THE 4TH INTERNATIONAL CONFERENCE ON GREEN TECHNOLOGY AND DESIGN (ICGTD 2022)

Scenarios of Reducing Emissions Air Pollutants (SO_2, NO_x, CO, and $PM_{2.5}$) in the Power Generation and Residential Sector in DKI Jakarta Province

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Abstract. The Air Pollutant Standard Index (ISPU) showed that the air quality in DKI Jakarta Province is in decreasing trend. It can be seen from ISPU's "Unhealthy" category from 2014 – 2018 which tends to increase; hence air pollution has become a real environmental problem. Efforts to reduce emissions need to be made by creating a scenario for reducing air pollutant emissions of SO_2, NO_x, CO, and $PM_{2.5}$ generated from the power generation and residential sectors as the basis for improving air quality in DKI Jakarta Province. Emissions estimates use a top-down approach to common emission factors combined with high-level (national) activity data with the help of the atmospheric brown clouds (ABC) Microsoft Excel® workbook – emission inventory manual (EIM) tool. The power generation sector in DKI Jakarta Province mainly uses natural gas as its fuel, with the parameter NO_x being the most emitted. The scenario for reducing emissions of air pollutants SO_2, NO_x, CO, and $PM_{2.5}$ that can be done in the power generation sector is by gasifying power plants by converting the use of high-speed diesel fuel and marine fuel oil with natural gas target 100% by 2030. The fuel can be converted, where the most effective in reducing SO_2 is 8.44% in 2030. Most of the residential sector in DKI Jakarta Province uses liquefied petroleum gas as fuel for cooking, with CO emission parameters being the most emitted. The scenario for reducing air pollutant emissions of SO_2, NO_x, CO, and $PM_{2.5}$ that can be done in the residential sector is to substitute the use of LPG as fuel for burning gas stoves into electric stoves with a target of 4% by 2030. LPG can be substituted for electricity, where can be reduced all parameters effectively with the same percentage reduction with the target of reducing fuel consumption by 4% in 2030.

Keywords: DKI Jakarta Province, Power generation, Residential, Air Pollution, ABC-EIM, Reducing Emissions.

I. INTRODUCTION

Air pollution has become a real environmental issue. The Air Pollutant Standard Index (ISPU) shows air quality in the DKI Jakarta province, where the ISPU category "Unhealthy" from 2014 - 2018 tends to increase [1]. Air is an essential environmental component that must be maintained and improved so people can live optimally [2]. Air pollution monitoring based on government's regulation number 22 of 2021 regarding the implementation of environmental protection and management is the parameters SO_2, NO_X, CO, and $PM_{2.5}$. These pollutants can be emitted from the energy consumption of power generation activities and residential, where energy consumption can lead to an increase in air pollution levels and cause harmful effects to human health and the environment [3].

An emission inventory database (EI) is required comprehensively to show the contribution of emissions [4]. Emission estimates of air pollutant not only understand and add the knowledge but also assist to disperse the consciousness between public and policy makers [5]. In the power generation and residential sectors, many combustion activities produce emissions, so it can be calculated how many emissions are created and how much can make air pollutant emission reduction. Based on the above considerations, it is necessary to make efforts to reduce emissions by creating a scenario for reducing air pollutant emissions of SO_2, NO_X, CO, and $PM_{2.5}$ generated from the power generation and residential sectors as the basis for improving air quality in DKI Jakarta Province.

II. METHODOLOGY

2.1. Emission inventory

Emission estimation used the Microsoft Excel® workbook atmospheric brown clouds (ABC) – emission inventory manual (EIM) tool with a top-down approach to general emission factors combined with high-level (national) activity data (for example, emission factor x national fuel consumption) to estimate emissions [6]. The formula for calculating emissions is presented in Eq. 1, where EM is emission load; EF is emission factor of the pollutant; AR is activity data (can be expressed in production rate); EC is total control efficiency (%).

$$EM = EF \times AR \times (100 - EC)/100 \quad (1)$$

The inventory was conducted at three power plants that supply electricity to DKI Jakarta Province according to business plan for electricity supply in Indonesia (RUPTL) 2024-2030, including PLTGU/PLTU Muara Karang, PLTGU/PLTU Tanjung Priok, and PLTD Senayan. Emission control technology in the power generation sector in DKI Jakarta Province is assumed to apply to all power plants in Indonesia using flue gas desulfurization (FGD) for SO_2 control, low NO_x burner for NOx, and electrostatic precipitation (ESP) for PM control [7].

