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Research article

Comparing the impacts of fossil and renewable energy investments in Indonesia: A simple general equilibrium analysis

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ABSTRACT

Increasing electricity capacity to support economic growth has become a national development priority in Indonesia. The construction of a power plant needs to consider not only economic but also social and environmental impacts because the government can choose between fossil-based and renewable energy-based power plants. Thus, the decision to invest in a particular type of power plant technology must consider sustainability criteria. Using the social accounting matrix, this study aimed to simulate the impacts of an investment in a coal-fired power plant and compare those to the impacts of investments in renewable energy-based plants (geothermal, hydro, wind, and solar). The simulation results revealed that geothermal and wind power plants required the most significant investment and would increase the gross domestic product by 0.67% and 0.66%, respectively, representing the highest net value added to the economy compared to that of the other power plant options. The construction of a wind power plant promotes employment the most, by 0.70%. However, none of the power plant construction significantly affected income disparity. Additionally, compared to certain renewable power plants, a coal power plant might require less investment and have better employment and economic impacts. Nevertheless, its continuous emission effect from operation needs to be considered.

1. Introduction

Indonesia is well-known for its vibrant energy sources. However, the country is ironically poor in electricity (Maulidia et al., 2019). Indonesian electricity was scored 4.1 out of 7 IFC, 2015 and ranked 86th out of 140 countries (Schwab, 2015). This problem has become crucial because electricity strongly relates to economic growth (Abdoli et al., 2015). A 1% increase in electricity investment leads to a 0.72% increase in economic growth. Additionally, a 1% increase in other investments stimulates economic growth by only 0.025% (Yuxian et al., 2014). The Indonesian economy, which is predicted to become the 5th largest economy in the world by 2030, is threatened by the lack of proper management of the electricity. Therefore, the Government of Indonesia ambitiously set a target to build a 35,000 MW power plant for the cost of IDR 1,189 trillion. This megaproject is expected to be completed in 2028 (Ministry of Energy and Mineral Resources [MEMR], 2018).

There are 2 primary sources for generating electricity: renewable energy (RE) and high carbon energy (non-RE). Each option has consequences, including environmental, economic, and social impacts, depending on the type of technology. In terms of high carbon energy, fossil-based energy leads to a strong, positive impact on economic growth. In the long run, a 1% increase in coal electricity leads to a 0.27% increase in economic growth (Bento et al., 2017). However, the majority of studies have empirically proven that growth in gross domestic product (GDP) is a driver of an increase in the CO_2 emissions harmful to the environment (Menyah and Wolde-Rufael, 2010); notably, it has not been applied in some studies (Ozturk and Acaravci, 2010) (Acaravci and Ozturk, 2010). Correspondingly, each 1% increase in the renewable electricity share is followed by a 0.53% decrease in CO_2 emission (Hdom, 2019). RE electricity production is also estimated to contribute to social impacts by creating from 1.7 up to 14.7 times more jobs than the high carbon energy-based power plants will (Cameron & Van Der Zwaan, 2015).

Although the increasing share of RE has become a global priority policy, fossil fuels still account for the vast majority of the world's electricity generation (IEA, 2014). In Indonesia, the electricity sector heavily

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relies on high carbon energy sources because of the abundance of coal. Coal provides 59.9% of the total energy used to produce electricity (MEMR, 2018). Additionally, RE is thought to be expensive and difficult to implement on a large scale.

Recognizing the consequences related to the construction of each energy source is essential in optimizing a mixed-energy policy. Practically, a power plant investment decision is burdened when comparing the cost component and other components. The sole usage of cost components as the investment consideration covers the investment externalities (neither positive nor negative). As a consequence, coal continues to play a crucial role in the energy mix because of its low production, high profitability for its producers, and relatively small potential substitution with other energy sources (Szewranski, 2012).

Therefore, it is necessary to consider the multiple impacts of power plant investments. The available analysis comparing renewable and conventional power plants considers the variance of power plant development costs and estimated effects in emissions (see Bridle et al., 2018), whereas a large amount of investment in long-term power plant construction projects can also induce impacts on and trade-offs of various prosperity indicators. For instance, investment in energy infrastructure will undoubtedly affect the Indonesian GDP through the multiplier effect. Although the economic growth may not be a perfect measurement to portray welfare, the broad consensus is that GDP remains meaningful in describing the economic conditions of a country (Alexander et al., 2018). Additionally, with the higher output from the increase in final demand, the investment will also affect job creation and household income at diverse magnitudes because more labor will be necessary for the production process. However, the deviation of household income across income levels can promote an equal income distribution or otherwise. Thus, the impact analysis often includes a study of the income distribution (see Endriana et al., 2016; Joshi and Sharma, 2018) or employment (see Chen, 2018; Timmons et al., 2007).

Previous studies have not discussed the impacts of power plant investments on various economic and social indicators in Indonesia. Additionally, the available report in Indonesia only considers direct effects and neglects the indirect and multiplier effects from power plant construction (NEC, 2017). Based on the aforementioned research and the gaps within the literature, this study proposes a novel study with complete impact analysis of power plant investments (hydro, solar, geothermal, wind, and coal) for 4 indicators of the Sustainable Development Goals (SDGs): GDP, employment, income distribution, and CO_2 emission. It uses the social accounting matrix (SAM) to calculate both direct and indirect impacts from the construction phase, which absent from other methodologies. This study develops the Indonesian SAM 2015 (because the latest official Indonesia SAM was in 2008) to comprise specific power plant cost sectors and household income per decile, enabling income distribution measurement and RE investment simulations. Additionally, this study analyzes emissions from the operations of power plants and direct and indirect emissions from the power plant construction phase. Hence, it proposes a complete approach to assess power plant investment impact. The result is a crucial input for the government to design the best energy diversification strategy considering economic, social, and environmental targets toward green economy goals (Endriana et al., 2016).

This paper is organized as follows. Section 2 elaborates on the literature on energy investment. Section 3 describes the methodology of the study and the data sources. Section 3 presents the empirical results and discussion. Section 4 contains the conclusions of the study.

2. Literature reviews

In 2015, policymakers across countries adopted an international binding resolution called the Paris Agreement, to mitigate climate change issues. One of the consequences of this agreement for ratified countries, including Indonesia, is the setting of RE in electricity as ambitious efforts to combat climate change translated into nationally determined contributions (NDCs; IRENA, 2018). Under the NDCs, Indonesia has pledged to lower its greenhouse gas emissions by 29% or 41% with international aid in 2030. Indonesia is endowed with a significant potential for renewable power sources, especially hydropower (75,000 MW), solar (4.80 kWh/m^2/day), and geothermal reserves (28, 000 MW). Additionally, certain Indonesian regions such as West Nusa Tenggara and Sulawesi have a wind speed of approximately 6–7 m/s, with an estimated 9.3 GW potential for a wind energy power plant.

