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Economic, Social, and Environmental Impact of Renewable Energy Investment: Empirical Study of Indonesia

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ABSTRACT

Stipulated by the Paris Agreement, the Indonesian government has committed to reducing CO_2 emissions from the power generator sector by achieving a national renewable energy mix share of 23 percent by 2025. Although the environmental impact may be obvious, there is a potential trade-off in environmental and social aspects of the energy mix transition that should be considered. This study aims to identify the effect of renewable energy investment in the power sector based on economic, social, and environmental aspects. This was assessed through the examination of several indicators, including Gross Domestic Product (GDP), household income in rural and urban areas, employment, and CO_2 emissions. Using Social Accounting Matrix (SAM) analysis, two scenarios are simulated in this study (1) we identify which renewable energy investment has the most significant impact (2) we examine the impact of non-renewable energy investment substitution to renewable energy investment. The result shows that the construction of hydropower plants generates the least emission but also moderate impact on socio-economic aspects compared to other renewable energy. In addition, emissions may be reduced higher if coal power plants are being substituted to only hydro and geothermal power plants.

1. INTRODUCTION

The world is hit by the phenomenon of worsening climate change due to global warming caused by the effects of CO_2 emissions [1]. This condition led to the Paris Agreement in 2015, which stated that global temperatures must stay below 2 degrees Celsius [2]. Climate change was caused by the dominance of CO_2, where 68% of it was produced by energy combustion substances. More than half of the growth in energy demand was due to power generator activities as it mostly uses fossil energy [3]. Thus, many countries implemented various policies to reduce emissions by alternating power plants' energy sources from fossil energy to renewable energy.

The climate issue has been also a concern for the Indonesian government. Indonesia is one of the highest emitters of CO_2 in the world with the fourth-largest population. According to data from the Potsdam Institute for Climate Impact Research, Indonesia's annual CO_2 emissions were 2.4 billion tons in 2015, representing 4.8 percent of the world's total global emissions for that year [4]. The energy sector plays a significant role in emitting CO_2 emissions. The contribution of the energy sector to emissions amounted to 558,890 Gg of CO_2 in 2017, 48% of its total CO_2 emissions, followed by forestry and peat fires 26%, agriculture 11%, and others [5]. Among the five energy-consuming sectors, the largest contributor to CO2 emissions is electricity generators, especially those produced by coal-fired power plants [6]. In the Republic of Indonesia's first National Determined Condition (NDC) document in 2016, Indonesia is committed to reducing CO_2 emissions by 29% and attaining 834 million tons of CO_2 equivalent in 2030 [6]. Due to a large number of CO_2 emission contributions from the energy sector in power generators, the government has made a policy plan for energy diversification from fossil-based to renewable energy-based to achieve the emission reduction target. The government's commitment to reduce CO_2 emissions from the power generator sector is to set the national renewable energy mix at 23% by 2025.

In terms of energy sources, Indonesia has enormous renewable energy potential. The total potential of renewable energy for the power generator sector is equivalent to 442 GW [7]. Indonesia has great renewable energy potential including hydropower, geothermal energy, bioenergy, solar energy, wind, and marine energy. The enormous potential of renewable energy can support targets to improve environmental quality, but the existence of an energy diversification policy plan must also go along with the considerations of economic, social, and environmental impacts.

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Suppose the energy diversification policy encourages investment in the long term to build renewable energy in power plants, the government then should also consider the impact of switching from fossil energy to renewable energy and choose which renewable energy is the most profitable economically, socially, and environmentally. The economic impact will measure how much investment in renewable energy can increase the aggregate economic output. Meanwhile, the social impact can be measured through the distribution of income and the difference in employment numbers. As renewable energy certainly has a significant positive impact on the environment, yet by measuring the economic and social impacts, we also can identify which renewable energy generators are the most profitable from the three aspects and mitigate if negative impacts occur economically and socially. The notion of achieving sustainable development by balancing economic, social, and environmental factors is commonly referred to as the triple bottom line (TBL) approach. This approach has been widely utilized in various studies, including to assess the development of renewable energy systems [8]–[11].

Several related studies analyze the economic, social, and environmental impacts of investing in renewable energy power plants. For example, research conducted by [12] in Malaysia using the Computable Generalized Equilibrium (CGE) method in 2005 - 2015 states that changes in investment made from fossil energy to renewable energy will have a negative impact on macroeconomic variables if there is no recycling of the earned income. Meanwhile, in a study conducted by [13] in 2015 using the Social Accounting Matrix (SAM) method, the findings showed that investing in the renewable energy sector requires a greater investment compared to fossil energy, but yields a positive economic impact. Additionally, this study reveals that investing in a geothermal power plant has the largest positive economic impact [13]. Research conducted by [14] using the CGE method for the period of 2010 - 2030 in the Netherlands states that the transition to renewable energy can have a positive impact on the economy in the Netherlands, such as an increase in 50,000 new workers and 1 percent of the Gross Domestic Product (GDP). From this literature, the economic, social, and environmental impacts of renewable energy are positive in general. Even so, research conducted by [15] in China and [16] in the United States provides further analysis by comparing what renewable energies have a greater impact. Using the input-output model, these two studies suggest that the most profitable investment from the social side of employment in various renewable energy sectors is bioenergy. By knowing which types of renewable energy are the most profitable, this research can provide clear and specific recommendations for governments during the current energy transition period. Another study conducted by Effendi and Resosudarmo [17] shows that the transition from fossil energy to renewable energy on power plant in ASEAN countries has negative economic and social impact in several countries, but significantly positive environmental impact for all ASEAN countries.