2.2. Activity data collection

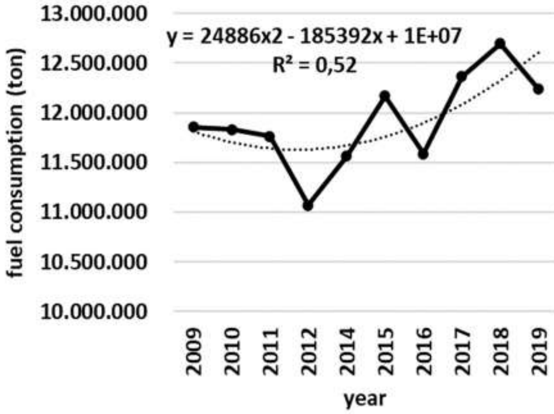
Activity data were collected such as fuel consumption in the power generation sector data obtained from the statistics book of PT. Indonesia Power 2009-2019 [8] and data on fuel consumption from cooking in the residential sector data from the DKI Jakarta Book in 2009-2019 figures [9] and the Handbook of Energy & Economic Statistics of Indonesia 2018 [10].

2.3. Factor emission compilation

The emission factor values have been compiled in this ABC-EIM Microsoft Excel® workbook which is expressed in the source category and the fuel used in each activity, collected from various literatures [4].

2.4. Projecting fuel consumption data

Data on fuel use activities are predicted or forecasted to determine fuel use in 2025 and 2030 using estimation, model selection, and time series forecasting using Microsoft Excel® with a coefficient of determination testing. By knowing the value of the coefficient of determination, researchers can explain how well the regression model predicts the dependent variable. The larger the value of R square, the better the model. The value of R square is said to be suitable if it is above 0.5 because R square ranges from 0 to 1. If the R-value is close to 1, then the influence of variable X on variable Y is considerable. On the other hand, if the value of R is away from the number 1, then the effect of variable X on variable Y is very small [11].



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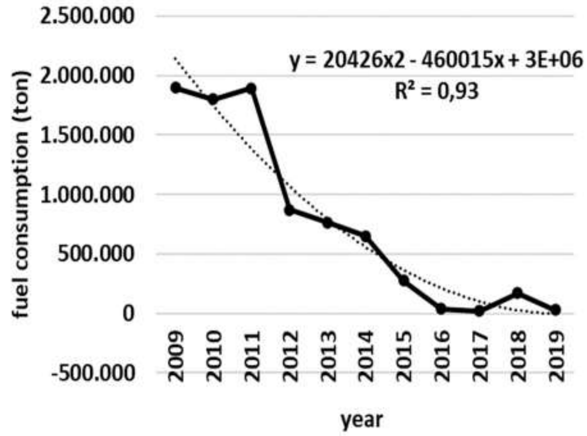

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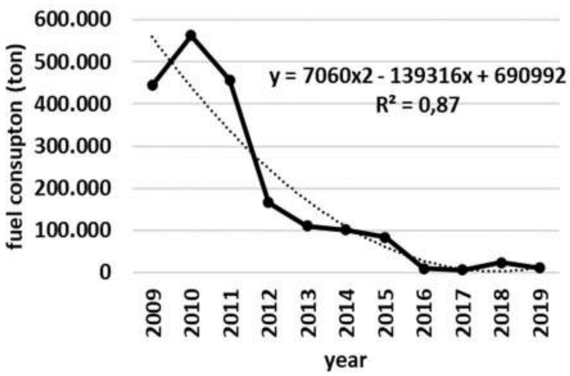

