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The Analysis of CO_2 Emission Reduction Scenarios in Industry Sector of Yogyakarta Province of Indonesia

(Analisis Skenario Penurunan Emisi CO_2 pada Sektor Industri di Pripinsi Daerah Istimewa Yogyakarta)

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ABSTRACT

The final energy demand and energy-related CO_2 emission in industrial sector of Yogyakarta Province were analyzed in this study. The potential of energy saving and reduction of CO_2 emission were estimated. The analysis was based on energy model. The model was constructed by LEAP model that describe the pattern of energy demand in industrial sector. Energy modeling and scenario analysis were used to simulate the impacts of various policies in energy demand and CO_2 emission. Three scenarios were implemented in the model. Initially, the model was developed under business as usual (BAU) scenario that include current situation of energy-related activity in industrial sector. 2008 was selected as base year with projection period was terminated in 2025. Then, two alternative scenarios were developed that focus on energy efficiency improvement (EE scenario) and fuel switching to cleaner fuel (FS scenario). The two alternative scenarios were integrated into mitigation scenario. The result of alternative and mitigation scenario compare to BAU scenario in term of the final energy demand and energy-related CO_2 emission. The result of the model showed the potential of energy saving by implementing mitigation scenario is 24.16% compare to BAU scenario. The expected reduction of CO2 emission under mitigation scenario is 20.22% compare to BAU scenario.

Keywords : energy demand, energy efficiency, fuel switch, energy model, LEAP model

INTRODUCTION

Scenario studies indicated that the emissions of greenhouse gas (GHG) are likely to increase in the future in most of the region (IPCC, 2000). After a 1% decline in 2009, the emission of GHG in the form of carbon dioxide (CO_2) increased by more than 5% in 2010 (Oliver et al., 2011). Many reseachers developed models to generate accurate prediction of CO_2 emission. Various model for prediction and the development of scenarios for mitigation can be devided into two models, which are models used for mitigation in energy sector and models used to survey mitigation methods in activity sector (IPCC, 2000).

In Yogyakarta Province, most of the energy carriers in industrial sector are oil fuel, LPG, electricity, and coal. Beside electricity, oil fuel that consists of kerosene, Industrial Diesel Oil (IDO), Automotive Diesel Oil (ADO), and Marine Fuel Oil (MFO), is dominating energy demand in industrial sector by 30.00% of total energy demand (CASINDO, 2009). One of the most important energy carriers in industrial sector is natural gas. Currently, this energy carrier has not been optimally used in industrial sector of Yogyakarta Province. On the other side, Indonesia is the tenth largest holder of proven natural gas reserves in the world and the single largest in the Asia-Pacific region (IEA, 2008).

Many studies analyzed the impact of energy efficiency programs and fuel substitutions in CO_2 emission reduction. A study in cement indusrty in Iran evaluted the impact of mitigation scenario in CO_2 reduction using LEAP that result in 13% emission reduction (Atabi et al., 2011). Research on substituting biomass with other energy carriers in Vietnam using LEAP model has shown that this fuel substitution leads to a 10.83 million-ton reduction in GHG emission (Amit, 2003).

Another analysis of the environmental and economic landfill gas (LFG) electricity generation in Korea using the LEAP model showed that LFG electricity generation would be an effective solution CO_2 emission reduction over a medium term with additional energy profits and will reduce the global warming potential by a maximum of 75% when compare to spontaneous emission of CH_4 (Shin et al., 2005). Another study in Korea evaluated the environment and economic aspects of chemical CO_2 absorption in power plant using this model. This study demonstrated that by applying various policies, the rate of CO_2 emission will decrease by approximately 15% in 2014 (Song, 2007).

In this study, LEAP model was used to demonstrate the impact of energy efficiency and fuel switch policies in GHG emission reduction of industrial sector in Yogyakarta Province. The fuel switch scenario focused on oil fuel replacement with natural gas based on national target of natural gas utilization in all sector in Indonesia.