There has been no research in Indonesia that discusses the effect of fossil energy substitution toward renewable energy and which type of renewable energy is the most profitable economically, socially, and environmentally in a power generator. Thus, this study aims to fill the existing research gap by assessing the impact of renewable energy investment using SAM sectoral analysis. Using sectoral analysis in SAM, this study was able to identify not only the direct ('own') effect but also the indirect ('open') effect of the whole economy activities due to the power plant investment [18].

This research will simulate two simulation scenarios. First, we assess the effect of power generator investment for each type of source to know the effect of each power plant investment, and second, we estimate the effect of renewable energy substitutes on current fossil power generators following the government's target of energy diversification in 2025. In this way, we simulate what happens to the socio, economic, and environmental indicators if the government's target of energy diversification is accomplished. We contribute in several ways, (1) by comparing the investment impact between fossil energy and renewable energy in Indonesia and (2) by constructing and creating a renewable energy sector using the Social Accounting Matrix (SAM) data. SAM analysis includes direct and indirect social impacts in the form of the number of workers generated as well as identifying inequality through income distribution that cannot be measured by other methods [13]. Therefore, it is possible to analyze the impact of substituting fossil energy for renewable energy in power plants and simulate the comparative economic, social, and environmental impacts of investing in various renewable energy types in Indonesia.

2. INDONESIA POWER PLANTS

Based on the Statistic of Electricity of 2018 [19], around 63% of power plants in Indonesia are owned by the public company, Perusahaan Listrik Negara (PLN), and 29% are owned by independent power producer and private public producer. Most of the power plants in Indonesia (45%) are steam power plants, followed by combined cycle power plants (17%), gas turbines (8%), and diesel (7%) (See Table 1). These fossil energy sources dominate power plants in Indonesia, amounting to 85% in 2018, dominated by coal and oil-fuelled plants. Even though Indonesia's steam power plant used supercritical or ultra-supercritical coal which emitted the least emission among other steam technologies, these power plants emitted the highest amount of emission, especially compared with renewable energy with no emission (see Table 1).

Meanwhile, Indonesia has enormous potential in utilizing renewable energy sources yet has not fully utilized them. The total potential of renewable energy for the power generator sector is equivalent to 442 GW [7]. With the goal of meeting the Paris Agreement, there is a push towards energy diversification which involves transitioning from fossil fuel-based energy sources to renewable energy sources [22]. Transitioning is essential to reduce emissions in the power plant sector. This method of energy diversification is in line with the theory of the transition model where this model highlights the importance of long-term policies to address structural problems of sustainability that have not been resolved by short-term policy approaches for several sectors, namely energy, construction, population mobility, or agriculture [23].

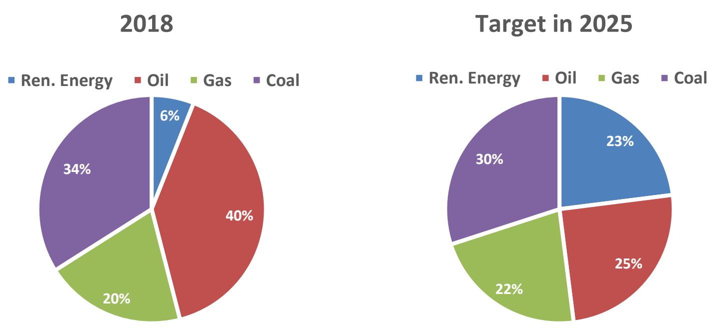
The government's commitment to reduce CO_2 emissions from the power generator sector is by setting 23% renewable energy sources on the total energy mix by 2025. According to the data from the National Energy Council, Indonesia's national energy mix target is 30% for coal, 25% for oil, 22% for natural gas, and 23% for renewable energy with a total capacity of 115 GW for power generators [24]. However, in 2018, power plants from renewable energy resources were still at 6.22%, coal 33.7%, petroleum 40.1%, and natural gas 20.1%. The realization of the 2025 energy mix target is questionable whether it can be achieved or not because the share of coal power plants still dominates. Figure 1 shows that there is a high gap between the current condition in 2018 and Indonesia's target in 2025.

The government aims to reduce the percentage of coal fossil energy and increase the percentage of renewable energy and gas energy by 2025. This study tries to simulate whether a substitution can be made from coal energy to renewable energy and gas, and how it will affect the economy, society, and environment. This study also simulates the comparison of renewable energy resources, assessing which energy source gives the biggest economic, social, and environmental impact.

Table 1. Energy capacity and emission table in power plant.

Power Plant	Energy Capacity, 2018 (MW)	Emission ($kgCO_2/MWH$)
Combined Cycle Gas Turbine	11,220	372
Open Cycle Gas Turbine	5,348	472.8
Steam	29,527	792
Diesel	4,631	270
Geothermal	1,948	0
Hydro	5,370	0
Mini Hydro	268	0
Micro Hydro	105	0
Wind Power	144	0
Solar	61	0
Other	8,343	

Source: [20], [21]



Power Plant: 51 GW
Energy Cons.: 0.8 TOE/capita
Electricity Cons.: 776 kWh/capita

Power Plant: 115 GW
Energy Cons.: 1.4 TOE/capita
Electricity Cons.: 2500 kWh/capita

Fig. 1. Comparison of the realization and target of renewable energy mix.

3. THEORETICAL FRAMEWORK AND METHODS

3.1 Theoretical Framework

The concept of sustainable development was established in 1978 as a worldwide goal to direct policies aimed at achieving equilibrium among economic, social, and ecological conditions [8]. The idea of achieving a balance among these three dimensions was subsequently developed by Elkington [26] and is now known as the Triple Bottom Line (TBL) approach; where the agenda focuses not only on the economic aspect but also on the environmental and social value-added or value-destruction. This perspective allows us to address current issues in a broad perspective. The impact assessment using TBL approach has been widely used in the literature, including in the assessment of renewable energy development. For instance, prior studies used TBL perspective to assess the current situation of wind energy in Brazil [8], solar power in China and Europe [9] as well as solar photovoltaic sector in Spanish [11].

