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Biogas Market in Indonesia: The Roles of Carbon Trading

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***Abstract*— As a consequence of being one of the largest greenhouse gas emitters, Indonesia targets emission reduction through several strategies, including command and control, infrastructure and technology investment, and market-based mechanisms. Whether the applied strategies are effective measures was unconvincing, as the amount of emission kept increasing. Therefore, this study focused on identifying the roles of market-based regulation on the renewable energy sector, particularly biogas. By employing qualitative content analysis from desks and a systematic literature review, this study was conducted to address the implication of emission incentives and taxation to the biogas market in Indonesia. The result showed that the absence of a clear baseline, price, and trade flow are the main obstacles to maximizing co-benefits between these two terms. Maintaining sustainability and low carbon footprint at every stage of biogas production is also challenging. However, the biogas sector has great potential to get into those market schemes by making its various utilizations as tradable commodities.**

Keywords*— *biogas, renewable energy, emission reduction, carbon trading

I. INTRODUCTION

Human activity towards modern livelihood has been clearly responsible for more heat stress and climate system alteration. Massive land cover changes such as urbanization and deforestation as well as the burning of fossil fuels are responsible for greenhouse gas (GHG) emitted into the atmosphere and environmental quality degradation, which are leading to the human health crisis and increasing vulnerability to high frequency and intensity of hazard events. Climate mitigation comes down to two instruments; economic-based (pricing) and regulation-based[1]. Through Nationally determined contributions (NDCs), regulatory-based efforts of each country to achieve long-term goals—climate resilience —become more structurally outlined and realized. Moreover, emission trading schemes were established as market-based climate policy instruments, which later updated and supported on Article 6 Paris Agreement, meaning that emission reduced can be transferred between countries and counted towards NDCs[2].

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As being one of the greatest contributor to worldwide GHG, Indonesia commits to reducing emissions and sets the unconditional target by 29% and up to 41% for the conditional of international support by 2030 in their NDCs. These intentions are expected to be contributed by five sectors—energy (utilization for industry and transportation), industrial process, agriculture, land-use change and forestry, and waste[3]. However, whether the strategies in these five sectors have been fully successful in reducing GHG emissions are questionable since Indonesia's emissions keep increasing. Land-use change and energy (fuel combustion) are the largest drivers of overall GHG emissions, in which the industrial sector contributes the most at 37% to the energy-related $C0_2$ emissions in 2019, followed by transport (27%) and electricity and heat generation (27%)[4]. The fulfilment of Indonesia's energy consumption needs is still strongly dependent on fossil-based energy, while the utilization of renewables is not yet optimal both in power and non-power (transportation and industry) sectors. From the 23% contribution target of renewable energy (RE) into the national energy mix by 2025, only 11.2% that has been realized in 2020 [5].

In addition to focusing on infrastructure and technology investment to increase energy efficiency, the capacity of RE plant, as well as RE utilization, market-based mechanisms also become one of the mitigation measures in achieving GHG emissions reduction targets[6]. However, drawing the correlation between these market-based mechanisms with RE development is still rarely discussed compared to the emissions reduction efforts through the Reduced Emissions from Deforestation and forest Degradation (REDD+) program[7][8][9]. The contribution of RE, particularly wind and solar photovoltaics (PV), to diminish carbon dioxide (CO_2) emissions have been proven by certain studies such as in Bangladesh[10] and Italy[11]. The effect of GHG emissions reduction through RE with economic growth has also been investigated by taking the case study of EU-15 countries [12] and China[13]. Apart from techno-economic perspectives, the linkage between GHG emissions reduction and energy-related integrity has been analyzed from the

regulation point of view and mainly on general renewables[14][15][16].

From the previously mentioned studies, it can be known that how GHG emissions reduction and RE development are interconnected within such a regulatory framework has not been widely carried out, especially for particular RE sources. This study, therefore, aims to fill the gap by identifying the roles of emission reduction regulation on the renewable energy market, specifically biogas. Biogas was chosen as the focus because its technology development takes important roles in reducing GHG emissions through various sectors—power, heat supply, transport, organic waste, and agriculture[17]. Biogas produces promising energy in the form of heat and electricity as well as being upgraded to biomethane for vehicle fuel and gas grid injection to replace fossil fuels and enhance energy security[18]. In the meantime, digestate resulting from the anaerobic digestion process is one of the reliable materials for agriculture uses[19].