Most of Indonesia's electricity is from coal (59.9%), gas (22.3%), oil (6%), and the other 11.8% is from renewable sources (MEMR, 2018). However, the acceleration of electricity infrastructure development still requires a significant financial investment. The rapidly increasing energy demand has forced the government to use the easiest and possibly cheapest methods to provide electricity in the short term by building large-scale coal power plants (Maulidia et al., 2019). Thus, the assessment of the construction of various power plants is crucial for the Indonesian Government because it provides a comprehensive impact measurement of the energy transition, considering costs other than the installation cost.

Numerous studies have developed the relationship between power plant investment and economic growth (i.e., GDP). The studies have been conducted in different countries with various methods and led to different findings. Silva et al. (2012) used a structural vector autoregressive (SVAR) model to explain the impact of an increasing share of RE on GDP in Denmark, Portugal, Spain, and the United States. The study revealed a negative relationship between RE and economic growth, except for the United States. This result is contrary to the affirmations by Bhatacharya et al. (2016), Ohler and Fetters (2014), and Bulavskaya and Reynès (2017). Those authors have demonstrated a definite link between RE and GDP growth. Ohler and Fetters (2014) demonstrated positive long-run relationships between biomass, hydroelectricity, waste, and wind and GDP. That result was in agreement with the findings of Bhattacharya et al. (2016) in Austria, Bulgaria, China, and the United Kingdom and Bulavskaya and Reynès (2017) in the Netherlands. The definite link between energy investment and GDP growth also occurs in the non-RE sources studied by Bento et al. (2017).

Madlener and Koller (2007), based on the impact of power plant investment on the environment, revealed a positive relationship between bioenergy system promotion and CO_2 emission mitigation. The study was in line with the findings of Jebli et al. (2020). Employing the generalized method of moments system and Granger causality test to assess the relationship between RE consumption and CO_2 emissions, Jebli et al. (2020) demonstrated that RE consumption leads to a decrease in CO_2 emissions in all countries, except the lower-middle income countries. That result was confirmed by Ito (2017), suggesting that RE consumption leads to a decrease in emissions, whereas non-RE consumptions supported the increase in emissions. The opposite results were found in Apergys et al. (2010) and Salim and Rafiq (2012) demonstrating a positive correlation between RE and CO_2 emission. Despite the finding of less contribution of RE to emission reduction, Apergys et al. (2010) found that a 1% increase in nuclear energy as part of fossil energy was associated with a 0.48% decrease in emission. However, the study disagreed with Hanif et al. (2019), who showed that a 1% increase in fossil fuel consumption raised carbon emissions by 0.29%. Nonetheless, an international agency such as IRENA or the IEA has calculated the embodied emission from both RE and non-RE power plants. From a direct approach, they found that, unsurprisingly, operations of a coal-based power plant had the highest embodied emission, and RE power plants had almost produced no emissions.

Social impacts, including unemployment and income distribution, are also the concerns of policymakers and the economic and environmental effects of electricity production. Solar and wind energy investments have significant impacts in Egypt because they increase the average household annual income to USD 3,382, which is high compared to the government target (Farag and Komendantova, 2014). The finding was in line with those of Timmons et al. (2007) and Chen (2018). Using the input–output model, Timmons et al. (2007) found that biomass energy would provide substantial new economic activity and employment in Massachusetts. Chen (2018) estimated that every $1 million investment in RE creates 60–70 indirect jobs, whereas fossil energy creates 50–60 jobs. However, those results opposed the study of Rivers (2013), who found a positive correlation between RE investment and the unemployment equilibrium. Rivers (2013) used general equilibrium analysis and suggested that the reduction of electricity sector emissions by 10% through renewable electricity policies is likely to increase the unemployment equilibrium rate by 0.1%–0.3%.

Various studies have been conducted to assess the impact of RE and non-RE investment on economic, social, or environmental aspects. However, studies that have analyzed the effects of RE and non-RE power plant investments on those factors in single research are rare. Thus, this study uses the SAM framework to measure the variance impact of multiple power plant choices while considering data availability. This study contributes to the literature in several ways. First, the CO_2 emission is analyzed at both the operational and construction phases on the basis of the type of power plant. In the construction stage, it also differentiates the indirect emission effect by sectors and households, derived from 17 types of energy input, based on Imansyah and Putranti (2017). Second, the official SAM is manually updated, and the 2015 Indonesian SAM was constructed with specific sectors related to investment in power plants. Third, household data were modified into urban and rural deciles to analyze the income distribution among household groups. This type of analysis has not been conducted in studies on energy investment impacts. Moreover, regional-based analysis is crucial in the Indonesian context because of distinct differences between rural and urban areas.

3. Data and method

Impact assessment in the power sector is relatively complex with dynamic channels because constructing a power plant is a crucial input for most sectors; it also needs various data (IFC, 2015). The impact of the partial equilibrium model poorly represents the dynamics of the changes in the economy. Thus, power plant impact has been widely and optimally analyzed using a multisectoral approach, such as the SAM approach (Allan et al., 2011; Farag and Komendantova, 2014; Joshi and Sharma, 2018).

SAM is a data framework designed in matrix forms to maintain the national accounting balance within a given period. SAM is a traditional double accounting economic matrix that records all financial transactions between agents, with particular regard to sectors in the production blocks, within institution blocks (including households and government), and within production factors (Hartono and Resosudarmo, 2008; Pyatt and Round, 1979). Consequently, its analyses provide suitable perceptions for the evaluation of economic development in many areas, such as GDP, the sectorial economy, institution expenditure and income, household income distribution, and sectorial employment distribution. The first studies on this topic have explained how to use SAMs as general equilibrium models and were conducted by Pyatt (1988) and Pyatt and Round (1979). The official Indonesia SAM data were produced by the Central Bureau of Statistics (Statistics Indonesia - Badan Pusat Statistik [BPS]).

Similar to other methodologies, SAM analysis has limitations and advantages. First, caution must be in elucidating the results, because of the restrictive suppositions in the model. An assumption is that prices are fixed and that a variation in demand affects the physical output rather than the prices. The model also assumes that the resource factors (e.g., land, labor, capital) are unlimited. Additionally, the model does not consider regional differences, such as geographical and demographic factors, because it uses national SAM instead of interregional SAM (IRSAM). Thus, this study assumes that the construction of different types of power plants is applicable throughout Indonesia. However, Sudaryadi (2007) demonstrated that SAM is a comprehensive, compact, and consistent data system capturing the sectorial interdependencies within an area. The data are relatively available, allowing the assessment of the effects of government policies related to employment, poverty, and income distribution (Allan, 2015; Misdawita et al., 2019). Additionally, SAM is a straightforward analysis tool. Thus, SAM can be easily applied to different countries (Hartono and Resosudarmo, 2008). Nonetheless, the results should solely focus on magnitudes, directions, and distributive patterns rather than definite outcome values (Fathurrahman et al., 2017).