In the context of developing a TBL for macroeconomics and environmental indicator, the study by Wiebe *et al.* [27] used value added for the economic indicator, employment for the social indicator, and CO_2 emissions for the environmental indicator, all of which are known to be connected to input-output based models. By this framework, this study employs the TBL concept and SAM framework to simulate the impact of renewable energy investment on economic, social, and environmental indicators.

3.2 Methods

The impact of renewable energy investment in the electricity sector can be measured both by partial equilibrium, such as regression, or general equilibrium model. However, changes in economic output cannot be seen correctly with the partial equilibrium model, because one sector's production may become vital input to other sectors and construct a complex input-output connection between sectors [28]. Therefore, the electricity sector's impact is analyzed using a multi-sectoral approach, one of which is the SAM approach.

This study uses a SAM analysis framework. SAM is a data frame that records economic transactions in the economy, which consist of transactions between production sectors (called production blocks), corporate and households (institutional blocks), and factors of production during a specific period, combined in the form of a matrix [29]–[31]. Because it summarizes all economic activity transactions, the SAM approach model provide information on the socio-economic structures such as economic output, number of workers, and income distribution in each production sector [29]. By employing the SAM analysis framework, this methodology can generate multiplier matrix that facilitate the examination of sectoral impacts across multiple domains, including on value added or GDP, household income, sectoral employment, and sectoral emission. Its application is also relatively simple to be applied in various countries [32]. Therefore, the SAM analysis is commonly used in prior sectoral studies regarding energy investment [13], [33]–[35].

Like other methodologies, SAM also has analytical limitations. When describing the results, the researcher must be careful about restrictive suppositions in the model. This limitation is explained by Hartono *et al.* [13] that the prevailing assumption is that fixed prices and variations in demand will affect nominal output in preference to prices. In addition, the model assumes that the economy has unlimited resource factors for land, labor, and capital. Another major limitation is that the model covers country-level transactions and thus, fails to account for regional variations such as geographic and demographic factors. Consequently, this study concludes that the deployment of diverse types of power plants can be built in all regions of Indonesia. In Indonesia, the Indonesian Central Bureau of Statistics publishes SAM official data.

3.2.1 Accounting multiplier matrix (AMM) to simulate the impact of various renewable energy investment

The purpose of this analysis is to compare three kinds of Indonesian renewable energy power plants (hydro, geothermal, and biofuel) and identify which one has the biggest economic, social, and environmental impact. Following Hartono [13] study, we apply SAM analysis framework by multiplying the accounting multiplier matrix (AMM, M_a) with changes in exogenous account (renewable energy investment, ΔX) to assess its impact on endogenous account such as GDP, household income, and employment (ΔY). In general, the mathematical equation is expressed as follows:

$$\Delta Y = M_a . \Delta X \tag{1}$$

To estimate the economic impact of investment in renewable power plant, the study analyses its impact on the changes of value added in all production sectors (GDP). To estimate the social impact, this study assesses the employment effect by calculating the impact of investment expenditure on the number of workers created in each sector. Additionally, this study computes the effect of renewable energy investment on diverse household income groups to evaluate the extent to which such investment affects income inequality among these groups. The last is to calculate the environmental impact. To estimate the environmental impact, this study calculated the impact of investment on CO_2 emission produced from the production of goods and household enterprises from each sector.

3.2.2 Constrained Fixed Price Multiplier (CFPM) to Simulate the Impact of Substituting Coal Power Plant with Renewable Power Plant

The CFPM method is used to find the impact of changes in output from a restricted endogenous account to an unrestricted endogenous account. This can be illustrated by modifying the SAM framework, which differentiates endogenous accounts into constrained and non-constrained (See Table 2). This study uses the CFPM method by Hartono and Resosudarmo [32] to simulate what is the impact if we substitute the investment from the non-renewable energy power plant with a renewable energy power plant.

This CFPM method is explained in Hartono and Resosudarmo [32]. The equation is:

$$\begin{aligned} \begin{bmatrix} \frac{yNC}{yC} \end{bmatrix} = \begin{bmatrix} \frac{nNC}{nC} \end{bmatrix} + \begin{bmatrix} \frac{xNC}{xC} \end{bmatrix} \\ = \begin{bmatrix} \frac{ANC}{R} \Big| \frac{Q}{AC} \end{bmatrix} \begin{bmatrix} \frac{yNC}{yC} \end{bmatrix} \\ + \begin{bmatrix} \frac{xNC}{xC} \end{bmatrix} \end{aligned} \tag{2}$$

where yNC denote the overall income derived from the non-constrained account matrix and yC represent the total income from the constrained account. The endogenous vector of the non-constrained sector is denoted by nNC and that of the constrained sector by nC. Moreover, xNC and xC refer to the exogenous vectors of the non-constrained and constrained sectors, respectively. Additionally, the matrix of average expenditure propensities for the non-constrained sector is denoted as ANC. Finally, matrix of constrained average expenditure propensities is denoted by AC, and $\left[\frac{ANC}{R} \middle| \frac{Q}{AC}\right]$ is the matrix of average expenditures propensities.

Table. 2. The SAM with constrained and non-constrained accounts

				Endogenous			Exogenous		Total
				Non Constrained	Constrained	Sum	Transaction	Sum	
Endogenous	Non-Constrained	1 2a	Factor Institution	T_{NC}	T_Q	n_{NC}	X_{NC}	x_{NC}	y_{NC}
	Constrained	3	Sector	T_R	T_C	n_C	X_C	x_C	y_C
Exogenous		2b 4	Government Other	L_{NC}	L_C	L	U	u	y_E
Total				y_{NC}^1	y_C^1		y_E'		

This study uses the CFPM method to see the impact of substituting renewable energy investments in power plants that replace coal power plants on household income in each production sector. Meanwhile, to see the impact of GDP, employment, and CO_2 emission as an indicator of economic, social, and environmental for this study, the development of the CFPM method uses the same process as AMM method by Hartono *et al.* [13] to see the impact of substituting renewable energy investments in power plants that replace coal power plants toward the changes of GDP, employment, and CO_2 emission.