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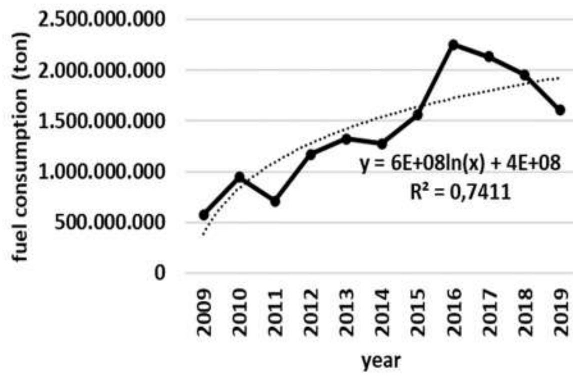
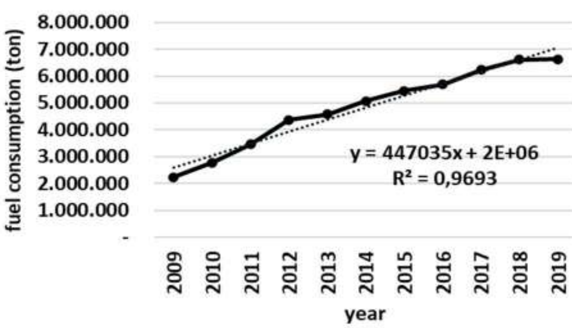


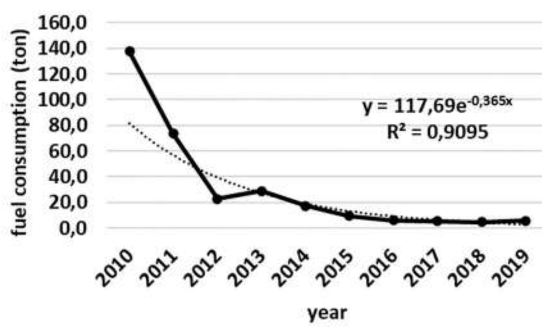
(d)

FIGURE 1. Coefficient of Determination Diagram. (a) Quadratic diagram of coal. (b) Quadratic diagram HSD (c) Quadratic diagram of MFO (d) Logarithmic diagram of natural gas

The trend of fuel used in the power generation sector fluctuates. The most suitable projection used with an R square value > 0.5 is to use a polynomial trend of order two or quadratic trend and a logarithmic trend which can be seen in the image above on the four projections of the R square value > 0.5.



(a)



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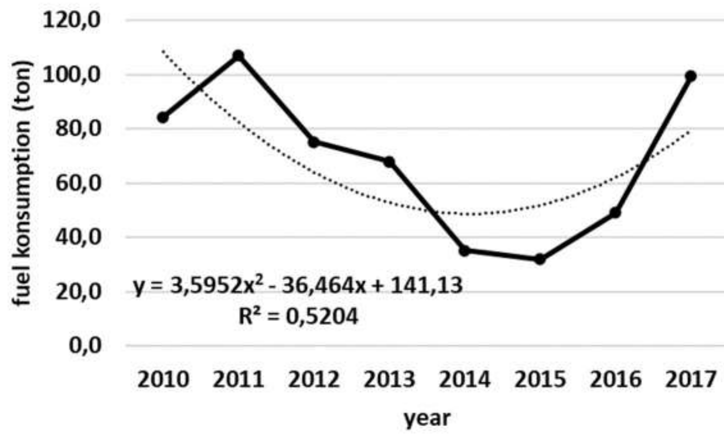


(c)

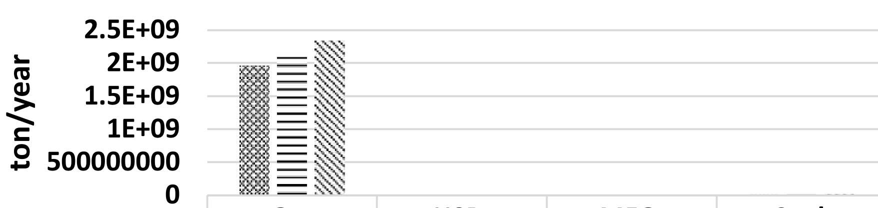
FIGURE 2. Coefficient of Determination Diagram. (a) Linear diagram of LPG. (b) Exponential diagram kerosene (c) Quadratic diagram electricity