METHODOLOGICAL APPROACH

LEAP Model

Long-range Energy Alternative Planning (LEAP) is an energy planning model that consists of an end-use structural model. Based on procedural analysis of the supply and demand network, the model describes technological energy carrier utilization based on energy demand and technological change (SEI, 2011). Therefore, structural change of energy carrier and efficiency of energy conversion system can be implemented in LEAP model. LEAP model consists of hierarchical structure in which energy flows from the last point of usage (equipment and technology) toward higher level. Total energy is computed from each subcategory or category in a tree structure. In the model, the rate of energy demand is computed according to equation (1).

$$\sum E_t = T_i \times I_i \qquad (1)$$

where, E_t is the total energy demand (in BOE), T_i is the data (i) of activity level (million Rp.), and I_i is energy intensity (BOE/million Rp.).

In this study, 2008 is chosen as a base year and the end year is 2025. All relevant information was gathered from the base year. The future demand of energy and GHG emission of industrial sector will be analyzed for 15 year period.

Data of Energy Intensity and Activity Level

Data describing the energy intensity of each type of energy in each sub-sector of industry is shown in Table 1 (CASINDO, 2009). Gross Domestic Product (GDP) data as an activity level of each sub-sector of industry is shown in Table 2 (BPS, 2008).

TABLE 1. Energy intensity of industrial sector in Yogyakarta Province 2008.

No.	Subsector	Energy Use Intensity in 2008 (BOE/million rupiah/year)						
		ADO	IDO	Kerosene	Fuel Oil	Electricity	LPG	Coal
1	Food	0.01266	0.00000	0.00055	0.01283	0.01745	0.00105	-
2	Textile	0.02079	0.00039	0.00090	0.01573	0.13004	0.00089	0.01911
3	Wood	0.00077	0.00000	0.00003	0.00093	0.01128	0.00023	-
4	Paper	0.00056	-	0.00002	0.00011	0.01379	0.00002	-
5	Chemical	0.01960	0.00002	0.00085	0.00232	0.05139	0.00007	-
6	Non Metal	0.04135	0.00001	0.00179	0.01864	0.04618	0.00345	0.00315
7	Machinery	0.00206	-	0.00009	0.00024	0.06310	0.00016	-
8	Other	0.00967	0.00004	0.00042	0.00214	0.02598	0.00014	0.01550

TABLE 2. GDP of industrial sector in Yogyakarta Province 2001-2008.

No.	Subsector	Value added (Constant Price 2000) (million rupiah)							
		2001	2002	2003	2004	2005	2006	2007	2008
1	Food	696,555	695,205	742,507	800,848	845,594	860,186	907,914	946,419
2	Textile	465,973	489,219	502,380	508,391	510,219	511,559	508,540	506,725
3	Wood	311,451	316,500	316,920	323,944	323,919	336,147	327,564	331,821
4	Paper	115,899	112,777	122,742	124,966	129,735	129,201	133,385	135,900
5	Chemistry	103,019	109,942	110,043	112,353	114,892	117,393	113,887	116,098
6	Non Metal	117,875	139,423	121,658	126,292	129,566	126,765	119,285	116,582
7	Machinery	224,906	239,015	235,737	225,655	226,719	220,145	227,699	224,278
8	Others	164,222	159,805	173,250	178,328	182,586	179,771	189,745	188,599
	Total	2,199,898	2,261,886	2,325,236	2,400,776	2,463,230	2,481,167	2,528,020	2,566,422

Scenarios Development

1. BAU Scenario

In the Business as Usual (BAU) scenario, it is assumed that the current status of industrial sector in Yogyakarta Province will be maintained in the future. The energy demand and GHG emission will be predict by the variable of BAU, such as the growth rate of GDP of industrial sector, the type of energy consumption, and the energy intensity.