Resosudarmo and Thorbecke [36] applied the CFPM approach to examine the effects of policies aimed at decreasing air pollution levels on the income of households in different economic strata across Indonesia. Hartono and Resosudarmo [32] also used the CFPM method to analyze the impact of energy policies whose goal is reducing and improving the efficiency of energy use on various household groups' incomes in Indonesia. Another recent study using CFPM method has been done by Van Nguyen [37] to estimate the economic impact of restricted energy supply management on the Vietnamese Major Business Sector . A study by Effendi and Resosudarmo [17] used inter-country CFPM analysis in determining the impact of the development of renewable electricity on macroeconomic indicators. The study employed an inter-regional Social Accounting Matrix incorporating data from various Southeast Asian nations to assess and compare the effects of increasing electricity production from non-renewable sources such as fossil fuels against those generated from renewable resources like solar, wind, and hydro. It then simulated these effects through an inter-regional CFPM.

4. RESULT AND DISCUSSION

4.1 Scenario

This section describes two scenarios that we conducted, the impact comparison of renewable energy investment on power plants (Scenario 1) and investment substitution from non-renewable energy to renewable energy (Scenario 2A and 2B).

To assess the total impact of the investment in a power plant, we do a simulation analysis by putting a shock or injection in the particular sectors and assess the total impact of the injection on the economy (see Table 3). Indonesia does not have a particular sector for the construction of each type of power plant. Thus, we use a simulation approach by giving a shock in the cost structure of each electricity generator. The idea is that these sectors reflect the sectors influenced by the establishment of specific types of power plants. It is noteworthy that the Ministry of Public Affairs data is utilized to differentiate the construction of power plants from the construction sector, leading to a more accurate simulation since power plant construction constitutes the highest cost among the cost structure of each power plant. The cost structures of three renewable energy types, specifically hydro, geothermal, and biofuel power plants, are presented in Table 4.

This study aims to model the economic impact of constructing a 1 GW power plant by considering the cost structure of different types of renewable energy plants. The total investment value is based on a report from the National Energy Council (NEC) in collaboration with the Danish Energy Agency. The investment cost for each power plant includes all physical, engineering, procurement, and construction (EPC) equipment prices or connection costs, but not reinforcement and land purchases. The data then was converted into Rupiah (IDR) and applied as the investment value for the 1 GW construction simulation.

From the NEC report, geothermal and hydroelectric power plants' construction requires a very large investment to build them. On the other hand, a biofuel power generator has a low cost. Biofuel power plants have a mix of fossil energy and biodiesel by 20% in 2015. Despite the lowest cost, this biofuel-powered power plant still produces more significant emissions than hydro and geothermal energy. Due to these three renewable energies' enormous investment costs, we need to find which renewable energy power plants have the most significant economic, social, and environmental impact.

Table 3. Scenario 1.

Technology	Hydro	Biodiesel	Geothermal
	Large system	Diesel-engine	Geothermal-Large
Plant Size (MW)	150	20	55
Capacity Factor	80	-	80
Economic Life (Years)	50	25	30
Investment (Million $/MW)	2	0.8	3.5
Investment (Billion IDR/MW)	29.19	11.68	51.08
Simulation			
Investment 1 GW (Billion IDR)	29,190	11,680	51,082

*1 USD equals 14.595 IDR (using the yearly average exchange rate of 2020)
Source: [38], modified by authors

Table 4. Renewable power plant cost structure.

Hydro	Electricity Machinery and Equipment	46.6
	Power Building Construction	37.4
	Company Service	16.0
Geothermal	Geothermal Mining	17.5
	Power Building Construction	66.5
	Company Service	16.0
Biofuel	Extraction of Petroleum and Natural Gas	42.5
	Chemical (extraction palm oil)	7.5
	Power Building Construction	20.0
	Other Construction	5.0
	Other Services	25.0

Source: [13], [15].

The second simulation conducted in this study is a simulation of particular renewable energy, geothermal, hydro, and/or gas used to replace coal energy. Thus, the simulation estimates the impact of a higher share of renewable energy (geothermal, hydro, and/or gas) as well as a decrement share of coal energy power plants. The proportion used for the substitution simulation is the difference between the realization of power plants in 2015 and the target of the renewable energy mix for power generators in 2025. For the second simulation, we estimated two scenarios which are described in Table 5.

Table 5. Scenario 2A - substitution of coal power plant to hydro and geothermal power plant.

(in Billion IDR)	Hydro	Geothermal	Coal
Initial Value	13,044	5,725	126,150
Weight	10.31 %	4.53 %	14.8%
Investment	23,732	10,417	34,149

In the second scenario, there are two scenarios, scenario 2A and 2B. For scenario 2A, the study simulates the investment of renewable energy such as geothermal and hydro to replace energy from coal. For scenario 2B, the study simulates another energy mix to replace coal with hydro, geothermal, and gas. The proportion of energy mix is determined by the Indonesian government through the National Energy Council.

Table 6. Scenario 2B - substitution of coal power plant to hydro, geothermal, and gas power plant.