3.1. Mathematical model of SAM

The basic structure of a SAM is a 4×4 matrix based on the consolidated balance sheets of economic actors (Figure 1). SAM describes the monetary flows of economic transactions between 4 accounts: production activities (various agriculture, manufacture, and services sectors), production factors (labor and capital), institution (household and government), and other accounts (exogenous account)[1]. Accounts are represented by columns and rows displaying the economic transactions within the accounts. The columns represent expenditures, and the rows represnt income. Sub-matrix T_{13} in Figure 1 shows the allocation of value added generated by various production activities to the production factors as remuneration for the use of these production factors. For example, wages and salaries are remunerations for the use of labor (factor production). The T_{21} sub-matrix shows the allocation of income from production factors to various institutions, generally comprising households, government, and companies. In other words, this matrix shows the distribution of income from production factors to multiple institutions. For example, parts of workers in the agricultural sector are members of smallholder farmers' groups. Thus, there is money flowing from agriculture workers to smallholder farmers' households. The sub-matrix T_{22} shows transfers of payments between institutions, for example, government subsidies to households or subsidies for companies. The T_{32} sub-matrix displays the demand for institutions in terms of goods and services; in other words, it shows the amount of money the production sectors received from the institutions, to purchase goods or services. Additionally, the T_{33} sub-matrix illustrates the inter-industry demand for goods and services or transactions between production sectors. SAM requires that the total expenditures (vectorY_i) are the same as the total incomes (vectorY_j'); in other words $Y_j'$is transposed from Y_i, for every $i = j$ representing each account.

The production factors, production activities, and institutions are assumed to be endogenous accounts in the SAM data, and other accounts are considered exogenous. Income dispansion within endogenous accounts can be mathematically written as $Y_i = \sum_j T_{ij} + X_i$, for $i, j = 1, 2, 3$. The share of the expenditure of each account is identical to the ratio of the corresponding cell over its column's total; thus, it can be written as $A_{ij} = T_{ij} Y_j^{-1}$or $T_{ij} = A_{ij} Y_j$, whereA_{ij}represents the ratio of expenditure in row-i and column-j;T_{ij} is the entry of matrix T in row-i and column-j, and Y_j is a diagonal matrix representing the total expenditure of column-j. Therefore, the SAM framework can also be described in a mathematical equation as follows:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} = \begin{bmatrix} & & A_{13} \\ A_{21} & A_{22} & \\ & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} + \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} \quad [1]$$

or expressed as

$$Y = AY + X \leftrightarrow Y - AY = X \leftrightarrow (I - A)Y = X \leftrightarrow Y = (I - A)^{-1} X \leftrightarrow Y = M_a X \quad [2]$$

The matrix $(I - A)^{-1} = M_a$ is also called the multiplier matrix (M_a) or accounting multiplier matrix, suggesting different levels within the endogenous accounts because of a shock unit in an exogenous account.

[1] Further explanation of the SAM framework are in Fathurrahman et al. (2017).

		EXPENDITURE				
		Endogenous Accounts			Exogenous Account	TOTAL
		Production Factors	Institutions	Production Activities		
RECEIPTS: Endogenous Accounts	Production Factors	***0***	***0***	T_{13}	X_1	Y_1
	Institutions	T_{21}	T_{22}	***0***	X_2	Y_2
	Production Activities	***0***	T_{32}	T_{33}	X_3	Y_3
RECEIPTS: Exogenous Account		T_{41}	T_{42}	T_{43}	X_4	Y_4
TOTAL		Y'_1	Y'_2	Y'_3	Y'_4	

Figure 1. SAM framework.
Source: Hartono and Resosudarmo (2008).

Thus, each variation unit in the exogenous account (X) affects the endogenous account (Y) by M_a. The accounting multiplier matrix in the SAM framework is essential because it captures the overall impacts of the variations in a particular sector, along with other sectors within the economy. Additionally, it is used to describe the effects of changes in exogenous (ΔX) and endogenous accounts (ΔY); thus, it can be mathematically expressed $\Delta Y = M_a.\Delta X$.

This paper uses the coefficients of the multiplier matrix to explain the impacts of changes in an exogenous account (in this case, investment expenditure) on GDP, household income, employment, and CO_2 emission. For the household income impact measurement, it is sufficient to use a matrix M_a contained in the equation $Y = M_aX$(Equation [2]) to calculate the impact of investment spending on income between various groups of households. Additionally, there is a need to develop or adjust the accounting multiplier matrix $M_a$to calculate the effect of investment spending on GDP (value added), employment, and CO_2 emission.

3.2. Impact analysis of GDP (value added)

Modification of the multiplier matrixM_a is necessary to analyze the impact of investment spending on GDP. First, the coefficients of a sectorial value-added matrix (Matrix V) are calculated. The Matrix V is a diagonal matrix, the members of which are value-added coefficients (va_{ij}). Those coefficients are determined only for the production sectors. In the production sectors, va_{ij} is the ratio of the GDP or value added (by sector) and total sectoral output; hence,

$$V = [va_{ij}] \quad [3]$$

The va_{ij}element is equal to zero if $i \neq j$, and$va_{ij}$is equivalent to va_{ij} if $i = j$. After a sectorial value added (GDP) matrix is constructed, a value-added multiplier (VAM) matrix is calculated as follows:

$$VAM = V.M_a \quad [4]$$

where the $VAM$is a VAM matrix displaying the effects of variations in exogenous accounts on value added or GDP; V is a sectorial value-added matrix in Equation [4], and M_a is an accounting multiplier matrix in Equation [2].

3.3. Impact analysis to employment

It is also necessary to adjust a multiplier matrix$M_a$to analyze the impact of investment expenditure on labor. First, the coefficients of a sectorial labor matrix (Matrix$L$) are calculated. The matrix L is a diagonal matrix whose member is the labor coefficient (l_{ij}). Those coefficients are calculated only for the production sectors. In the production sectors, l_{ij} is the ratio of labor (by sector) and the total sectoral output; hence,

$$L = [l_{ij}] \quad [5]$$

The element $l_{ij}$is equal to zero if $i \neq j$and$l_{ij}$is comparable to l_{ij}if $i = j$. After the construction of the sectorial labor matrix, the labor multiplier (LM) matrix is determined as follows:

$$LM = L.M_a \quad [6]$$

where the $LM$is an LM matrix displaying the effects of variations in the exogenous account on employment; L is a sectorial labor matrix in Equation [6], and M_a is an accounting multiplier matrix in Equation [2].