The BAU scenario was developed according to current plans as well as future policies, change in GDP growth rate, energy intensity, the type of energy contribution that supply energy demand and other factor in industrial sector from 2010 to 2025. The BAU scenario assumes no change in the structure of industrial sector. Therefore, the structure of industrial sector will remain constant during time frame. The GDP growth in 2008 is 5% and the growth rate in 2025 is assumed 6%. The GHG emission rate in BAU scenario was based on IPCC data.

2. EE Scenario

Energy Efficiency (EE) scenario was developed based on the same macro-economic assumption as the BAU scenario. The EE is design to accommodate energy efficiency improvement in industrial processes. It has a target of 10% to 20% energy efficiency improvement by 2015 to 2025, and applied to all industrial sub-sectors. This scenario also considers efficient electricity end-use devices. It is assumed that increasing 20% of electricity efficiency by 2025 in pumps, compressors, and motors.

3. Fuel Switch Scenario

The fuel switch scenario is design to implement cleaner fuels and technologies. Switching to natural gas from oil fuel is assumed for thermal energy. Oil fuel consumption will be replaced by natural gas starting 2015 to 2025. In 2025, 30% of oil fuel will be replaced by natural gas (IEA, 2008). The use of combine heat and power (CHP) in industrial sector is also considered. CHP will use to produce electricity in designate factories and waste heat will be used to replace heat from oil fuel-fired boilers. Thus, CHP will replace oil fuel by 2015 and assumed that CHP will contribute in decreasing electricity consumption by 10%.

4. Mitigation Scenario

In the mitigation scenario, different policies to mitigate the energy demand and GHG emission reduction are consider as an input data for the LEAP model. In other word, mitigation scenario is the integration of EE and Fuel Switch scenarios. Then, the result of this scenario is compared with the BAU scenario by predicting the demand of energy carriers and the calculated mitigation in emission.

RESULT OF THE MODEL

The main result obtained using the model based on the assumption, scenario description, and data collections as in the previous section are presented in this section. The results of the model are future energy demand and CO_2 emission in industrial sector, and potential energy demand and emission reduction.

Energy Consumption

Final energy demand by four different scenarios is shown in Figure 1. The comparison of final energy demand by type is shown in Figure 2. In all scenarios, it is simultaneously estimated that energy demand of industrial sector will increase due to the economic development.

In the BAU scenario, the final energy demand is influenced only by economic development with no additional energy and climate policies are implemented. It can be seen that the final energy demand will continue to rise from 201.01 thousand BOE in 2010 to 312.08 thousand BOE in 2025 with average annual growth rate of 2.99%. Electricity account and coal product is 137.68 thousand BOE in 2010 and to continue rising to 202.72 thousand BOE in 2025. Natural gas and oil fuel product are also projected to continue rising. In 2010, demand of natural gas and oil fuel product are 2.14 thousand BOE and 61.2 thousand BOE respectively and rise to 35.66 thousand BOE and 74.47 thousand BOE respectively. The share of natural gas in BAU scenario is only 1.06% in 2010 and 1.20% in 2025 while the share of oil fuel product is 30.44% in 2010 and 34.00% in 2025.

In alternative scenarios: EE and FS scenarios, since most policies intervention are introduces between 2015 and 2025, a reduction of final energy demand compared with BAU scenarios becomes apparent in that year. Compare to BAU scenario, the final energy demand will decrease with energy efficiency improvement, fuel substitution, and other measures within these two scenarios. Therefore, the final energy demand in 2025 will grow to 255.54 thousand BOE. The energy demand under FS scenario will reach 294.59 thousand BOE in 2025. Compare to BAU scenario, the potential of energy saving in EE and FS scenarios are expected to be 18.32% and 5.84% respectively.