Until 2021, 52 of 56 biogas projects in Indonesia were registered as Clean Development Mechanism (CDM) projects with the potential to reduce GHG emissions of 2.68 million tCO_2/year[20]. The credits certified reached 1.52 million from 22 projects with a total investment of USD 153 million during two periods of CDM. Closed anaerobic digester for methane capture in biogas plants featured its contribution to the emission reduction. Despite these benefits and biogas opportunities to contribute to GHG emission reduction, the development of the biogas market itself in Indonesia is still considered not as significant as the other renewables[21]. Therefore, this study is expected to dig deeper into how concern on carbon emission reduction can go along with renewable energy deployment.

II. Theoritical Framework

A. Biogas Market in Indonesia: Now and in the Future

Biogas is unique as it is at the heart of green development and aligns with the Sustainable Development Goals (SDGs) as multi problem-solvers—contributing to better agriculture, environment, health, as well as climate and air pollution in which no other renewable energy could do that. Unfortunately, with the abundant feedstock of bio-waste, the contribution of biogas to the national energy mix target reached less than 0.1% in the first quarter of 2021 or only 27.86 million m3 of 489.9 million m3 by 2025[5]. Several efforts to develop biogas have been carried out, such as through biogas power plants, domestic and communal biogas, and compressed biogas. In the power sector, the installed capacity of biogas power plants both on grid and off grid only reached 112MW in 2020[20]. Up to the same year, 47,754 units of Domestic Biogas and 38 units of Communal Biogas have also been built and operated across the country, dominantly supported by private sectors[21]. A domestic biogas program, called BIRU, estimated two million small biogas digesters could reduce 6.4 million tons CO_2/year through its use for heat and cooking fuel [22].

Apart from household or small utilization and power generation, the national government also encourages the conversion of biogas into bio-compressed natural gas (bio-CNG) for other commercial uses such as transportation and industry. However, based on a recent progress report by the Ministry of Energy and Mineral Resources (MEMR) of Indonesia[23], the efforts and progress of bio-CNG development in Indonesia are still at an early stage. The current status showed that the country already has bio-CNG market studies, high-pressure biogas standardization, and one bio-CNG plant for internal mills and plants usage. Although its journey has only just begun, Indonesia's bio-CNG has proven the existence of a large market opportunity from various scales of utilization, such as bottling for households, industry, and transportation, as well as for power generation. As with other renewable energy developments, speeding up the biogas industry and broadening its market still have to face challenges including the high initial cost for investment, the need for advanced and adaptable technology, less variability of project funding sources, and clear governance and regulatory framework as a form of legal support.

B. GHG Emission Reduction through Renewable Energy Sector

Renewable energy (RE) plays a significant role in emission reduction. In order to satisfy the clean energy demand and become the exchange of carbon-emitting energy sources, the government ought to set a sensible green share on the implementation of renewable energy [24]. In comparison, most of the research found that renewable energy has not yet replaced fossil fuel (FF) energy on a 1-to-1 basis and would not reduce the emission reduction target if it is running only on short-term production. Studies found in a simulation basis of wind and photovoltaic energy; on average of the electricity production, 1 kWh of RE displaces 0.8 kWh of fossil power plants [25]. Various scenarios of RE with an equal energy generation capacity project, in the short term, showed undesirable carbon reduction results [26]. However, technology change, productivity, and efficiency of RE would decrease the rate of emission even though its amount will keep increasing [27]. The European Union, for example, shows support mechanisms and subsidies to promote renewable energy sources, resulting in the increased number of patents of emission reduction technology [28]. The use of carbon capture technology in coal-plant could reduce CO_2 emissions ranging from 11 to 24%, while using biomass waste could save up to 148% of CO_2 emissions and using carbon capture could beneficially reduce up to 262% of CO_2 emissions [29].

C. Market-based Schemes in GHG Emission Reduction

Within the emission trading scheme (ETS), cap-and-trade and baseline-crediting are two mechanisms recognized globally. The origin of these two concepts is basically the same. Emissions cap/baseline is set by the government and auctioned to organizations or entities by sectors in the cap-and-trade system, while in the baseline-crediting mechanism, emission baseline is set according to polluters' internal regulation and credited based on their performance relative to their own baseline[30]. Pros and cons continue to accompany the implementation of these two schemes in the carbon market. Some said emission trading was created to force the neoliberal paradigm into environmental-related regulation instead of purely aiming to reduce emission[31]. These cons refer to the fact that companies or industries are allowed to cover their excess emission by purchasing the allowance or credits from high performers or those who can reduce

emissions below the predetermined cap or baseline[32][33]. This practice has driven the fossil fuel facilities to keep emitting CO_2 while high-performance companies can earn additional revenue[30]. In simple words, as long as an allowance or credit can be sold by the "cleaner" companies or industries, the "dirty" ones can always have the chance to avoid controlling their emissions; thus, emissions will not be lower than or equal to the initial amount of cap or baseline.