The use of LPG tends to increase in line with population growth in meeting the need for cooking, where LPG is currently the primary fuel for cooking. Using a linear trend is the most suitable projection for use with an R square value > 0.5. In contrast to kerosene, the trend tends to decrease due to changes in kerosene to LPG gas. Using the exponential trend is the most suitable projection for kerosene fuel with an R square value > 0.5. The use of electricity for cooking from year to year tends to fluctuate because the use of electricity as cooking fuel has not become a consistency for the community and has not been a consistent encouragement by the government. The most suitable projection for the use of electricity with a value of R square > 0.5 is to use a quadratic trend.

III. RESULT AND DISCUSSION

3.1. Fuel consumption

The projection of fuel consumption from the power generation and residential sectors are presented in Fig. 3 and Fig. 4.



	Gas	HSD	MFO	Coal
2018	1957359827	169167	23478	12695811
2025	2167241897	868816	269296	13404544
2030	2341520882	2347551	878816	17081494

2018 2025 2030

FIGURE 3. The projection of fuel consumption from the power generation sector

The results of the projection of fuel consumption can be seen in Fig. 3. the graph shows that in the power generation sector, the use of fuel from 2018 to 2030 tends to increase. The dominant fuel used is natural gas, according to field conditions in DKI Jakarta Province. According to the business plan for electricity supply in Indonesia (RUPTL) in 2024-2030, three power plants supply the electricity in the DKI Jakarta Province, including PLTGU/PLTU Muara Karang, PLTGU/PLTU Tanjung Priok, and PLTD Senayan.

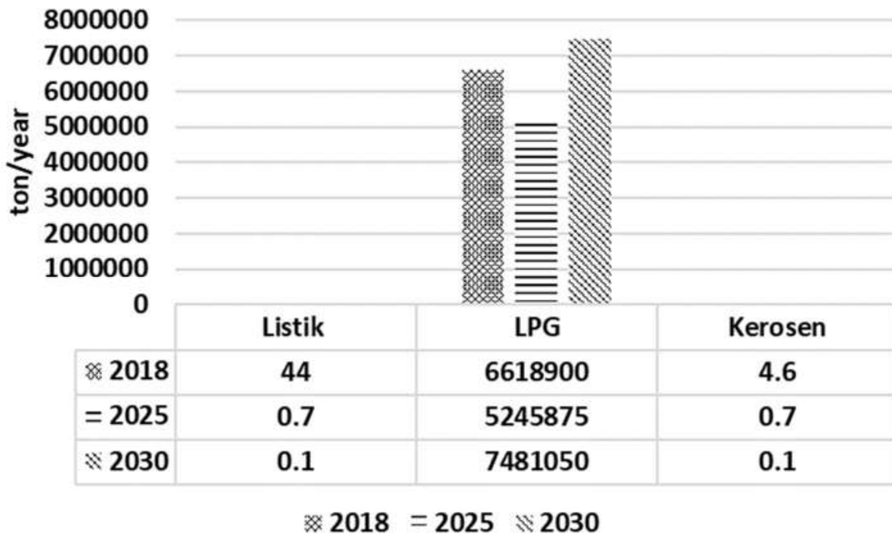


FIGURE 4. The projection of fuel consumption from the residential sector

The results of the projection of fuel consumption can be seen in Fig. 4. The graph shows that in the residential sector, the use of fuel from 2018-2030 tends to fluctuate. The dominant fuel used for cooking today is LPG. The LPG fuel graph shows that the projected results will decrease and then continue to increase in 2030. The chart shows a downward trend because kerosene is no longer used, in addition to the scarcity of kerosene which causes a lot of air pollutant emissions. The projected use of electricity for cooking shows that there will be a decline due to high prices. However, using cooking fuel using electricity does not cause air pollution or zero emissions when cooking.