(in Billion IDR)	Hydro	Geothermal	Gas	Coal
Initial Value	13,044	5,725	58,961	126,149,862
Weight	6.14%	2.7%	6.0%	14.8%
Investment	14,138	6,205	13,804	34,149

In this simulation, the total investment is calculated based on the difference between the proportions of the renewable energy mix target in 2025 with the realization in 2015 using SAM 2015 data. Aiming to attain the power plant target in 2025, simulation 2A is carried out by investment in coal power plant by IDR 34.15 trillion and hydro power plant investment by IDR 23.73 trillion, and the geothermal power plant by IDR 10.42 trillion. Then, in the simulation using a gas power plant (SIM 2B), coal power plant investment is IDR 34.15 trillion while investment in hydro power plant is IDR 14.14 trillion, geothermal power plant IDR 6.21 trillion, and gas and combined cycle power plant IDR 13.8 trillion (see Table 5 and Table 6).

Hydro and geothermal energy are used in simulation based on the direction of the government's development of renewable energy power plants. These two energies are renewable energies with the most extensive development compared to other renewable energies. Even though gas energy is not a government priority, the development target of gas energy always increases every year. Meanwhile, coal energy is the energy that is targeted to be decreasing over the years (see Figure 1). Therefore, two simulations were carried out to compare the effect of government focus on alternate coal power plants with hydro and geothermal power plants (SIM 2A) or also including gas and combined cycle power plants (SIM 2B) concerning their effect on economic, social, and environmental issues.

4.2 Comparison of Renewable Energy Investment Impact in Power Plant

4.2.1 Sectoral overview

Based on Indonesian SAM 2015, the sector which has the biggest value-added is Manufacturing Sectors, with 21.5% of the total GDP (Table 6). On the other hand, the agriculture sector absorbs the biggest labor than any other sector, with 33.1% of Indonesia's total employment. In respect to emissions, Indonesia's emission is the biggest in the world. According to data from the Potsdam Institute for Climate Impact Research, Indonesia's annual CO_2 emissions were 2.4 billion tons in 2015 and represented 4.8% of the world's total global emissions for that year [4]. Energy contributes to CO_2 emission the most, amounting to 558,890 Gg of CO_2 in 2017. This figure contributed 48% of national CO_2 emissions, followed by forestry and peat fires 26%, agriculture 11%, and others [5]. Among the five energy-consuming sectors, the largest contributor to CO_2 emissions is electricity generators, especially those produced by coal-fired power plants [6]. The manufacturing sectors, the mining and quarrying sectors, and the electricity sectors emit the most energy-related emission (Table 7).

Table 7. Overview of the sectoral contribution.

Sectors	Value added (trillion)		Employment (000)		CO_2 Emissions (thousand ton)	
	IDR	%	Individuals	%	Tons	%
Agriculture, Forestry, and Fishery (Agr.)	1,622.3	14.1%	38,458.8	33.1%	277.5	0.1%
Mining and Quarrying (Mining)	872.5	7.6%	1,320.6	1.1%	60,104.3	25.3%
Manufacturing Industry (Man. Ind.)	2,464.3	21.5%	15,312.8	13.2%	89,142.8	37.5%
Electricity, Gas, and Water Supply (Utility)	166.2	1.4%	293.0	0.3%	56,068.4	23.6%
Construction (Cons.)	1,170.5	10.2%	8,315.2	7.2%	7,638.0	3.2%
Trade, Hotel and Restaurant (Trade)	1,868.0	16.3%	25,917.2	22.3%	2,643.9	1.1%
Transportation and Communication (Trans. Comm.)	1,102.9	9.6%	5,757.3	5.0%	8,277.7	3.5%
Finance, Real Estate, and Company Services (Fin.)	1,025.4	8.9%	2,671.5	2.3%	12,321.7	5.2%
Services (Serv.)	1,183.0	10.3%	18,245.1	15.7%	1,140.2	0.5%
Total	11,475.2	100.0%	116,291.6	100.0%	237,614.6	100.0%

*The abbreviations in the bracket will be used for other tables to simplify the sector name
Source: SAM (2015), modified by authors

4.2.2. Overall impacts

The results of the overall analysis of the SAM model can be seen in Table 8. This study simulates a 1 GW investment for three power plants that use renewable energy. From the same initial investment, the impact between power plant types is different because of the different investment values to build particular types of power plants and the different affected sectors where the investment flows. Based on the economic aspect, geothermal power plants generate the most significant GDP. The result is align with the study conducted by [13], [14] that investment in renewable energy power plant has a positive economic impact that measured with GDP and positive social impact that measured by employment. Geothermal power generators also have the most significant impact on increasing household income and employment, but at the same time, increase CO_2 emissions the most. In this study, it is also seen that the construction of renewable energy power plants can increase urban households' income, which is higher than in rural areas (see Table 8).

4.2.3 Impacts on economic indicators

GDP is one of the instruments to measure economic indicators in a country. Although several other economic indicators are also essential to use, GDP data is easy to obtain and able to indicate both the economic situation and people's welfare [39]. Table 9 shows that the construction of 1 GW of geothermal power plants has the biggest economic impact among others, like, hydro and biofuel. This finding is supported by Hartono *et al.* [13] that investing in geothermal power plant has the biggest positive economic impact among other renewable power plants. The construction of a 1 GW geothermal power plant can increase the value added by 0.757% or IDR 86 trillion. The construction sector has a direct effect on the investment in geothermal and hydropower generators. The mining and quarrying sector is also directly affected by biofuel and geothermal power plants' construction because geothermal and biofuel power plants' main input is from the mining and quarrying sector.

Another sector directly affected by the renewable energy power plant investment is the finance and company service sector as it involves planning, research, and development that necessitate the expertise of professionals. Additionally, some of the service sectors are value chains for renewable energy power plant construction. IRENA [40] explained that the effect of service sectors resulted from induced effects because of the general economic improvement. When the electricity prices go down, the real household income will increase which also stimulates activity in the service sectors such as the retail or hospitality sector. Improvement in service sector activity can significantly increase the induced employment as these sectors operated in the relatively labor-intensive production (see Table 9).