3.4. Impact analysis of CO_2 emission

This study adjusts a multiplier matrix $M_a$to analyze the impact of investment spending on CO_2 emissions. First, the coefficients of a sectoral CO_2 emission matrix (Matrix$E$) are determined. The Matrix E is a diagonal matrix whose members are CO_2 emission coefficients (e_{ij}). The mentioned coefficients are evaluated for households and production sectors. e_{ij} represents the ratio of the total CO_2 emissions in the households (emitted by the institution) and the total household expenditure. In the production sectors, it represents the ratio of the total CO_2 emission (emitted by industry) and total sectoral output; hence,

$$E = [e_{ij}] \quad [7]$$

The e_{ij}element is equal to zero if $i \neq j$, and$e_{ij}$is equal to e_{ij}if $i = j$. An emission multiplier (EM) matrix is calculated. Next, a sectorial CO_2 emission matrix is constructed:

$$EM = E.M_a \quad [8]$$

Where EM is a CO_2 EM matrix showing the effects of variations within the exogenous account on CO_2 emissions. E is a sectorial CO_2 emission matrix in Equation [8]; M_a is an account multiplier matrix in Equation [2]. Matrix E comprises several parts, namely, emission-sector, emission-household, and other elements, to be used in policy impact analysis (Pal et al., 2012). However, the CO_2 emissions are calculated only for the production sectors and households in this study. Thus, the$E$ element is the ratio of the total emission from each sector and different types of households. Microsoft Office Excel was used to conduct the calculation.

3.5. SAM data

This study uses the 2015 Indonesian SAM. However, the data were unavailable at Statistics Indonesia – BPS. Thus, the study constructs the Indonesian SAM 2015 by using the following steps: (i) disaggregate sectors from the National I-O 2015 created by BPS and Ministry of Public Works to enable power plants' investment impact such as on Electricity Machinery and Equipment and Power Building Construction[2]; (ii) construct the Indonesian SAM 2015 with 35 sectors based on National I-O 2015 (results from step [i]), the National Labor Force Survey (SAKERNAS) year 2015, the National Socio-Economic Survey (SUSENAS) year 2015, and other data from BPS and MEMR; and (iii) conduct validation and reconciliation to check the balance in SAM (see Yusuf, 2007). The comprehensive data sources are presented in Table 1.

The Indonesian SAM 2015 has features that accommodate the purposes of this study: (i) The Indonesian SAM 2015 has 10 decile household income classifications for urban and rural areas, and this is useful because this study attempts to identify investment impacts on income distribution. This feature is different from the Indonesian SAM Table commonly produced by BPS. Thus, this study has an advantage in the discussion of income distribution; (ii) several specific sectors are included to provide details on power plant investment sectors (Table 2): (1) Electricity Machinery and Equipment, (2) Power Building Construction, (3) Crude Oil and Natural Gas, (4) Basic Non-Ferrous, (5) Metal Product, (6) Boiler and Prime Mover, (7) Rubber and Plastic, (8) Electricity, (9) Coal and Metal Mineral, (10) Rail Transportation, and (11) Company Service. These specific sectors have features (this sector classification is also different from the SAM table commonly produced by BPS) intending to measure more accurately the impacts of investment spending of various power plants on the Indonesian economy. All simulations identifying the effects of power plant construction used 35 sectors calculation. However, in the interest of better and simpler descriptions and analyses, all calculation results were presented in 9 aggregated sectors. The mapping rules from 35 to 9 sectors are presented in Table 2.

3.6. Weighting the power plant cost structures

A shock or injection within the economy in a related sector or institution is necessary to simulate the impact of a particular investment. The sectors included in the power plant cost structures are shocked as representation sectors impacted by the building of specific types of power plants. This approach is used because Indonesia does not have a specific sector for power plant construction. This section focuses on estimating the cost components of 4 types of RE—hydro, geothermal, solar, and wind—and a coal power plant. Table 3 presents the aggregated information on the respective weighting structures.

Table 1. Data sources.

Variables	Source of Data
I-O Table 2015	BPS – Ministry of Public Works (2017)
Indonesia SAM 2015	Constructed by Author based on Indonesia I-O 2015
- Employment by Sector	SAKERNAS (2015)
- Household Income	SUSENAS Module (2015)
- Household consumption	SUSENAS Module (2015)
GDP by Sector	BPS (2015)
Emission by Sector	Imansyah and Putranti (2017) based on MEMR report

[2] Disaggregation technique refers to the study by Misdawita et al. (2019).

Table 2. Indonesian SAM 2015-energy power plant sectors.

35 Sectors (Aggregated into 9 Sectors)	
1	Food Crop (1)
2	Other Crop (1)
3	Livestock (1)
4	Forestry (1)
5	Fishery (1)
6	Coal and Metal Mineral (2)
7	Crude Oil and Natural Gas (2)
8	Other Mining (2)
9	Food and Beverage (3)
10	Yarn Spinning (3)
11	Timber and Wooden Products (3)
12	Paper (3)
13	Basic non-Ferrous (3)
14	Metal Product (3)
15	Boiler and Prime Mover (3)
16	Electricity Machinery and Equipment (3)
17	Chemical (3)
18	Rubber and Plastic (3)
19	Electricity (4)
20	Gas and Clean Water (4)
21	Power Building Construction (5)
22	Other Construction (5)
23	Trading (6)
24	Restaurant (6)
25	Hotels (6)
26	Rail Transportation (7)
27	Other Land Transportation (7)
28	Air and Water Transportation (7)
29	Transportation Supporting Services (7)
30	Bank and Insurance (8)
31	Real Estate (8)
32	Company Service (8)
33	General Government and Defense (9)
34	Social Community Services (9)
35	Other services (9)

Note: Numbers in parentheses represent code for 9 aggregated sectors.

3.7. Simulation scenario

This study simulates the impacts of a 1 GW power plant investment based on the weight of the cost structure of each power plant option. The investment value is based on the report from Indonesia National Energy Council (NEC), in collaboration with the Danish Energy Agency (Table 4). The investment cost per MW comprises all physical equipment and the engineering, procurement, and construction price or the overnight cost and connection cost, but not the cost of reinforcements and buying land. Next, the data are converted into Indonesia rupiah and used as fundamental values to simulate 1 GW construction.

Table 4 represents the basic information on the power plant used as a database for the calculation of investment cost. The Government of Indonesia has mandated the use of Coal Super Critical technology for at least 600 MW power plants, making the investment cost more expensive than that for the usual coal power plant. According to the NEC report, the construction of geothermal and wind power plants requires a higher investment for building compared to other types of power plant. By contrast, the total expenditure for solar PV has been rapidly declined, especially in Indonesia, as the experience with the installation of PV plants in Indonesia increases (NEC, 2017). Therefore, compared to other types of RE power plants, solar PV power plants require the least investment cost. However, solar PV power has a low capacity factor (only

Table 3. Industries and weight for power plant cost structure.

