e			GHG Emission Reduction MTon CO_2e		GHG Emission Reduction % of Total BaU		Annual Average Growth BAU (2010-2030)	Average Growth 2000-2012
		BaU	CM1	CM2	CM1	CM2	CM1	CM2		
1. Energy*	453.2	1,669	1,355	1,223	314	446	11%	15.5%	6.7%	4.50%
2. Waste	88	296	285	256	11	40	0.38%	1.4%	6.3%	4.00%
3. IPPU	36	70	67	66	3	3.25	0.10%	0.11%	3.4%	0.10%
4. Agriculture**	111	120	110	116	9	4	0.32%	0.13%	0.4%	1.30%
5. Forestry and Other Land Uses (FOLU)***	647	714	217	22	497	692	17.2%	24.1%	0.5%	2.70%
TOTAL	**1,334**	**2,869**	**2,034**	**1,683**	**834**	**1,185**	**29%**	**41%**	**3.9%**	**3.20%**

According to a study conducted by Firmansyah et.al in [13] the energy sector is the largest contributor to greenhouse gas emissions in Indonesia. Fossil fuel-based power plants have an emission factor of approximately 1.140 kg of CO_2 per kWh. Bima and Vissia in [14] research further explains that this emission factor is used to calculate the total emissions produced by fossil fuel power plants. The classification of CO_2 emissions as a taxable subject aligns with the designated tax object, given the significant contribution of fossil-based power generation, which accounts for 67% of total greenhouse gas emissions in the energy sector.

The Indonesian government's carbon tax policy is implemented through an emission trading mechanism under a cap-and-trade scheme, in accordance with national regulatory frameworks. Based on the study by Alif and Niken in [15] a comparison between Indonesia and Singapore reveals that Indonesia still needs to improve several aspects of its carbon tax implementation. Singapore, currently the only ASEAN country to have adopted a carbon tax, may serve as a model for

Indonesia, which plans to implement the policy starting in 2025. While Indonesia applies both cap-and-trade and cap-and-tax systems, Singapore focuses on carbon trading to determine carbon pricing. Research suggests that carbon taxation holds strong potential in supporting the achievement of the Sustainable Development Goals (SDGs). For successful implementation, Indonesia must consider several key elements, including the identification of taxable entities, appropriate tariff settings, management systems, payment mechanisms, and the enforcement of sanctions.

7. Conclusion

The implementation of carbon trading and carbon tax in Indonesia is a strategic step in reducing greenhouse gas emissions, in line with the country's commitment to global climate agreements. Through mechanisms such as cap and trade and fiscal instruments like carbon tax, the government encourages energy efficiency and supports the transition toward low emission energy sources.

In this context, the energy sector is a primary focus, as it is one of the largest contributors to carbon emissions in Indonesia. Therefore, the transition from fossil energy to clean and renewable energy sources is crucial. The Geothermal Power Plant, as one of the renewable energy sources developed in Indonesia, has significant potential to contribute to the carbon trading framework. Geothermal Power Plant has much lower emissions compared to fossil fuel power plants, making it a key player in generating surplus emissions allowances that can be traded.

By including Geothermal Power Plant in the carbon trading scheme, there is a strategic opportunity not only to strengthen the national energy mix with cleaner sources but also to provide additional economic value to geothermal project developers. Furthermore, integrating Geothermal Power Plant into the carbon tax system also reinforces the position of renewable energy as part of the solution to climate change challenges. This demonstrates that fiscal policies and markets can work in tandem to stimulate greater investment in the clean energy sector.

The effectiveness of this policy remains highly dependent on clear regulations, carbon market transparency, and the readiness of supporting infrastructure, including monitoring, reporting, and verification systems. The government must ensure that the implementation of carbon trading and carbon tax is fair, measurable, and integrated with national energy policies. With the synergy between appropriate regulations and the abundant geothermal resources available, Indonesia has the potential to lead in the implementation of the carbon value mechanism in Southeast Asia.

Overall, carbon trading and carbon tax are not only tools for reducing emissions but also serve as instruments for fostering sustainable green economic development. Therefore, Geothermal Power Plant as part of the low carbon

energy solution, needs stronger policy support to optimally contribute to meeting national emission reduction targets and fulfilling global climate commitments.

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