Table 8. Summary of the results: change in all indicators.

Indicators	Initial Value	Hydro	Biofuels	Geothermal
GDP (trillion)	11,475	47.3	18.4	86.9
		0.413%	0.161%	0.757%
Household income (trillion)	8,345	33.7	12.7	61.6
		0.4%	0.2%	0.7%
Rural (trillion)	3,285	12.6	4.8	23.7
		0.4%	0.1%	0.7%
Urban (trillion)	5,059	21.1	8.0	37.9
		0.4%	0.2%	0.7%
Employment (000 person)	116,291	441.8	301.4	759.0
		0.380%	0.259%	0.653%
CO_2 (thousand ton)	339,886	1,511.5	735.8	3,093.9
		0.445%	0.216%	0.910%
Investment (IDR trillion)		29.2	11.7	51.1

Source: Author's Calculation (2021)

Table 9. Sectoral GDP Changes (in trillion)

Sectors	Initial Value	Hydro	Biodiesel	Geothermal
Agr.	1,622	3.9	1.4	7.3
		0.2%	0.1%	0.5%
Mining	873	2.0	4.4	11.2
		0.2%	0.5%	1.3%
Man. Ind.	2,464	9.9	2.8	12.3
		0.4%	0.1%	0.5%
Utility	166	0.6	0.2	1.0
		0.4%	0.1%	0.6%
Cons.	1,171	5.7	1.6	17.3
		0.5%	0.1%	1.5%
Trade	1,868	8.6	1.9	9.7
		0.5%	0.1%	0.5%
Trans. Comm.	1,103	5.2	1.6	7.8
		0.5%	0.1%	0.7%
Fin.	1,025	7.5	1.4	12.9
		0.7%	0.1%	1.3%
Serv.	1,183	4.1	3.0	7.3
		0.3%	0.3%	0.6%
Total	11,475	47.3	18.4	86.9
		0.413%	0.161%	0.757%

Source: Author's calculation (2021).

4.2.4 Impacts on social indicators

Apart from the economic impact, the development of renewable energy power plants can also create jobs and create a more equitable income distribution. Renewable energy such as geothermal and hydro use energy inputs that are freely available. The technology for this kind of energy typically involves jobs in the processing of raw material, manufacturing of the technology, designing the project as well as managing its operation, installing and planning the construction, operation and maintenance, and eventual decommissioning [41]. The sectors for this technology are mainly the manufacturing industry, construction, and services sectors. Table 10 describes the change in the amount of labor employed when the construction of a renewable energy power plant is carried out. The agricultural sector is the second sector with the most significant number of workers in Indonesia (BPS, 2015). Therefore, the agricultural sector is the sector that accounts for the largest workforce in each investment in the construction of renewable energy power plants in this simulation. This simulation result on social indicator is align with the study conducted by Hartono *et al.* [13] that agriculture sector is the one of the sector that generate most of the employment among other sectors.

Geothermal power plants construction generates the most extensive job opportunity among renewable energy power plants. Based on IRENA [41], geothermal power plant construction processes such as deep drilling companies, civil engineering services, supply companies, project developers, power plant builders, and drill and process engineering skills for heating and cooling technologies are needed, absorbing much employment. This is in accordance with the result where the construction, trade, and service sectors got the most significant impact from the investment in the construction of geothermal power plants (see Table 10).

Table 10. Sectoral employment changes (000 people).

Sectors	Initial Value	Hydro	Biodiesel	Geothermal
Agr.	38,459	95	35	174
		0.2%	0.1%	0.5%
Mining	1,321	4	7	20
		0.3%	0.5%	1.5%
Man. Ind.	15,313	58	18	87
		0.4%	0.1%	0.6%
Utility	293	1	0	2
		0.4%	0.2%	0.7%
Cons.	8,315	53	14	162
		0.6%	0.2%	1.9%
Trade	25,917	117	25	127
		0.5%	0.1%	0.5%
Trans. Comm.	5,757	25	7	35
		0.4%	0.1%	0.6%
Fin.	2,672	18	4	32
		0.7%	0.1%	1.2%
Serv.	18,245	70	190	120
		0.4%	1.0%	0.7%
Total	116,292	442	301	759
		0.380%	0.259%	0.653%

Source: Author's calculation (2021).

Table 11. Change in household incomes (in trillion).

		Initial Value	Hydro	Biodiesel	Geothermal
Rural	Low Income	840	3.1	1.2	5.8
			0.4%	0.1%	0.7%
	Middle Income	1,237	4.7	1.8	9.0
			0.4%	0.1%	0.7%
	High Income	1,208	4.8	1.8	8.9
			0.4%	0.2%	0.7%
Urban	Low Income	1,076	4.5	1.7	8.2
			0.4%	0.2%	0.8%
	Middle Income	1,916	8.0	3.0	14.4
			0.4%	0.2%	0.8%
	High Income	2,067	8.5	3.3	15.3
			0.4%	0.2%	0.7%
Total Rural		3,285	12.6	4.8	23.7
			0.4%	0.1%	0.7%
Total Urban		5,059	21.1	8.0	37.9
			0.4%	0.2%	0.7%
Total		8,345	33.7	12.7	61.6
			0.4%	0.2%	0.7%

Source: Author's calculation (2021)

The changes in household income have quite the same patterns as GDP and the geothermal power plant investment has the most significant impact among other renewable energy. It is also shown that the urban household income is more significant than the rural household income after the investment. This finding is align with the study conducted by Hartono *et al.* [13] that an increase in household income for urban households as a result of any power plant construction was higher than for rural households. Compared to rural households, labour from urban households has a higher capability to produce materials and services necessary to construct power plants, thus it affects urban households more than rural households [13]. Geothermal power plant construction increases the middle class's household income, most significant among other classes in the rural area. However, in the urban area, each renewable energy investment had a similar impact on any household income level. However, the geothermal power plant produces the highest income while the biofuel power plant produces the lowest income (see Table 11).