3.2. Business as usual (BAU)

The emission load in the power generation and residential sectors is estimated in 2025 and 2030 are presented in Fig. 5. and Fig 6.

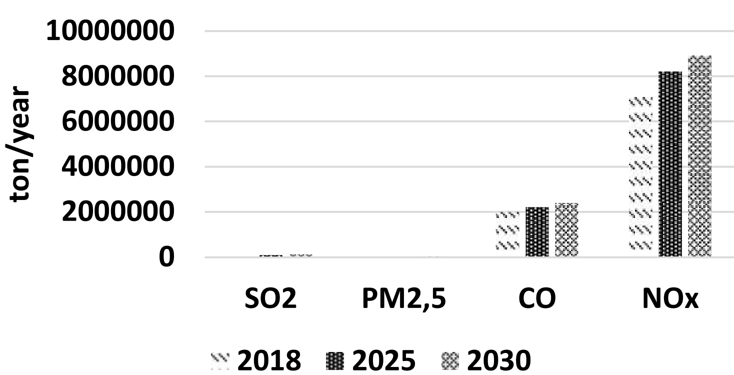


FIGURE 5. Emission burden in power generation sector in 2025 and 2030

The results of the calculation of the emission load in the power generation sector in Fig. 5. show that from 2018-2030 the emission load produced tends to increase, and the dominant emitted is the NO_x parameter, followed by CO, then SO_2, and the lowest emitted is $PM_{2.5}$.

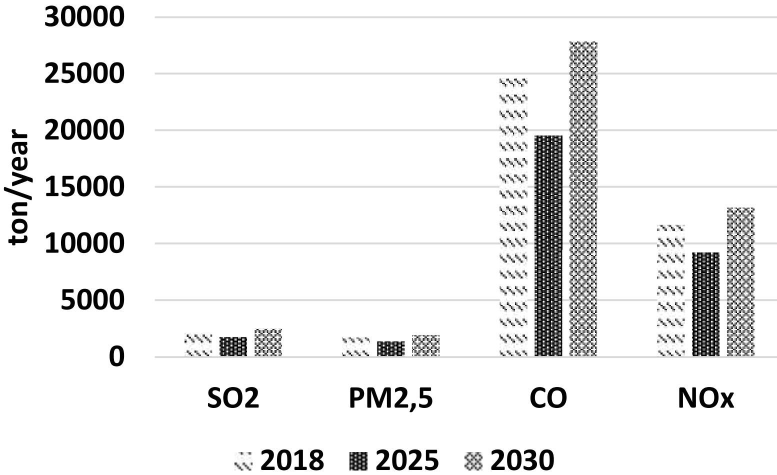


FIGURE 6. Emission burden in residential sector in 2025 and 2030

The results of the calculation of the emission load in the residential sector in Fig. 6. show that from 2018-2030 the emission load generated tends to fluctuate. The dominant fuel emitted is CO parameter, followed by NO_x, then SO_2, and the lowest emitted is $PM_{2.5}$.

3.3. Emission reduction scenario in 2030

Emission reduction scenarios are conducted based on several regulations or policies related to air pollution in power generation as follows:

- Based on the Minister of Environment and Forestry Regulation Number 15 of 2019 concerning Emission Quality Standards for Thermal Power Plants, power plants have the potential to cause air pollution, so it is necessary to control emissions produced by thermal, for example, gas and steam power plants. (PLTGU), namely, activities that produce electricity. Using fuel oil or gas that produces gas from combustion and diesel power plants (PLTD) are activities that produce electricity using liquid fuels that produce gas. In line with the importance of controlling air pollution due to the use of fuel oil, it is necessary to reduce the use of fuel oil.
- Conversion of petroleum into natural gas is one alternative solution. According to www.defra.gov.uk in technical reports on the preparation of an inventory of air pollution emissions in urban areas which are used as examples of scenarios of emission reduction measures to reduce SO_2 and NO_x [12]. Referring to business plan for electricity supply in Indonesia (RUPTL) 2021-2030 and RUEN that gasification of power plants is required by converting the use of HSD fuel into fuel oil.
- The ESDM Strategic Plan 2020-2024 is planned to convert PLTG/PLTGU/PLTU fueled from oil into natural gas so that natural gas can be used as an emission reduction solution. Data on fuel use activities at PLTGU DKI Jakarta Province has used natural gas but not yet fully used. Natural gas is used as transitional energy before 100% NRE in power plants. Natural gas is used as fuel for intermittent renewable energy generation and to meet domestic needs to meet energy needs towards NZE in 2060.