Energy Source	Sector	Weight (%)
Hydro Energy	Electricity Machinery and Equipment	46.6
	Power Building Construction	37.4
	Company Service	16
Geothermal Energy	Oil and Gas Mining	17.5
	Power Building Construction	66.5
	Company Service	16
Solar Energy	Basic non-Ferrous Industry	8.5
	Metal Product Industry	17.1
	Electricity Machinery and Equipment	39
	Power Building Construction	22.7
	Company Service	12.7
Wind Energy	Metal Product Industry	23
	Boiler and Prime Mover Industry	10
	Electricity Machinery and Equipment	21
	Rubber and Plastic Industry	21
	Power Building Construction	16
	Company Service	9
Coal	Coal and Metal Mineral	28
	Electricity Machinery and Equipment	27
	Rail Transportation	23
	Other Services	22

Source: Appendix Table A1.

20%), the least of any type of power plant (Table 4). Detailed technical specifications are in the NEC report (2017).

4. Results

This study simulated the impacts of 1 GW of various RE power plants and conventional (coal) power plants investment on 4 selected indicators from the SDGs. It is represented in 3 dimensions: economic, social, and environment.

4.1. Sectoral overview

Based on the Indonesian SAM 2015, the Indonesian economy is mainly supported by the manufacturing sectors, accounting for 24.2% of the total GDP (Table 5). Although not a significant contributor to the GDP, the agriculture sector absorbs the most labor compared to other sectors. Additionally, energy-related CO_2 emission in Indonesia is one of the biggest in the world, causing Indonesia emission reduction policies to become a global concern (Yusuf and Resosudarmo, 2008). The manufacturing sector causes most energy-related emissions in Indonesia (37.5%), followed by the mining and quarrying sector (25.3%), and the utility sector (23.6%). The majority of the electricity supply in Indonesia is from low-quality, coal-based power plants. Thus, unsurprisingly, the utility sector, including the electricity sector, contributes substantially to emissions (PWC, 2018).

In Indonesia, each sector uses different ratios of labor and capital for production. However, almost all sectors pay more for capital than for labor sources, even within the service sectors such as trade, hotels, and restaurants, and 70% of production cost is for capital input (Indonesia SAM, 2015). Regarding the household dimensions, most household incomes, both from employment or capital sources, are enjoyed by the 10 wealthiest individuals in urban areas (Table 6). Relatively, compared to rural households at the same decile level, urban households earn higher incomes.

4.2. Overall impact

Table 7 shows the overall results from the model through the SAM analysis. From the same 1 GW power plant capacity investment, the impacts across power plants differ significantly because of the different investment values, and the investment flows through different sectors. On the basis of the economic aspect, compared to other types of power plants, the geothermal and wind power plant stimulates the most significant net GDP. Similar results were observed in the household income, employment, and carbon emission analyses. Additionally, the result revealed that construction of a power plant, in general, had a higher increment in urban household income compared with that of a rural household. The following sections explain the topics in detail.

4.3. Economic impacts

Although GDP cannot measure environmental degradation or other changes in stock, it remains widely used as an economic indicator and an integral part of measuring individuals' prosperity (Alexander et al., 2018). Table 8 reveals that the 1 GW construction of a geothermal power plant induced the highest GDP, namely, 0.67% or IDR 77.5 trillion, even after the investment values were subtracted (IDR 28.0 trillion). The impact on the net value added was slightly above that of the wind power plant. Because no studies or reports have identified GDP per GW with a similar simulation and methodology, this result cannot be compared to previous results. However, IRENA found that GDP in the construction years of a renewable power plant may increase by 0.2%–4% (Ferroukhi et al., 2016). Additionally, the IRENA case study in Japan found that an additional 1 GW of solar PV power may increase GDP by USD 2.0 billion or IDR 28.8 trillion. Meanwhile, an additional 1 GW renewable capacity in Saudi Arabia may increase GDP by USD 1.0 billion or IDR 13.3 trillion based on K.A. CARE data (Ferroukhi et al., 2016). Therefore, these study findings are not significantly different from other previous results[3].

The manufacturing industry is directly affected by investment in wind power plants and indirectly by investment in geothermal power plants. Nonetheless, both power plants require electrical and other manufacturing components inducing high demand from the manufacturing industries. Thus, although both are considered to have high direct capital investment, construction in these RE power plants may boost the manufacturing industry (Burke et al., 2019). Aside from the manufacturing sector, the impacts on the construction and mining sectors were significant in terms of building a geothermal power plant. Another important aspect is the finance and company service sector, which has a large percentage of changes from RE power plant construction, mainly induced by company services. Different from the construction of the coal power plant, the construction of the RE power plant requires planning, research, and development, which require experts (IRENA, 2018). Thus, direct investment in company services generates a more vital impact on the RE power plant sector compared to the coal power plant.

Although the coal power plant requires lower investment costs, the coal power plant provides more benefits to the net GDP than the hydropower plant does (IDR 15.0 trillion). The construction of coal power plants requires direct investment in the service sector. In comparison with the hydropower plant, the service is required to produce value added within the economy. Hence, coal power activities have a high multiplier effect within the economy, as stated by Bento et al. (2017) and Pirlogea and Cicea (2012).

4.4. Social impacts

In addition to the increased GDP, the massive projects in power plants can also be utilized to create job opportunities and promote equal income distribution.

Table 9 presents information on the changes in employment among sectors for each power plant construction scenario. In comparison to the GDP impact result, investment in wind power plants promotes the

[3] USD 1 = IDR 14,136 (yearly average exchange rate in 2019).

highest employment. This result is different than the results of the same investment value in geothermal power plants. Based on the Indonesia official report, the approximation of total direct employment from the construction of a renewable power plant is 20,000 to 50,000 individuals per GW. This finding shows that, compared with indirect employment, construction may generate more than 10 times the jobs. This finding is supported by Chen's (2018) study in China, which revealed that USD 1 trillion (IDR 14.1 trillion) of power plant investment might generate 100, 000 to 286,000 additional jobs, directly and indirectly.

The agriculture, manufacturing, trade, and construction sectors are responsible for the differences between geothermal and wind power plant impacts. Directly, all RE power plants, especially wind power plants, create more employment in manufacturing industries because the construction requires direct products from the metal and electric product manufacturer (Bulavskaya and Reynès, 2017). Indirectly, trade sector activities are also boosted from the higher demand from manufacturing, as the investment directly stimulated manufacturing industries. Additionally, agriculture, particularly other food crop sectors, are significantly affected by wind power plant construction, because it directly invests in Rubber and Plastic manufacturing. This sector has a high multiplier effect on non-food crop sectors, inducing a great demand for the non-food crop sector. Besides, labor absorption seems to depend on the initial condition of the stimulated sector, whether or not it is a capital intensive or labor-intensive sector. The agriculture sector is the second largest contributor to GDP, and it absorbs 33.1% of the Indonesian labor force (BPS, 2015). High production demand in agriculture increases employment in the respective sectors. However, the construction of a geothermal power plant simultaneously increases employment in construction sectors by 1.1%, making it the greatest among the types of power plants.