4.2.5 Impacts on environmental indicators

Based on the simulation that can be seen in Table 12, the geothermal power plant is the power plant that generates the most emission in the construction stage, followed by the hydropower plant and biofuel plant. This finding is supported by Hartono *et al.* [13] that in construction stage, 1 GW investment on geothermal power plant generates highest emission among other power plant. The highest emission is caused by the direct effect of investment in the company service and the construction sector to build a geothermal power plant and the indirect effect from the manufacturing industry, as the energy-intensive sector (SAM, 2015). Both the direct and indirect effect of construction contributes to high emission, for example, the construction sector has inputs such as cement and metal products, while the company's services include civil engineering which requires input from chemical and mining products [13].

4.3 Impact of Substitution of Non-Renewable Energy Power Plant to Renewable Energy

The following simulation conducted is a simulation of renewable energy from geothermal, hydro, and/or gas substitute coal energy.

4.3.1 Overall impact

The results of the overall analysis of the SAM model for the second scenario showed in (Table 13). This study simulates the substitution of conventional energy to renewable energy in power plants based on Indonesia's target of NDC in 2025. Overall, the substitution scenario has a negative economic impact based on GDP indicator but using gas as one of the alternatives (SIM 2B), has a better impact compared to simulation 2A.

Table 12. Sectoral emission changes (in thousand tons).

Sectors	Initial Value	Hydro	Biodiesel	Geothermal
Emission from Household				
Rural Household	44,810	171.1 0.4%	64.9 0.1%	322.2 0.7%
Urban Household	57,462	239.6 0.4%	90.3 0.2%	430.9 0.7%
Emission from Industry				
Agr.	278	0.6 0.2%	0.2 0.1%	1.1 0.4%
Mining	60,104	95.9 0.2%	288.3 0.5%	292.5 0.5%
Man. Ind.	89,143	255.3 0.3%	145.2 0.2%	490.0 0.5%
Utility	56,068	203.0 0.4%	71.5 0.1%	320.2 0.6%
Cons.	7,638	226.8 3.0%	49.9 0.7%	702.2 9.2%
Trade	2,644	11.4 0.4%	1.9 0.1%	9.9 0.4%
Trans. Comm.	8,278	38.0 0.5%	11.4 0.1%	55.5 0.7%
Fin.	12,322	265.6 2.2%	10.4 0.1%	461.4 3.7%
Serv.	1,140	4.3 0.4%	1.7 0.2%	8.0 0.7%
Total	339,886	1,511.5 0.445%	735.8 0.216%	3,093.9 0.910%

Source: Author's calculation (2021).

This finding is supported by Chatri *et al.* [12] that in Malaysia, the transition from fossil to renewable generates a negative impact on macroeconomic indicator. The socio-economic impact using household income indicator also has a negative impact. This result is align with the study conducted by Effendi and Resosudarmo [17] that in Philippines and Indonesia, renewable power plant development leads to higher poverty incidence than the business as usual scenario. However, the result shows no significant difference between simulations 2A and 2B. The negative impact on rural society is more significant than on urban society. Employment has a positive impact through this scenario. This scenario can also reduce CO_2 emissions significantly, so it has a positive impact on the environment. The study by Effendi and Resosudarmo [17] support the result for the environmental impact that shows the development of renewable power plants is beneficial to reduce the carbon emission in ASEAN country.

4.3.2 Impacts on Economic Indicator

The simulation shows a significant direct impact on the mining and manufacturing sectors. Another sector indirectly affected by the investment is the agricultural and services sectors, which are the labor-intensive sectors (see Table 14).

Table 13. Summary of the results: change in all indicators.

Indicators	Initial Value	SIM 2A	SIM 2B
GDP (trillion)	11,475	-0.880 -0.008%	-0.848 -0.007%
Household Income (trillion)	8,345	-0.342 -0.003%	-0.327 -0.003%
Rural (trillion)	3,285	-0.179 -0.005%	-0.171 -0.005%
Urban (trillion)	5,059	-0.163 -0.003%	-0.156 -0.003%
Employment (000 person)	116,292	2.41 0.002%	2.35 0.002%
CO_2 (thousand ton)	339,886	-14,544.67 -4.3%	-14,244.78 -4.2%

Source: Author’s calculation (2021).

Table 14. Sectoral GDP changes (in trillion).

Sectors	Initial Value	SIM 2A	SIM 2B
Agr.	1,622	-0.032 -0.002%	-0.030 -0.002%
Mining	873	-1.522 -0.174%	-1.475 -0.169%
Man. Ind.	2,464	0.765 0.031%	0.745 0.030%
Utility	166	-0.001 -0.001%	-0.001 -0.001%
Cons.	1,171	0.001 0.000%	0.001 0.000%
Trade	1,868	0.016 0.001%	0.016 0.001%
Trans. Comm.	1,103	-0.014 -0.001%	-0.013 -0.001%
Fin.	1,025	-0.017 -0.002%	-0.016 -0.002%
Serv.	1,183	-0.078 -0.007%	-0.075 -0.006%
Total	11,475	-0.880 -0.008%	-0.848 -0.007%

Source: Author’s calculation (2021).

4.3.3 Impacts on social indicators

From the employment aspect, simulation 2A, or substitution of coal to hydro and geothermal, induces more job opportunities compared to simulation 2B (see Table 15). Aside from employment, the social impact is also used to measure the distributional income in rural and urban society. In both simulations, the society in rural and urban areas negatively affects the changes in income (see Table 16). Using gas sources, middle income in urban areas gets a better impact compared to investment in only hydro and geothermal power plants.