Then the emission reduction scenario can be done by gasifying power plants by converting the use of high-speed diesel (HSD) and marine fuel oil (MFO) fuels with a natural gas target of 50% in 2025 as a transition and 100% in 2030 in the supply of electricity.

Emission reduction scenarios are conducted based on several regulations or policies related to air pollution in the residential as follows:

- It refers to Presidential Regulation Number 22 of 2017 concerning National Energy Planning which states that the occurrence of LPG shortages is caused by increasing LPG consumption, so efforts are made to control the growth of LPG consumption.
- In the Summary of the Strategic Plan of the Ministry of Energy and Mineral Resources (ESDM) 2020-2024 is planned to encourage the development of electric stoves in the household sector.
- www.defra.gov.uk also supports this scenario. Technical report on the compilation of air pollution emissions inventory in urban as an example of emission reduction efforts to reduce [12].

Then the emission reduction scenario that we can do is to replace the use of LPG as fuel for gas stoves with electric stoves with a 2025 target of 2% based on the Indonesia Energy Outlook 2019 book and 4% of the 2030 target so that it can also support RUED regarding supply-demand, that the need for to overcome the scarcity of fuel, where the use of induction cookers can encourage an increase in the use of electrical energy in Indonesia, which is still low according to BUMN [13].

3.4. BaU vs Emission reduction scenario

A comparison of emission load on parameters of SO_2, NO_x, CO, and $PM_{2.5}$ between the business-as-usual scenario and the reduction scenario is presented in the following figure.