In Figure 2 and 3, the increase of natural gas share is very apparent in FS scenario. In 2025, the share of natural gas is 12.11% of final energy demand. The comparison between EE and BAU scenarios in fuel share is not so significant. The impact of EE scenario is only in reducing the demand of final energy. In the other hand, the impacts of FS scenario are the role of natural gas is more significant and slightly reduce the demand of final energy.

Figure 3 shows the energy structure in aggregate of the final energy demand in industrial sector. It is obvious that from 2010 to 2025 electricity and oil fuel will remain the dominant fuels under four different scenarios. There are few differences between FS scenario and others because policy interventions of switching fuels to cleaner fuels.

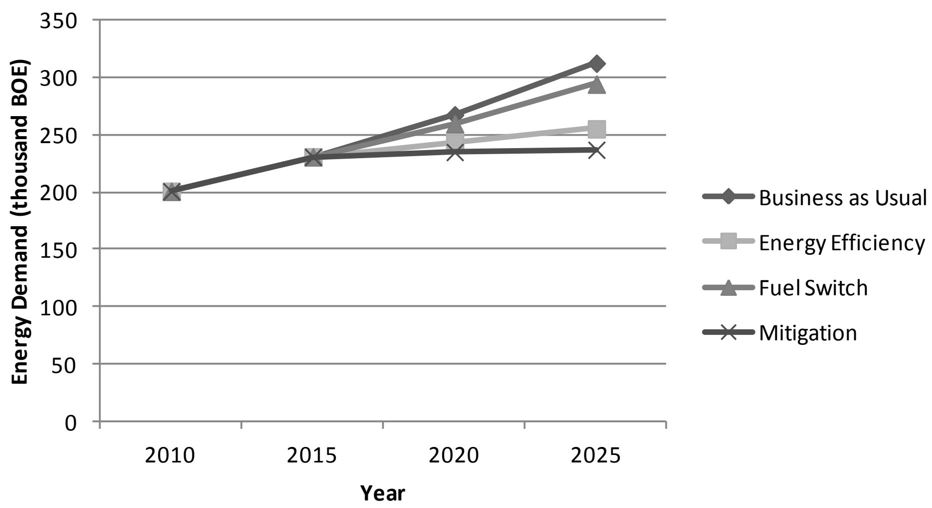

FIGURE 1. Final energy demand in industrial sector in defferent scenarios from 2010 to 2025.

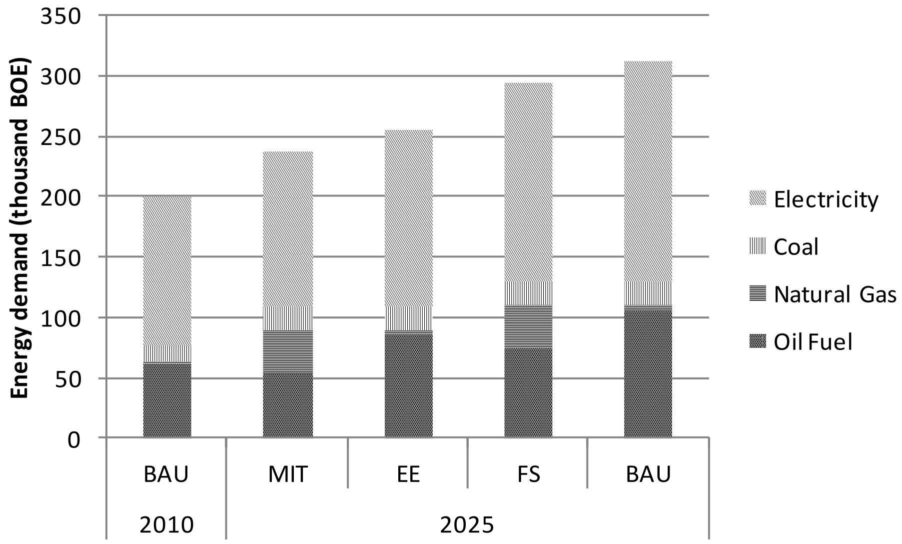

FIGURE 2. Energy demand by type of energy in industrial sector in defferent scenario in 2010 and 2025.