However, the above condition occurs due to a trading scheme that is not carried out based on its basic principles as a whole. The number of allowances or credits that can be sold is expected to decrease so that trading to emitters is unlikely to happen[6][30][32]. The emission cap or baseline is also supposed to be set down in order to pave the way for fossil fuel-based companies to reduce emissions through technology and infrastructure investments unless they are willing to pay a higher fine of the emission produced in accordance with a lower emission capped or baseline[30].

Another instrument under market-based mechanisms is taxation. The basic concept of a carbon tax is to charge GHG emitters based on carbon content they produce in which the tax rate depends on national economic circumstances [30][34][35]. The carbon tax is expected to be an effective policy in reducing the use of fossil fuels. This instrument is a broad economic regulation in emission reduction that tends not to limit the target sector so that it is applicable to all types of fossil fuels as well as GHG emissions[36][37]. In addition, the carbon tax regulation is considered more powerful than ETS because there are no predetermined emission limits or baseline to be complied with[35].

III. Methodology

This research employed qualitative and thematic analysis. Data collection involved desk review from secondary documents. Reviews of journals related to the biogas market and emission/carbon trading mechanism in Indonesia were combined with relevant normative documents, the current issues in Indonesia, and other supporting information obtained during Digital Global Biogas Cooperation (DiBiCoo) workshops from Indonesian carbon experts. Referring to the various efforts that have been made to reduce GHG emissions, two main measures come from technology and infrastructure investments and market-based schemes. This study would only focus on market-based approaches, including trading and taxing mechanisms. Analysis was conducted from a regulation point of view to address how emission/carbon reduction regulations affect the renewables sector, specifically market expansion, within the scope of RE financing.

IV. Discussion: Impact of Carbon Trading on Biogas Market

A. Emerging Carbon Market Schemes in Indonesia

The development of Indonesia's carbon market started when Indonesia ratified the UNFCCC in 1994. Market-based approaches which have become the Government of Indonesia's (GoI) options include emission trading mechanisms—cap-and-trade (Emission Trading System/ETS) and baseline-and-crediting mechanism such as the Clean Development Mechanism (CDM) and the Joint Crediting Mechanism (JCM)—, Nusantara Carbon Scheme (NCS), and Renewable Energy Certificates (RECs) [6]. The strategy towards Indonesia's carbon market development is defined in TABLE 1.

TABLE 1. INDONESIA STRATEGY TOWARDS CARBON MARKET DEVELOPMENT[38]

Multilateral carbon market	● Joining World Bank initiatives on Partnership for Market Readiness ● Involving in the UNFCCC negotiation ● Developing CDM projects and Verified Carbon Standard (VCS)
Bilateral and regional carbon market	● Cooperating with Japan under Joint-Crediting Mechanism (JCM) ● Open for international (bilateral and regional) collaboration for carbon offset schemes
Domestic carbon market	Developing Nusantara Carbon Scheme (NCS) as the simple yet legally robust framework for: ● Facilitating voluntary market opportunity ● Being flexible and adaptable to be combined with other mechanisms

1) CDM in Indonesia - CDM is a system based on projects, and the projects can be considered separately or as aggregated projects [32]. The study of CDM in Indonesia started in 2002 through international and multilateral collaboration. Most of the CDM are used to deepen or explore the potential of renewable energy projects and resources in Indonesia. The set of criteria that CDM energy-related projects need to comply with has been established—support energy diversification and conservation, clean energy technology, and environmental conservation; maintain employment rates; optimizing high quality local human resources; and provide community development programs [39]. By regulation, only a few of Indonesia's regulations are directly related to the CDM, one example is geothermal-based electricity generation.

2) Joint-Crediting Mechanism (JCM) - The Joint Crediting Mechanism (JCM) is joint-project between Japan and developing worlds, including, under initiative of Japan Government, to incentivize low-carbon development activities. JCM in Indonesia have started since 2010 and developed up to 115 feasibility studies as per the end of 2017. The most common fields covered by JCM include RE, energy efficiency technology (e.g.carbon capture storage), forestry and agriculture, as well as transportation [40].