Similar to the GDP result, the coal power plant produces the third highest increment in employment but with less investment compared to that of the hydropower plant. The construction of the coal power plant stimulates higher job creation in other services by 1.9% or 349,000 additional jobs. Additionally, the construction is in favor of agricultural employment. It creates an additional 1.4% employment in the transportation and communication sectors, especially in rail transportation because coal is transported to the power plant by rail.

Overall, the changes in household income had slightly different patterns than the net GDP results did, with the highest one from investing in geothermal power plants, followed by wind, hydro, coal, and solar power plants (Table 10). However, it also showed that an increment in urban household income from the construction of any power plant was greater than the rural household. Indeed, most materials and services necessary for power plant construction were from sectors with laborers from urban households. Nationally, this study revealed that investment in each simulation had a similar impact on middle, low, and high-income households. An identical pattern of household income impact was found in all income levels; additionally, the geothermal power plant induced the highest income, and the solar power plant induces the lowest income.

A simple t test was conducted to test whether the power plant investment promotes income disparity. The t test result revealed that investment in any power plant did not significantly alter income distribution between low-income and high-income households and urban and rural households. All power plants induced more income for low-income households (focusing on urban area), although this was not significant. By contrast, all power plants created more additional income for high-income households than for low-income households in rural areas.

Table 4. Simulation scenarios.

Technology	Hydro	Geothermal	Solar	Wind	Coal
	Hydro- Medium	Geothermal-Large	Solar PV-Large	Wind-Offshore	Coal-Super Critical
Plant Size (MW)	50.0	55.0	10.0	8.0	600.0
Capacity Factor	80	80	20	48	n.a.
Economic Life (years)	25.0	25.0	25.0	25.0	25.0
Investment (Million $/MW)	2.2	3.5	1.1	3.5	1.4
Investment (Billion IDR/MW)*	31.1	49.5	15.5	49.5	19.8
Simulation					
Investment for 1 GW (Billion IDR)	31,099	49,476	15,550	49,476	19,790

* 1 USD = 14,136 IDR (yearly average exchange rate in 2019).
Source: National Energy Council (2017), modified by authors.

Table 5. Value added, employment, and CO_2 emission by sectors.

Sectors	Value Added (Trillion)		Employment (Million)		Tons of CO_2 Emissions (Million)	
	IDR	%	Individuals	%	Ton	%
Agriculture, Livestock, Forestry, and Fishery	1,555.8	*13.4*	38.5	*33.1*	0.3	*0.1*
Mining and Quarrying	883.2	*7.6*	1.3	*1.1*	60.1	*25.3*
Manufacturing Industry	2,806.4	*24.2*	15.3	*13.2*	89.1	*37.5*
Electricity, Gas, and Water Supply	51.1	*0.4*	0.3	*0.3*	56.1	*23.6*
Construction	1,249.8	*10.8*	8.3	*7.2*	7.6	*3.2*
Trade, Hotel & Restaurant	1,885.9	*16.3*	25.9	*22.3*	2.6	*1.1*
Transportation and Communication	999.5	*8.6*	5.8	*5.0*	8.3	*3.5*
Finance, Real Estate, and Company Services	988.2	*8.5*	2.7	*2.3*	12.3	*5.2*
Services	1,155.1	*10.0*	18.2	*15.7*	1.1	*0.5*
	11,575.0	*100.0*	116.3	*100.0*	237.6	*100.0*

Source: Indonesia SAM (2015), SAKERNAS (2015), and Imansyah and Putranti (2017), modified by the authors.

Table 6. Household income distribution per decile (in trillions).

		Employment		Capital	
		Values	%	Values	%
Rural	Decile 1	78.1	*2.1*	33.9	*1.7*
	Decile 2	92.8	*2.5*	48.2	*2.4*
	Decile 3	102.5	*2.7*	53.0	*2.7*
	Decile 4	116.0	*3.1*	59.5	*3.0*
	Decile 5	130.9	*3.5*	68.2	*3.4*
	Decile 6	134.6	*3.6*	78.7	*4.0*
	Decile 7	155.1	*4.1*	89.4	*4.5*
	Decile 8	175.3	*4.7*	110.6	*5.6*
	Decile 9	216.9	*5.8*	125.0	*6.3*
	Decile 10	333.9	*8.9*	159.0	*8.0*
Urban	Decile 1	103.6	*2.8*	32.1	*1.6*
	Decile 2	126.3	*3.4*	53.8	*2.7*
	Decile 3	143.5	*3.8*	64.2	*3.2*
	Decile 4	166.1	*4.4*	68.2	*3.4*
	Decile 5	179.9	*4.8*	88.1	*4.4*
	Decile 6	210.8	*5.6*	97.7	*4.9*
	Decile 7	231.6	*6.2*	115.7	*5.8*
	Decile 8	261.9	*7.0*	140.0	*7.1*
	Decile 9	328.6	*8.8*	171.2	*8.6*
	Decile 10	455.2	*12.2*	325.2	*16.4*
		3,743.69	***100.00***	**1,981.58**	***100.00***

Source: SAM (2015)

According to the t test results, however, all power plants had insignificant impacts on income disparity at the rural and urban levels.

4.5. Environmental impacts

In the construction stage, a 1 GW geothermal power plant generates the highest emission, followed by the wind and coal power plants (Table 11). The high emission is mainly because of an indirect effect on the energy-intensive sectors in the manufacturing industry and the direct effects of investment on company services and construction to build a geothermal power plant. Regarding the accounting multiplier matrix (SAM, 2015), those sectors had high EMs because they require input from the energy-intensive sector. The construction sector requires cement and metal products, whereas company service comprises civil engineering, which requires input from chemical products, electricity, and mining. Hence, investment in these sectors generates and multiplies emissions. With the same investment shock, wind power plant construction creates slightly lower emissions. This type of power plant requires a large amount of metal produced from energy-intensive sectors, increasing emissions in the manufacturing sector by 1.1%. Additionally, high emission was also observed from coal power plant construction, mainly from mining activities. Nonetheless, because the investment value for each source-of-power plant differs, emissions from operations must also be considered.