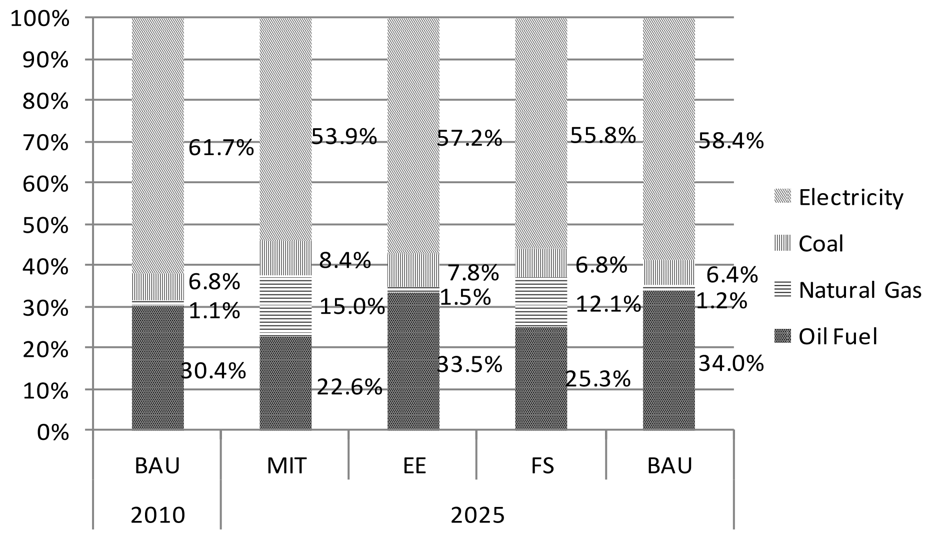

FIGURE 3. Energy structure in aggregate of final energy demand in different scenarios.

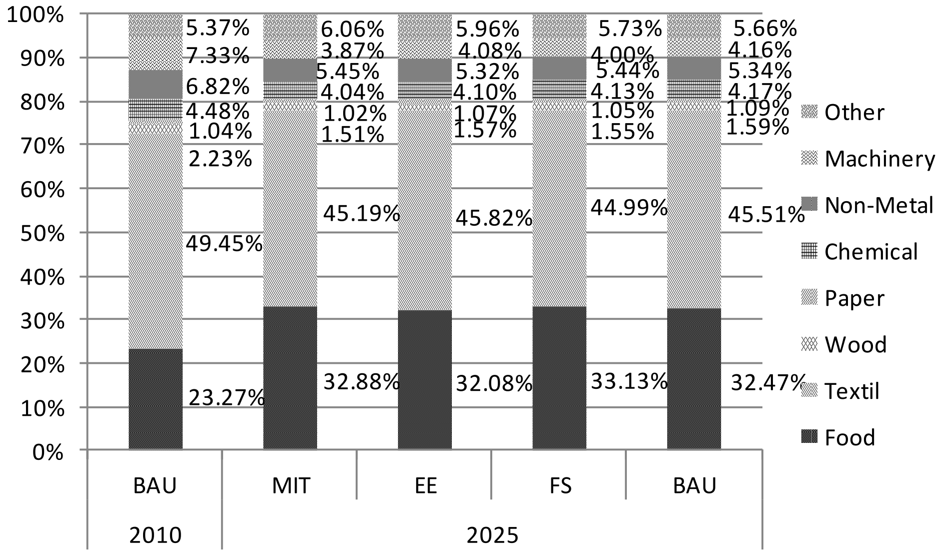

FIGURE 4. Comparison of sub-sectors structure in aggregate of final energy demand in defferent scenarios.

From sub-sector point of view, Figure 4 present some useful information. Textile and food industry will remain dominant sub-sector along projection period. The energy demand of textile and food industry is affected by the share of GDP in industrial sector.