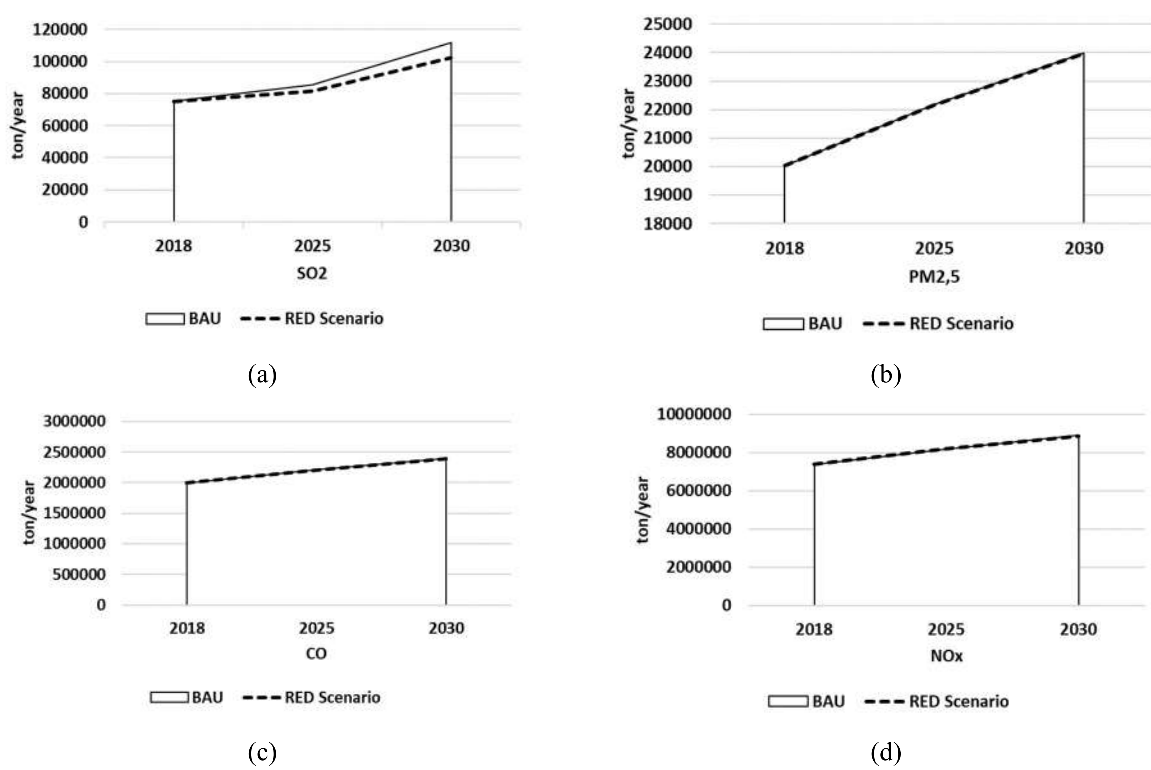


FIGURE 7. Comparison of scenarios in the power generation sector. (a) SO_2 (b) $PM_{2.5}$ (c) CO (d) NO_x

Fig. 7. Using the selected scenarios for the power generation sector, the most effective parameter that can be reduced is SO_2, with a reduction percentage of 4.5% in 2025 and 8.44% in 2030. This is in line with www.defra.gov.uk., where this scenario effectively reduces SO_2 and NO_x. and followed by the $PM_{2.5}$ parameter with a percentage reduction of 0.29% in 2025 and 1.49% in 2030. Then the NO_x parameter with a percentage reduction of 0.09% in 2025 and 0.57% in 2030, and CO parameter with a reduction percentage of 0.14% in 2025 and 0.23% in 2030. The percentage of emission reduction is presented in Table 1.

TABLE 1. Results of emission load reduction scenario in the power generation sector

Parameter (ton)	(Baseline) 2018	2025			2030		
	BAU	BAU	Scenario	Reduction	BAU	Scenario	Reduction
SO_2	75159	85340.71	81.496.95	4.50%	111940.99	102488.96	8.44%
CO	3885583.65	4309220.02	4303249.60	0.14%	4659628.07	4648990.47	0.23%
$PM_{2.5}$	1020.74	1128.71	1125.58	0.29%	1,258.47	1239.66	1.49%
NO_x	7391004	8194329.64	8187184.54	0.09%	8900169.88	8849013.01	0.57%