3) Nusantara Carbon Scheme (NCS) – As a form of national action, Indonesia has initiated voluntary schemes for emission reduction certification, called the Nusantara Carbon Scheme (NCS)— adapting the baseline-and-crediting mechanism. This scheme intends to facilitate carbon market in national level and voluntary market by private sectors or companies. NCS is very similar to the CDM run by the UNFCCC. In the output context, CDM certification outputs are carbon credits that can be used to fulfil emission reduction obligations under the Kyoto Protocol, while NCS carbon credits are not related to any greenhouse gas emission reduction/limitation policy [41]. Improving the CDM

schemes, NCS is expected to compose a simple and robust mandatory and verifiable requirement to make the project outcomes align with emission reduction agenda towards low-carbon Indonesia[42]. Since national government has not yet had compliance-based market instrument for emission reduction, NCS can take parts as an element to bolster future domestic carbon market in Indonesia.

B. Impact of Emission Trading Schemes

The correlation between emission/carbon trading mechanisms and clean energy is evident. The reduction of 90% of energy-related CO_2 emissions was expected to come from renewable energy and energy efficiency [43]. Installing carbon capture storage (CCS) technology, shifting to renewable energy—for power, heat generation and transport as well as cooking fuels—, and creating an energy-efficient living design are considered as the most effective ways for RE to reduce GHG emission [44]. According to the characteristics of RE, wind, solar, hydro, geothermal, and ocean energy are categorized as emission/carbon-free, while bioenergy is emission/carbon neutral [45]. Since most renewables are carbon-free, these industries are less likely to enter the carbon market because there are no tradable items—emission/carbon [33]. The most common practice in the existence of renewables in the emission/carbon trading is through market claims from emitters who pay fines or consequences for CO_2 they produce to build or finance renewable energy plants [32][33]. In this case, it can be simply concluded that the emission/carbon trading schemes have opened up opportunities for renewables developers to get financing support even from emitters. Another way is to trade emissions from fossil fuel grids replaced by renewable power generation and become their additional revenue[32].

Meanwhile, bioenergy in reducing emissions is different. Bioenergy conversion not only reduces emissions through its role as a fossil fuel substitute, but also the cycle of bioenergy production itself has sequestered the amount of emission and reaches net negative emissions if combined with CCS technology [44][46]. For specific bioenergy such as biogas, baseline-crediting schemes like CDM and JCM are those already implemented in Indonesia. In the CDM and JCM schemes, because “emission reduction” is compared to a certain “baseline” which can be in the form of energy technology that is currently used, the opportunity to obtain certified emission reduction (CER) from the energy sector in the country will lie in the use of energy technology for renewable energy sources. Through anaerobic digestion and biogas upgrading technology, biogas can contribute to capturing methane gas emissions released. Moreover, by converting biogas into energy matters—e.g. gasoline and diesel for electricity, heat, cooking, and transport—, the increase of emissions from burning fossil fuel can be avoided [47]. In addition to supporting emission reduction in order to achieve NDC targets related to the energy sector, biogas is also a measure of the waste, agriculture, forestry, and land-use sectors.

Although the biogas production process is technically supportive as an effort to reduce GHG emissions, the implementation of emission trading needs to be carried out carefully. For biogas that is utilizing agricultural waste feedstock, it is important to ensure that the upstream sectors perform sustainable agriculture and keep their carbon footprint as low as possible. Emission release from the manner in which palm oil is grown, processed, and the waste brought into the biogas plant should be taken into account in the trading schemes. For Indonesia, where the largest source of biogas is palm oil waste [48], the challenges that must be considered are also more complex. Socio-environment impacts arising from the expansion of oil palm plantations by burning the peatlands include emission release, biodiversity loss, and land rights conflicts with local communities [32][49]. Apart from socio-environmental constraints, CDM projects also face challenges in high transaction or project cost which are still difficult to calculate. Therefore, it requires the readiness of domestic institutions to handle CDM projects as well as international regulations developed regarding CDM.

C. Carbon Tax Implications

Until now, Indonesia has not implemented a carbon tax, but this is not impossible in the near future. With the flexibility of carbon tax application, it is important for the national government to firstly have a clear definition and context of carbon tax, such as deciding which fuel or resource to be taxed and at which level it will be placed—upstream or downstream sector. In addition to paying attention to how to collect the taxes, determining high tax rates can be a stronger driving factor to change people's behavior and, at the same time, provide more funds for GHG emission reduction programs. However, an appropriate tax rate setting must carefully consider the marginal benefit and the marginal cost of adding and subtracting one tonne of GHG emissions [50].