GHGs Emission

Figure 5 shows the growth rate of GHGs emission under four different scenarios. In BAU scenario, it is obvious that the growth rate of the emission of NO_x, CH_4, and CO_2 increased along projection period. In 2025, it is also seen that FS scenario produced the highest growth rate GHGs emission as a result of high growth rate of the CH_4 emission. This growth rate of the CH_4 emission is produced by the increase of the share of natural gas in industrial sector. In the other hand, EE and MIT scenarios produced lower growth rate of the GHGs emission compare to BAU scenario. The energy-related CO_2 emission from 2010 to 2025 under four different scenarios is shown in Figure 6. The trend of CO_2 emission is very similar with the trend of final energy demand that is projected to increase for all different scenarios. In BAU scenario, CO_2 emission is rising from 34.82 million $KgsCO_2$ in 2010 to 58.74 million $KgsCO_2$ with the average annual growth of 3.55%. In EE and FS scenario, the CO_2 emission in 2025 is 49.97 million $KgsCO_2$ and 55.63 million $KgsCO_2$ respectively. The mitigation scenario, as combination of EE and FS scenarios, produced CO2 emission of 46.86 million $KgsCO_2$. The potential of CO_2 emission reductions by implementing various policies in EE, FS, and MIT scenarios compare to BAU scenario are 14.93%, 5.29%, and 20.22% respectively. The energy efficiency improvement will be the main contributor of the reduction of CO_2 emission. This due to low energy efficiency equipment was used by industrial sector in Yogyakarta Province. This comparison will be very useful for the government where the target of CO_2 emission to be made for coming future.

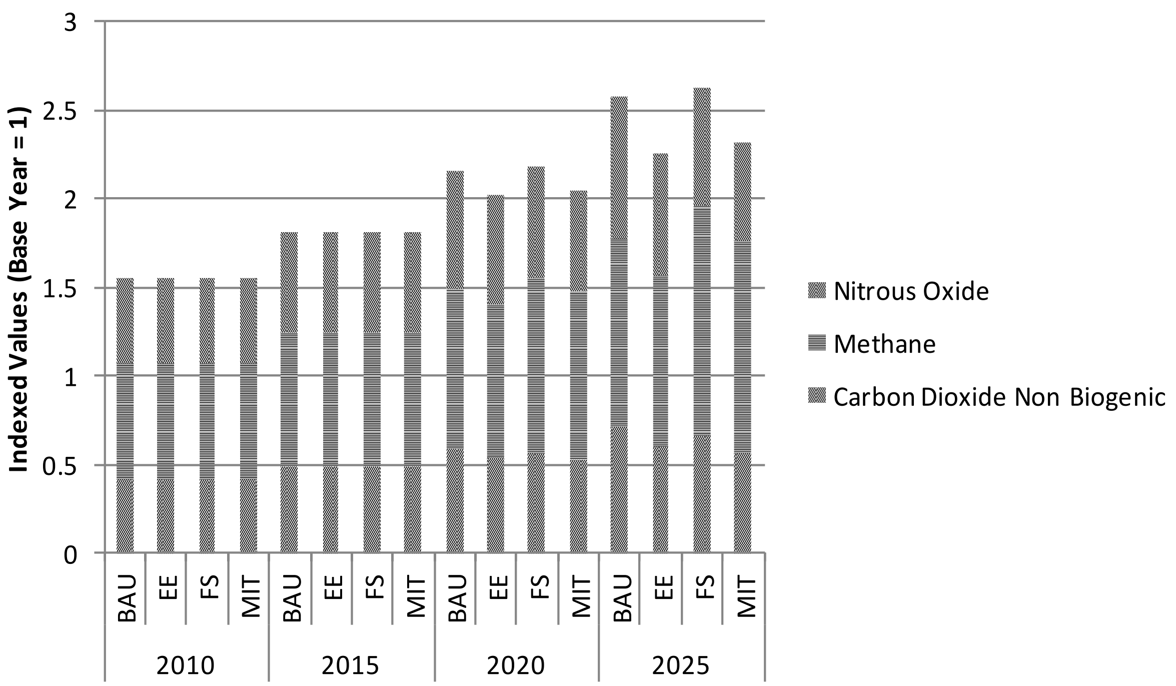

FIGURE 5. The indexed values of GHGs emission in four different scenario.