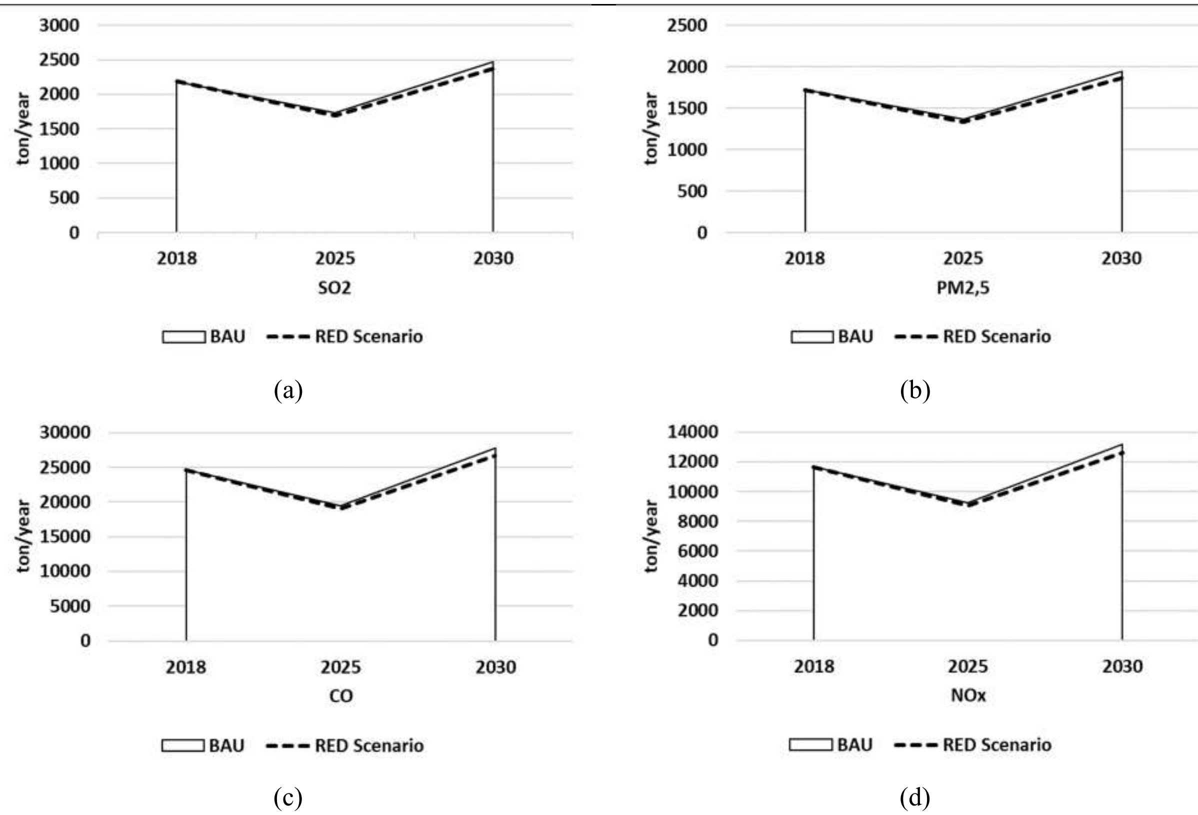


FIGURE 8. Comparison of scenarios in the residential sector. (a) SO_2 (b) $PM_{2.5}$ (c) CO, and (d) NO_x

Fig. 8. by using selected for the residential sector, shows that can reduce all parameters effectively with the same percentage reduction as the target for reducing fuel consumption. Table 2 shows that using the selected scenario for the residential sector will reduce all parameters by 2% in 2025 and 4% in 2030. this is in line with the www.defra.gov.uk statement, where we can use this scenario for emission reduction efforts.

TABLE 2. Results of emission load reduction scenario in the residential sector

Parameter (ton)	(Baseline) 2018	2025			2030		
	BaU	BaU	Scenario	Reduction	BaU	Scenario	Reduction
SO_2	2.184	1731.13	1696.51	2.00%	2468.75	2369.99	4,00%
CO	24.622	19515	19124	2.00%	27829.51	26716.33	4,00%
$PM_{2.5}$	1.721	1363.92	1336.65	2.00%	1945.07	1867.27	4,00%
NO_x	11.649	9232.74	9048.09	2.00%	13166.65	12639.98	4,00%

IV. CONCLUSION

Based on the research results, it can be concluded that the quantified emission reductions are as follows:

1. In the power generation sector, the scenario for reducing air pollutant emissions of SO_2, CO, NO_x, and $PM_{2.5}$ can be done by gasification by converting the use of high-speed diesel (HSD) and marine fuel oil (MFO) with natural gas targets 50% in 2025 as a transition and 100% in 2030 in electricity supply, where the most effective parameter in reducing SO2 is 8.44% in 2030, the power generation sector in DKI Jakarta Province primarily uses natural gas as its fuel.
2. In the residential sector, the scenario for reducing air pollutant emissions of SO_2, CO, NO_x, and $PM_{2.5}$ that can be done is to substitute the use of LPG as gas stove fuel into an electric stove with a 2025 target of 2% based on the Indonesia Energy Outlook 2019 book. And 4% of the 2030 target, which can be reduced to all parameters effectively with the same percentage reduction as the target for reducing fuel consumption of 4% by 2030, the residential sector in DKI Jakarta Province primarily uses liquefied petroleum gas as its fuel for cooking.

ACKNOWLEDGMENTS

The author would like acknowledge various governmental agencies in Indonesia for providing data in both online and physical documents.

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