Even though the carbon tax has set a clear price to make investment decisions easier for companies, the assumption that tax will increase investment costs still remains[34][36] because the tax rate is ideally designed to increase over time[30]. Not only for investment cost, the increase in tax rate thus can result in the increase in commodity price [34]. These have clearly shown that the carbon tax cannot stand on its own. Alternative to replace fossil fuels—by renewable energy—must support this mechanism at least to maintain the economies of scale of the industries and make the business keep running while reducing GHG emissions. Speeding up the biogas market through carbon tax is basically the same as other renewables. Revenue received from the carbon tax is potential to be distributed to build green projects including biogas, and can also be allocated to subsidize the price of renewable energy.

Carbon tax levies are considered to have the potential to support a reduction in carbon emission levels, as well as to support the development and innovation of renewable energy technology, although the implementation of carbon levies in Indonesia is still under discussion by the national government. Indeed, to support the implementation of a carbon tax in Indonesia, several considerations are needed. First, the government needs to properly design the target sectors, activities, and goods that clearly cause pollution. Carbon taxes are also oriented towards mitigating climate change and becoming an instrument to protect the environment. Its nature which reduces negative externalities will be in line with the principles of sustainable development.

The second consideration is what kind of levy scheme will be imposed on these sectors. Is it a new type of tax or will it refer to existing tax levies such as excise, Income Tax (PPh), Value Added Tax (PPN), Luxury Goods Sales Tax (PPnBM) or other levies. Likewise, the basis for the imposition of taxes or rates. For example, whether it is based on estimates of the resulting carbon emissions, fuel consumption, or others.

The third consideration is that this carbon levy is applied based on the principle of justice. Carbon taxes have been proven to reduce pollution and emissions in several countries that apply them, and increase state revenues. Carbon tax revenues can be allocated to incentivize or subsidize sectors which have urgent needs such as education, health, low carbon transport, green industry, and could financially help to secure unstable condition of workers affected by the renewables transition.

D. Renewable Energy Certificate (RECs) Trading in Voluntary Market

Besides focusing on the side of emitters, how the carbon regulation might affect the RE market could come from the user side. Participation in emission reduction can be done voluntarily by purchasing RE and claiming that it would "offset" their energy consumption which is associated with their emission footprint [33]. The most growing renewables trading mechanism today is electricity purchase or Renewable Energy Certificate (RECs). REC is a tangible and tradable commodity to substantiate renewable electricity use-claims [51]. Carbon regulation allows consumers to purchase and retire RECs, expecting the increase in green electricity demand; thus, reducing GHG emission by switching from fossil fuel [30][33]. RECs is getting a lot of attention as one of the potential instruments in market-based mechanisms of emission reduction because not only as a recognition of support for environmental issues through RE but also its potential as one of revenue streams, especially for RE generators [30][33][51]. However, the implementation of RECs is also inseparable from the complexity to be in line with carbon regulation.

In Indonesia, options are currently limited when it comes to purchasing electricity from renewable energy sources. State-owned Electricity Enterprise (PLN) comes with a RECs product that aims to facilitate buyers in obtaining recognition for using renewable energy. This innovation rises to meet Indonesian market demand as more than 240 multinational companies have pledged to use 100% renewable energy sources to electrify their facilities and supply chains, including in Indonesia[52][53]. Unfortunately, customers can only choose one option at the moment because the only one who has registered is Geothermal Power Plant Kamojang in Garut, West Java, even though RECs basically provide certificates from wind, biomethane, geothermal, or other power renewable plants [52][54].

Although RECs from biogas power plants are currently unavailable in Indonesia, it is not impossible that this instrument will soon be practiced. Comprehensive applications of biogas to tackle environmental issues from various lines has opened a wide way for it to get into this standard system. Since biogas does not contribute to GHG emission reduction only as renewable electricity, reduction in energy consumption through by-products of biogas upgrading for transportation and cooking fuels could also be certified and traded as a tangible commodity to get credit in the market. Diverse utilization options of biogas, which is tradable, will accelerate biogas development and increase its market uptake. In order to go hand in hand with the emission reduction agenda, this must be supported by clear carbon regulation, especially in setting the standards to be qualified as credible offset [33]. Setting the level of cap or baseline should also take biogas into account, given its emission or carbon-neutral characteristics. In addition, because the price of RECs or other certificates must compete with fossil-fuel prices, allocating tradable allowance for biogas developers can be an alternative to splitting revenue streams from the carbon market; thus, the RECs or other certificate prices can also be dropped down.