Considering operational emission, the operation of the conventional power plant continuously emits CO_2, although it may emit less in the construction process. MEMR (2018) calculated that on average, an Indonesian coal power plant with supercritical technology induces 768.8 kg CO_2/MWh. Additionally, geothermal power plants generate much lower emissions (62.9 kg CO_2/MWh). Coal power plants emit the highest CO_2 per kWh of electrical power (Asiedu et al., 2019), and this finding supports that found in other countries (Sharvini et al., 2018; Siagian et al., 2017). Some reports have indicated that other renewable power plants also induce slight emission in the process, though 10 times lower than that of coal power plants (World Nuclear Association, 2011). However, the official Indonesian report assumed that RE, aside from geothermal power plants, creates no direct emission in the process. To conclude, the construction of 1 GW geothermal and wind power plants may induce more significant emissions in the construction stage because of a considerable number of investments. However, the operation of the coal power plant may continuously create high emissions in the long run, causing severe long-term impacts on the environment.

5. Conclusions

This study simulated the impacts of 1 GW worth of investment in various types of power plants on several macroeconomic indicators, namely, GDP/value-added, employment, household income, and CO_2 emission, and used a simple general equilibrium approach, the SAM, to conduct those simulations. In addition to having several advantages in simulating the impacts of investment in power plants, the SAM also had limitations as follows: The SAM (i) does not accommodate price changes that may be crucial in policy analysis; (ii) has a fixed Leontief technology assumption, implying that technology is constant, something that may change with technological advances; and (iii) is generally more static and thus less relevant for long-term analysis. Notably, this study used national SAM, not IRSAM. Thus, it does not consider geographical and demographic differences between regions;

Table 7. Summary of the results: Changes in all indicators.

Indicators	Initial Value	Hydro	Geothermal	Solar	Wind	Coal
GDP (Billion)	11,575,015	47,766.0	77,483.4	23,876.7	76,066.9	34,769.6
		0.413%	*0.669%*	*0.206%*	*0.657%*	*0.300%*
HH Income (Billion)	7,966,361	31,060.7	50,601.6	15,487.2	48,992.1	24,235.5
		0.390%	*0.635%*	*0.194%*	*0.615%*	*0.304%*
Rural (Billion)	3,314,888	12,470.9	20,717.4	6,205.3	20,109.9	9,519.0
		0.376%	*0.625%*	*0.187%*	*0.607%*	*0.287%*
Urban (Billion)	4,651,472	18,589.8	29,884.3	9,281.9	28,882.2	14,716.5
		0.400%	*0.642%*	*0.200%*	*0.621%*	*0.316%*
Employment (000 Person)	116,292	437.9	660.0	223.1	816.8	624.9
		0.377%	*0.567%*	*0.192%*	*0.702%*	*0.537%*
Carbon Emission (000 Ton)	248,012	1,035.8	2,036.0	526.3	1,968.2	1,174.9
		0.418%	*0.821%*	*0.212%*	*0.794%*	*0.474%*
Investment (Billion)		31,099	49,476	15,550	49,476	19,970
Net GDP (GDP-Investment)		16,666.8	28,007.4	8,327.1	26,590.9	14,979.2

Source: Author's Calculation (2020)

Table 8. Sectoral GDP changes (in billion).

Sectors	Initial Value	Hydro	Geothermal	Solar	Wind	Coal
Agriculture, Livestock, Forestry, and Fishery	1,555,795.9	4,397.8	7,125.5	2,181.0	9,460.9	3,282.2
		0.283%	*0.458%*	*0.140%*	*0.608%*	*0.211%*
Mining and Quarrying	883,222.9	1,411.4	9,012.0	909.1	2,630.1	4,647.6
		0.160%	*1.020%*	*0.103%*	*0.298%*	*0.526%*
Manufacturing Industry	2,806,375.2	12,378.2	13,723.1	6,554.1	22,815.4	6,938.5
		0.441%	*0.489%*	*0.234%*	*0.813%*	*0.247%*
Electricity, Gas, and Water Supply	51,108.1	236.1	316.4	140.1	448.7	162.6
		0.462%	*0.619%*	*0.274%*	*0.878%*	*0.318%*
Construction	1,249,782.7	5,092.9	13,601.3	1,704.3	4,146.9	726.1
		0.408%	*1.088%*	*0.136%*	*0.332%*	*0.058%*
Trade, Hotel & Restaurant	1,885,934.6	8,142.5	8,158.2	4,651.1	13,615.8	4,449.9
		0.432%	*0.433%*	*0.247%*	*0.722%*	*0.236%*
Transportation and Communication	999,499.5	5,326.5	7,721.6	2,714.4	8,088.0	4,797.3
		0.533%	*0.773%*	*0.272%*	*0.809%*	*0.480%*
Finance, Real Estate, and Company Services	988,161.4	6,796.2	11,222.3	3,028.4	8,448.6	2,583.2
		0.688%	*1.136%*	*0.306%*	*0.855%*	*0.261%*
Services	1,155,134.8	3,984.3	6,603.2	1,994.2	6,412.5	7,182.2
		0.345%	*0.572%*	*0.173%*	*0.555%*	*0.622%*
Total	11,575,015.0	47,766.0	77,483.4	23,876.7	76,066.9	34,769.6
		0.413%	*0.669%*	*0.206%*	*0.657%*	*0.300%*
Net GDP (GDP-Investment)		16,666.8	28,007.4	8,327.1	26,590.9	14,979.2

Note: aggregated value from 35 sectors. Calculated using Equation [4].
Source: Author's Calculation (2020)

additionally, (iv) it assumed that all materials and sources were from a local context.

The result showed that the construction of a 1 GW geothermal or 1 GW wind power plant requires the most significant investment, followed by hydro, coal, and solar power plants. On the basis of the results, each power plant had advantages and disadvantages. From the economic side, geothermal and wind power plants require the greatest investment but also add the highest net GDP to the economy. The presence of multiplier effects, mainly from manufacturing industries, is the reason for the high impacts of these 2 types of power plant construction. In employment, the development of the wind power plant promoted employment the most because of the large direct effect on manufacturing and indirect impact in the agriculture and trade sectors.

Table 9. Changes in employment by sectors (in Person).

Sectors	Initial Value	Hydro	Geothermal	Solar	Wind	Coal
Agriculture, Livestock, Forestry, and Fishery	38,458,811	110,371	178,103	54,803	248,428	82,430
		0.287%	*0.463%*	*0.142%*	*0.646%*	*0.214%*
Mining and Quarrying	1,320,593	2,629	10,833	1,760	4,610	4,136
		0.199%	*0.820%*	*0.133%*	*0.349%*	*0.313%*
Manufacturing Industry	15,312,822	57,098	73,041	30,989	154,330	34,086
		0.373%	*0.477%*	*0.202%*	*1.008%*	*0.223%*
Electricity, Gas, and Water Supply	293,044	1,303	1,736	731	2,389	1,006
		0.445%	*0.593%*	*0.250%*	*0.815%*	*0.343%*
Construction	8,315,205	34,152	91,244	11,423	27,781	4,836
		0.411%	*1.097%*	*0.137%*	*0.334%*	*0.058%*
Trade, Hotel & Restaurant	25,917,236	111,563	113,285	63,552	186,264	61,432
		0.430%	*0.437%*	*0.245%*	*0.719%*	*0.237%*
Transportation and Communication	5,757,258	36,720	50,037	19,168	56,702	80,576
		0.638%	*0.869%*	*0.333%*	*0.985%*	*1.400%*
Finance, Real Estate, and Company Services	2,671,511	16,547	27,048	7,504	21,635	6,974
		0.619%	*1.012%*	*0.281%*	*0.810%*	*0.261%*
Services	18,245,086	67,563	114,625	33,132	114,697	349,423
		0.370%	*0.628%*	*0.182%*	*0.629%*	*1.915%*
Total	116,291,566	437,946	659,953	223,062	816,837	624,899
		0.377%	*0.567%*	*0.192%*	*0.702%*	*0.537%*

Note: aggregated value from 35 sectors. Calculated using Equation [6].
Source: Author's Calculation (2020)

Table 10. Changes in household incomes (in billion).