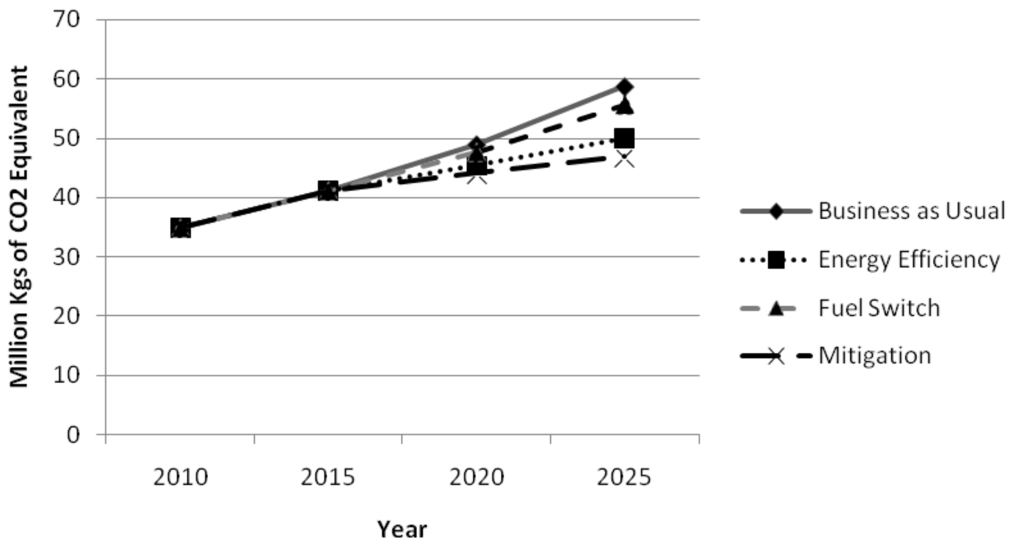

FIGURE 6. CO_2 emission under four different scenarios.

CONCLUSION

This study applied the energy modeling and scenario analysis. LEAP model of industrial sector of Yogyakarta Province was constructed by implementing energy efficiency and fuel switching to cleaner fuel scenario. The final energy demand for industrial sector in 2025 will reach 312.85 thousand BOE under BAU scenario. By improving energy efficiency process in industrial sector, the final energy demand can be reduced by 18.32%. The reduction of final energy demand by implementing cleaner fuel in industrial sector is 5.84%. Therefore, the total reduction of the final energy demand by implementing mitigation policy is 24.16%.

Under BAU scenario, energy-related CO_2 emission in 2025 will reach 58.74 million KgsCO_2. The energy efficiency improvement gives important role in CO_2 emission reduction. Under energy efficiency scenario, the expected CO_2 emission reduction is 14.93% compare to BAU scenario. The substitution to cleaner fuel under fuel switch scenario gives 5.29% of CO_2 emission reduction compare to BAU scenario. The integration of energy efficiency and fuel switching under mitigation scenario shows high possibility to reduce CO_2 emission. The expected reduction of CO_2 emission under mitigation scenario is 20.22%.

The result of this study can contribute to identify the target of emission reduction and implementing energy and climate policy in industrial sector of Yogyakarta Province. The advance study can be done by implementing local factors of emission in the same LEAP model. Therefore, the result of the model will be closer to the real world of industrial sector in Yogyakarta Province.

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