V. CONCLUSION

Referring to market-based instruments for emission reduction, carbon trading regulation was debatable in accelerating the development of renewables. Even though it could become a tradable commodity in the carbon market and be exchanged equivalent with emission released, supporting regulation particularly in cap or baseline level, carbon price, and trade flow determination remained unclear; thus, whether the renewables is an effective measure was questionable. In addition, carbon trading and renewable energy regulation cannot stand on its own. While in the market-based mechanisms carbon regulations focus on incentivizing and taxing the emission released, the renewable energy sector, on the other hand, should compose strategies on increasing the capacity and its market uptake.

However, multi-problem solver biogas is prospective to reduce emission while performing as clean energy. By having contribution chances from various directions, biogas is considered to be adaptable within any carbon trading instrument. The important thing that should be noted is to ensure sustainability and keep the carbon footprint as low as possible in every stage of biogas production. Since this study discussed only the economic implication of carbon trading regulation to the biogas market, potential technical constraints may arise due to biogas construction being neglected; thus, further analysis is strongly encouraged.

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REFERENCES

[1] UNFCCC. (1997). Kyoto Protocol - UNFCCC. 1–24. https://unfccc.int/sites/default/files/resource/docs/cop3/l07a01.pdf

[2] UNFCCC. (2015). Paris Agreement - UNFCCC. 1–60. https://unfccc.int/sites/default/files/resource/parisagreement_publication.pdf

[3] KESDM. (2016). First Nationally Determined Contribution Submitted to UNFCCC. November 2016, 1–18.

https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Indonesia First/First NDC Indonesia_submitted to UNFCCC Set_November 2016.pdf

[4] IESR (2021). (2020). Indonesia Climate Transparency Report. Institute for Essential Services Reform (IESR), 1–20.

[5] Ministry of Energy and Mineral Resources (MEMR). (2021). *Bioenergy Development Policy*. Bioshare #3:Bioenergy Project Finance (August 5, 2021)

[6] Amarjargal, B., Ebro, H., Nylander, J., Duggal, V. K., & Bank, A. D. (2020). Achieving Nationally Determined Contributions through Market Mechanisms in Asia and the Pacific, (64).

[7] Espejo, A. B., Becerra-Leal, M. C., & Aguilar-Amuchastegui, N. (2020). Comparing the environmental integrity of emission reductions from REDD programs with renewable energy projects. Forests, 11(12), 1–16. https://doi.org/10.3390/f11121360

[8] Boer, H. J. (2018). The role of government in operationalising markets for REDD + in Indonesia. Forest Policy and Economics, 86, 4–12. https://doi.org/10.1016/j.forpol.2017.10.004

[9] Murray, J. P., Grenyer, R., Wunder, S., Raes, N., & Jones, J. P. G. (2015). Spatial patterns of carbon, biodiversity, deforestation threat, and REDD+ projects in Indonesia. Conservation Biology, 29(5), 1434–1445. https://doi.org/10.1111/cobi.12500

[10] Dulal, A., Yao, X., Barker-Gibb, M., Tachega, M. A., Ge, S., & Li, H. (2021). Impact of Renewable Energy on Carbon Dioxide Emission Reduction in Bangladesh. Journal of Power and Energy Engineering, 09(05), 134–165. https://doi.org/10.4236/jpee.2021.95009

[11] Aliprandi, F., Stoppato, A., & Mirandola, A. (2016). Estimating CO_2 emissions reduction from renewable energy use in Italy. Renewable Energy, 96, 220–232. https://doi.org/10.1016/j.renene.2016.04.022

[12] Heshmati, A., Abolhosseini, S., & Altmann, J. (2015). The development of renewable energy sources and its significance for the environment. The Development of Renewable Energy Sources and its Significance for the Environment (pp. 1–175). Springer Singapore. https://doi.org/10.1007/978-981-287-462-7

[13] Qi, T., Zhang, X., & Karplus, V. J. (2014). The energy and CO_2 emissions impact of renewable energy development in China. Energy Policy, 68, 60–69. https://doi.org/10.1016/j.enpol.2013.12.035