Table 15. Sectoral employment changes (000person).

Sectors	Initial Value	SIM 2A	SIM 2B
Agr.	38,459	-0.834 -0.002%	-0.797 -0.002%
Mining	1,321	-0.042 -0.003%	-0.054 -0.004%
Man. Ind.	15,313	2.887 0.019%	2.813 0.018%
Utility	293	-0.001 0.000%	-0.001 0.000%
Cons.	8,315	0.016 0.000%	0.014 0.000%
Trade	25,917	0.305 0.001%	0.304 0.001%
Trans. Comm.	5,757	-0.029 -0.001%	-0.025 0.000%
Fin.	2,672	-0.033 -0.001%	-0.032 -0.001%
Serv.	18,245	0.141 0.001%	0.131 0.001%
Total	116,292	2.410 0.002%	2.353 0.002%

Source: Author's calculation (2021).

Table 16. Change in household incomes (in trillion).

		Initial Value	SIM 2A	SIM 2B
Rural	Low Income	840	-0.045 -0.005%	-0.043 -0.005%
	Middle Income	1,237	-0.063 -0.005%	-0.060 -0.005%
	High Income	1,208	-0.071 -0.006%	-0.068 -0.006%
Urban	Low Income	1,076	-0.022 -0.002%	-0.021 -0.002%
	Middle Income	1,916	-0.050 -0.003%	-0.048 -0.002%
	High Income	2,067	-0.091 -0.004%	-0.087 -0.004%
Total Rural		3,285	-0.179 -0.005%	-0.171 -0.005%
Total Urban		5,059	-0.163 -0.003%	-0.156 -0.003%
Total		8,345	-0.342 -0.004%	-0.327 -0.004%

Source: Author's calculation (2021).

4.3.4 Impacts on environmental indicators

The scenario of investment substitution from non-renewable to renewable power plants significantly reduces CO_2 emissions (see Table 17). However, gas power plants require input from mining and quarrying which is an energy-intensive sector. Thus, it is not surprising that substitution with hydro and geothermal sources reduces emissions higher than simulation with a gas alternative. Additionally, the CO_2 emission drops higher in rural areas compared to urban areas. The simulation also has an indirect impact on reducing emissions from financial services sectors.

Table 17. Sectoral emission changes (in thousand tons).

	Initial Value	SIM 2A	SIM 2B
Emission from Household			
Rural Household	44,810	-2.4 -0.005%	-2.3 -0.005%
Urban Household	57,462	-1.8 -0.003%	-1.7 -0.003%
Emission from Industry			
Agr.	278	-4.0 -0.001%	-3.8 -0.001%
Mining	60,104	-202.3 -0.337%	-194.6 -0.324%
Man. Ind.	89,143	110.6 0.124%	107.6 0.121%
Utility	56,068	-14,448.9 -25.770%	-14,153.9 -25.244%
Cons.	7,638	0.1 0.002%	0.1 0.002%
Trade	2,644	0.1 0.003%	0.1 0.002%
Trans. Comm.	8,278	0.0 0.000%	0.0 0.000%
Fin.	12,322	0.0 0.000%	0.0 0.000%
Serv.	1,140	0.0 -0.004%	0.0 -0.004%
Total	339,886	-14,544.7 -4.3%	-14,244.8 -4.2%

Source: Author’s calculation (2021).

5. CONCLUSION

This study simulated two scenarios aiming to reduce CO_2 emissions to attain Indonesia's energy share target in 2025. The first scenario is to identify which renewable energy investment has the most significant economic, social, and environmental impact. The second scenario is to estimate the economic, social, and environmental impact of non-renewable energy investment substitution to renewable energy investment. Based on the result of the first scenario, the TBL concept using the SAM framework which simulated the impact of 1 GW investment in various renewable energy power plants has a positive impact on all indicators like economic, social, and environmental indicators.

The simulation has a different impact for the second scenario which simulated the substitution of investment from coal power plants to hydro, geothermal, biofuel power plants, and with the added of sub-scenario that also substitute coal power plants to the hydro, geothermal, biofuel, and gas power plants. This scenario has a negative impact on value-added as an economic indicator and employment as a social indicator. But income distribution as a social indicator is positive through this scenario. The GHG emission as an environmental indicator is decreasing through this scenario and imply that the scenario has a positive impact on the environmental indicator.

The first scenario simulated the impact of 1 GW worth of investment in various renewable energy power plants. Based on the economic aspect, geothermal power plants generate the most significant net GDP. Geothermal power generators also have the most significant impact on increasing household income and employment. The result also shows that the construction of renewable energy power plants can increase urban households' income, which is higher than in rural areas. In terms of environmental aspects, even though at the operational stage, geothermal power plants generate no emission, in the construction stage, geothermal power plants create the most significant emission compared to other renewable energy. However, the geothermal power plant has the most significant impact on the economic, social, and environmental aspects.

The second scenario has two simulations. The first simulation simulated the substitution of investment from coal power plants to hydro, geothermal, and biofuel power plants. The second simulation simulated the substitution of investment from coal power plants to the hydro, geothermal, biofuel, and gas power plants. The substitution scenario has a negative economic impact based on GDP indicator, and the 2nd simulation, using gas as the option for substitution, has a higher impact on the economic aspect. The socio-economic impact of using household income indicators also has a negative impact, and it does not vary significantly, either for the first simulation or for the second simulation. The negative impact on rural society is more significant than on urban society. Employment has a positive impact through this scenario. This scenario can also reduce CO_2 emissions significantly, so it has a positive impact on the environment. Therefore, if the government wants to focus on emission reduction, the construction of hydropower plants generates the least emission but also moderate impact on the socio-economic aspect. In addition, emissions may reduce higher if coal power plants are substituted to only hydro and geothermal power plants but not gas power plants.

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