		Initial Value	Hydro	Geothermal	Solar	Wind	Coal
Rural	Low Income	870,096	3,179	5,310	1,581	5,253	2,380
			0.365%	*0.610%*	*0.182%*	*0.604%*	*0.274%*
	Middle Income	1,301,403	4,912	8,168	2,444	7,927	3,722
			0.377%	*0.628%*	*0.188%*	*0.609%*	*0.286%*
	High Income	1,143,389	4,380	7,239	2,181	6,930	3,416
			0.383%	*0.633%*	*0.191%*	*0.606%*	*0.299%*
Urban	Low Income	1,031,868	4,173	6,652	2,083	6,481	3,355
			0.404%	*0.645%*	*0.202%*	*0.628%*	*0.325%*
	Middle Income	1,811,330	7,262	11,637	3,628	11,267	5,754
			0.401%	*0.642%*	*0.200%*	*0.622%*	*0.318%*
	High Income	1,808,274	7,154	11,595	3,571	11,134	5,608
			0.396%	*0.641%*	*0.197%*	*0.616%*	*0.310%*
Total Rural		3,314,888	12,471	20,717	6,205	20,110	9,519
			0.376%	*0.625%*	*0.187%*	*0.607%*	*0.287%*
Total Urban		4,651,472	18,590	29,884	7,004	9,282	14,716
			0.400%	*0.642%*	*0.200%*	*0.621%*	*0.316%*
TOTAL		7,966,361	31,061	50,602	15,487	48,992	24,235
			0.390%	*0.635%*	*0.194%*	*0.615%*	*0.304%*

Note: Household income was aggregated into 3 income groups based on the decile levels. Low income (40% lowest income); Middle income (40% middle income); and High income (20% highest income). A simple t test was conducted to identify whether there was a difference in the deviation between high-income and low-income households.
Source: Author's Calculation, 2020

Table 11. Changes in CO_2 emission (in Tons CO_2).

Sectors	Initial Value	Hydro	Geothermal	Solar	Wind	Coal
Emission from Household						
Rural Household	4,555,720	17,123	28,454	8,520	27,639	13,056
		0.376%	*0.625%*	*0.187%*	*0.607%*	*0.287%*
Urban Household	5,841,992	23,355	37,537	11,661	36,286	18,494
		0.400%	*0.643%*	*0.200%*	*0.621%*	*0.317%*
Emission from Industry						
Agriculture, Livestock, Forestry, and Fishery	277,541	632	1,015	312	2,129	455
		0.228%	*0.366%*	*0.112%*	*0.767%*	*0.164%*
Mining and Quarrying	60,104,323	66,586	333,824	42,551	135,485	690,322
		0.111%	*0.555%*	*0.071%*	*0.225%*	*1.149%*
Manufacturing Industry	89,142,773	266,047	472,386	173,365	941,842	151,366
		0.298%	*0.530%*	*0.194%*	*1.057%*	*0.170%*
Electricity, Gas, and Water Supply	56,068,376	237,366	314,222	123,270	414,667	209,532
		0.423%	*0.560%*	*0.220%*	*0.740%*	*0.374%*
Construction	7,638,014	135,895	377,261	43,026	99,871	6,350
		1.779%	*4.939%*	*0.563%*	*1.308%*	*0.083%*
Trade, Hotel & Restaurant	2,643,936	11,862	10,598	6,939	20,125	6,121
		0.449%	*0.401%*	*0.262%*	*0.761%*	*0.232%*
Transportation and Communication	8,277,678	48,232	67,749	24,913	74,011	54,643
		0.583%	*0.818%*	*0.301%*	*0.894%*	*0.660%*
Finance, Real Estate, and Company Services	12,321,673	224,689	386,496	89,699	209,791	21,471
		1.824%	*3.137%*	*0.728%*	*1.703%*	*0.174%*
Services	1,140,239	3,965	6,483	2,006	6,341	3,111
		0.348%	*0.569%*	*0.176%*	*0.556%*	*0.273%*
Total Emission from Power Plant Construction	248,012,265	1,035,752	2,036,025	526,263	1,968,189	1,174,922
		0.418%	*0.821%*	*0.212%*	*0.794%*	*0.474%*
Emission from Operation (kg CO_2/MWh)		-	**62.9**	-	-	**768.8**

Note: aggregated values from 35 sectors and 10 decile households; total emission from various industries for a 1 GW investment expenditure in each type of power plant; average emission from power plant operations. Calculated using Equation [8].
Source: Authors' Calculation, 2020; NEC, 2020; MEMR, 2018.

Regarding household income, the household income generated was impacted proportionally by the investment shock. However, compared to rural households, urban households earned higher additional income from construction power plants. Additionally, a simple t test found that power plant construction had no significant effect on income disparity. Nonetheless, compared to middle-income households, a high-income household in a rural area and a low-income household in urban had slightly higher income impacts. Notably, although coal power plants require a lower investment than hydro power plants, they have a better impact on net GDP and employment. This result occurs because of a large multiplier from other service sectors. Hence, with low investment, it has an outstanding effect on the changes in GDP and employment. A solar power plant requires the smallest investment but also has a small impact on economic and social factors.

Regarding emissions, geothermal construction generates the highest CO_2 emissions. However, when considering operational power plants, the emissions of coal power plants are more than 10 times that of RE, even for supercritical power plants. Hence, if the government commits to reducing emissions while fulfilling the electricity production target, the option to invest in coal power plants is an inappropriate policy choice because it would cause long-term harm to the environment. Construction of geothermal and wind power plants should be considered the best choices in terms of impact assessment on different factors in fulfilling future electricity provision targets without long-term side-effects on the environment.

Declarations

Author contribution statement

Djoni Hartono: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Sasmita H. Hastuti & Atina Saraswati: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Alin Halimatussadiah, Aria F. Mita & Vitria Indriani: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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