[14] Seutche, R. V. N., Sawadogo, M., & Ngassam, F. N. (2021). Valuation of CO_2 Emissions Reduction from Renewable Energy and Energy Efficiency Projects in Africa: A Case Study of Burkina Faso. International Journal of Renewable Energy Development, 10(4), 713-729. https://doi.org/10.14710/ijred.2021.34566

[15] Adams, S., & Acheampong, A. O. (2019). Reducing carbon emissions: The role of renewable energy and democracy. Journal of Cleaner Production, 240. https://doi.org/10.1016/j.jclepro.2019.118245

[16] Fakoya, Michael. (2014). On carbon tax and emissions reduction through investments in renewable energy in South Africa. Environmental Economics. 5. 88-92.

[17] World Biogas Association. (2017). How can biogas help mitigate climate change? Retrieved from http://www.worldbiogasassociation.org/wp-content/uploads/2018/07/WBA-Climate-Change-Biogas-factsheet-2.pdf

[18] World Biogas Association. (2017). How can biogas help mitigate climate change? Retrieved from http://www.worldbiogasassociation.org/wp-content/uploads/2018/07/WBA-Climate-Change-Biogas-factsheet-2.pdf

[19] Tambone, F.; Terruzzi, L.; Scaglia, B.; Adani, F. Composting of the Solid Fraction of Digestate Derived from Pig Slurry: Biological Processes and Compost Properties.Waste Manage.2015,35,55–61.DOI:https://doi.org/10.1016/j.wasman.2014.10.014

[20] IRID. (2021). Biogas Project Carbon Finance. RDI-DiBiCoo Capacity Building Series#2 (July 14-15th, 2021)

[21] Dilisusendi, Trois. (2020). Sustainable Biogas Production and Use in Indonesia. DiBiCoo Web Seminar#5, November 17th, 2020.

[22] Taylor, R., Devisscher, T., Silaenb, M., Yuwono, Y., & Ismail, C. (2019). Risks, barriers and responses to Indonesia's biogas development. Stockholm Environment Institute, (June 2019), 1–9. Retrieved from https://www.jstor.org/stable/resrep22991%0D

[23] MEMR. (2021). Potensi Pasar Biomethane Compressed Natural Gas (Bio-CNG) dalam pangsa Energi Terbarukan Nasional. RDI-DiBiCoo Biogas Workshops Series#2 (May 7th, 2021)

[24] Xin-gang, Z., Ling, W., & Ying, Z. (2020). How to achieve incentive regulation under renewable portfolio standards and carbon tax policy? A China's power market perspective. Energy Policy, 143, 111576.

[25] Aliprandi, F., Stoppato, A., & Mirandola, A. (2016). Estimating CO_2 emissions reduction from renewable energy use in Italy. Renewable Energy, 96, 220-232.

[26] Dulal, A., Yao, X., Barker-Gibb, M., Tachega, M. A., Ge, S., & Li, H. (2021). Impact of Renewable Energy on Carbon Dioxide Emission Reduction in Bangladesh. *Journal of Power and Energy Engineering*, *9*(5), 134-165.

[27] Heshmati, A., Abolhosseini, S., & Altmann, J. (2015). The development of renewable energy sources and its significance for the environment. Springer Singapore.

[28] Heshmati, A., Abolhosseini, S., & Altmann, J. (2015). The development of renewable energy sources and its significance for the environment. Springer Singapore.

[29] Sutrisno, Z. P., Meiritza, A. A., & Raksajati, A. (2021). Understanding the Potential of Bio-Carbon Capture and Storage from Biomass Power Plant in Indonesia. Indonesian Journal of Energy, 4(1), 36-56.

[30] Agency for International Development - USAID. (2019). RALI Series: Promoting Solutions for Low Emission Development - Bringing Harmony to GHG MRV (pp. 1–16). Retrieved from https://www.climatelinks.org/sites/default/files/asset/document/2018_USAID_RALI-Series-Introduction-to-MRV-Harmonization-Process.pdf

[31] Boer, H. J. (2018). The role of government in operationalising markets for REDD + in Indonesia. Forest Policy and Economics, 86, 4–12. https://doi.org/10.1016/j.forpol.2017.10.004

[32] Gilbertson, T., & Reyes, O. (2009). Critical Currents: Carbon Trading - How it works and why it fails. 7, 1–104.

[33] Bird, L., & Holt, E. (2007). Implications of Carbon Regulation for Green Power Markets Implications of Carbon Regulation for Green Power Markets. Contract, (April).

[34] Maulidia, M. (2014). Carbon tax for Indonesia: Time to act now. The Jakarta Post. https://www.thejakartapost.com/news/2014/04/29/carbon-tax-indonesia-time-act-now.html

[35] The World Bank. (2011). Pricing Carbon. https://www.worldbank.org/en/programs/pricing-carbon

[36] Ratnawati, D. (2016). Carbon Tax Sebagai Alternatif Kebijakan Untuk Mengatasi Eksternalitas Negatif Emisi Karbon di Indonesia. Indonesian Treasury Review: Jurnal Perbendaharaan, Keuangan Negara Dan Kebijakan Publik, 1(2), 53-67. https://doi.org/https://doi.org/10.33105/itrev.v1i2.51

[37] VANDERWOLK, J. (2021, April 6). Global Consistency on Carbon Tax: A Role For the OECD's Inclusive Framework? (Correct). Bloomberg Law. https://news.bloomberglaw.com/daily-tax-report-international/global-consistency-on-carbon-tax-a-role-for-the-oecds-inclusive-framework

[38] Hindarto, D. E. (2015). The Joint Crediting Mechanism (JCM) Current Development in Indonesia. April.

[39] Ministry of the Environment, J., Ministry of Environment, the R. of I., & Indonesia, C. and E. R. (2006). CDM Country Guide for Indonesia. Ministry of the Environment Japan.

[40] Panggilan proposal untuk Studi Kelayakan Kolaborasi Antar kota JCM. JCM Indonesia. (n.d.). http://jcm.ekon.go.id/id/index.php/content/MTE3/panggilan_proposal_untuk_studi_kelayakan_kolaborasi_antar_kota_jcm

[41] Purnomo, A. (2013). Mari Berdagang Karbon! 84.

[42] PMR. (2013). Market Readiness Proposal: Indonesia Identifying Suitable Market Instruments. 14–17. http://www.thepmr.org/system/files/documents/Indonesia MRP Final-September29.pdf

[43] United Nations. (2018). Renewable Energy Sources Cut Carbon Emissions, Efficiently Increase Electricity Output Worldwide, Delegates Say in Second Committee (Issue December, pp. 1–11). https://www.un.org/press/en/2018/gaef3501.doc.htm

[44] Hudson, C. R., & Badiru, A. B. (2008). Energy systems. In Operations Research Applications (pp. 5-1-5–30). CRC Press. https://doi.org/10.4324/9780203223017-18

[45] Sterner M (2009) Bioenergy and Renewable Power Methane in Integrated 100 % Renewable Energy Systems—Limiting Global Warming by Transforming Energy Systems. University of Kassel, Kassel, Germany

[46] IEA (2011) Combining Bioenergy with CCS. Reporting and Accounting for Negative Emissions under UNFCCC and the Kyoto Protocol. OECD/IEA, Paris, France.

[47] GEC. (2018). *12MW Biomass Power Plant Project in Aceh Province, Sumatera*. Retrieved from https://gec.jp/jcm/projects/

[48] Ministry of Energy and Mineral Resources (MEMR). (2021). *Bioenergy Development Policy*. RDI-DiBiCoo Workshop #2: "Accelerating Biomethane Utilisation in Indonesia: Lesson learned from European Countries (May 7, 2021)

[49] Holmes, D. (2000). Deforestation in Indonesia: A View of the Situation in 1999. Jakarta: World Bank.

[50] Metcalf, G. E., & Weisbach, D. (2009). The design of a carbon tax. Harv. Envtl. L. Rev., 33, 499.

[51] United States Environmental Protection Agency. (2021, May 5). *Renewable Energy Certificate Monetization.* https://www.epa.gov/repowertoolbox/renewable-energy-certificate-monetization

[52] PLN - Portal Layanan Pelanggan. (2021). Sertifikat Energi Terbarukan/Renewable Energy Certificate (REC). https://layanan.pln.co.id/renewable-energy-certificate/informasi.

[53] Wiratmini, N. (2020, January 20). PLN dan CEIA Kerja Sama Beri Sertifikat EBT ke Industri. https://ekonomi.bisnis.com/read/20200123/44/1193257/pln-dan-ceia-kerja-sama-beri-sertifikat-ebt

[54] United States Environmental Protection Agency. (2021, July 12). *Renewable Energy Certificates (RECs).* https://www.epa.gov/greenpower/renewable-energy-certificates-recs