End-Use Energy Efficiency Improvements and SO_2 Emissions in Indonesia: An Input-Output Analysis

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ABSTRACT

This paper analyses the production of SO_2 by the Indonesian economy in 1990 and 2000 using an input-output (I-O) model. It also assesses the implications of residential sector energy efficiency (EE) improvement programs for SO_2 production by the Indonesian economy in 2000 under both high and low growth scenarios. The study shows that the SO_2 emissions from Indonesia would increase from 740 million kg in 1990 to 1.614 billion kg in 2000 under the high growth scenario and to 1.166 billion kg under the low growth scenario in the absence of residential sector EE programs. With the EE programs in the residential sector, it is shown that the total SO_2 emissions in 2000 would be reduced by 25 million kg under the high growth scenario and by 22 million kg under the low growth scenario. Of the total SO_2 produced in 1990 and 2000, more than 60% are associated with the indirect production demand for fuels.

1. INTRODUCTION

Energy consumption in Indonesia is growing faster than GDP. During 1985-1995, the average annual growth rate (AAGR) of total primary energy requirements in Indonesia was 10% as compared to that of 7% in the case of GDP [2]. Furthermore, the share of fossil fuels in total energy consumption and consequently anthropogenic emissions of SO_2 the major precursor of acid rain have both been increasing. SO_2 production from a sector is associated not only with the direct demand for fuels by final users [hereafter "direct consumption demand (DCD)"] and that by producing sectors [hereafter "direct production demand (DPD)"], but also with the indirect demand for fuels in the production of other inputs [hereafter "indirect production demand (IPD)"]. Yet, to the knowledge of the authors, there is no study in the literature focused on the estimation of SO_2 productions associated to DCD, DPD and IPD for fuels in a developing country context.

This study assesses the level of total SO_2 emissions from the Indonesian economy in years 1990 and 2000 and the contributions of DCD, DPD and IPD to the total SO_2 emissions for two economic growth scenarios for the year 2000 (i.e., a "high growth" scenario which was considered to be the business as usual scenario (BAU) before the economic crisis started in mid 1997 and a

"low growth" (i.e., negative growth) scenario that appears to be more realistic in the face of the ongoing economic crisis. Furthermore, as Indonesia is planning to improve the efficiency of electricity use through the adoption of efficient appliances, the study also analyzes the reductions in SO_2 emissions that are likely to take place with the adoption of efficient electrical appliances under each scenario.

This paper discusses the electricity use and the planned energy efficiency improvement program in Indonesia, describes the input-output methodology used for the estimation of SO_2 production due to direct and indirect demands for fuels, presents data sources and assumptions, presents the results and discussions, and summarizes the major findings of the study.

2. ELECTRICITY USE IN INDONESIA

Power demand in Indonesia increased at the AAGR of over 14% during 1984-1993 [1, 2]. In 1990, about 46% of the total electricity generation was from oil fired power plants while coal-, hydro- and gas/geothermal- based plants accounted for 31%, 17% and 6%, respectively [3]. In 2000, the generation mix is expected to be significantly different from that in 1990 in that around 47% of the total electricity generation would be from coal fired plants, while gas/geothermal-, hydro- and oil- based plants would contribute 37%, 10% and 6%, respectively [4]. Electricity sales by P.T. PLN (PERSERO), the Indonesian electric utility, was 39 TWh in 1993 [5]. Electricity consumption is expected to grow annually, on the average, by 10.9% during 1997-2000 [4]. Of the total projected electricity consumption in 2000, industrial and residential sectors are estimated to account for about 54% and 30%, respectively [4]. In the residential sector, lighting is projected to have the share of 53% of the electricity consumption, while the projected shares of refrigerators, TVs and electric irons are 10%, 9% and 7%, respectively [6]. Air conditioners, fans, water pumps and others would account for the rest (21%). Around 40% of total lamps used were fluorescent lamps and the remaining 60% were incandescent lamps [6].

P.T. PLN (PERSERO) is planning to implement demand-side management (DSM) programs in different sectors of the economy [7]. In the residential sector, the DSM programs were focused on energy efficiency improvements. Electricity savings in 2000 in residential sector through the efficiency improvement programs are targeted to be around 20% [8]. The energy efficiency improvement program here is limited to refrigeration and lighting, as they together account for approximately two-thirds of the total household electricity consumption and three-quarters of peak household demand in 1990 [6, 8].

3. METHODOLOGY

The symbols used in this paper are defined as follows:

m = types of fuels used by producing sectors
n = number of producing sectors
A = matrix (n x n) of input-output (i.e., technological) coefficients
C = matrix (m x n) of direct fuel requirement coefficients (defined as fuel use per unit of output of a sector)
d = column vector (m x 1) of final demand for fuels by consumers

e = row vector (1 x m) of SO_2 emissions coefficients (defined as SO_2 emissions per unit of fuel used)
E = Total SO_2 emissions from fuel use by producing sectors and final users.
f = column vector (m x 1) of total fuel use by producing sectors
F = column vector (m x 1) of total fuel use by producing sectors and final users
P = matrix (m x n) of fuel-use coefficients by consumers (each coefficient expressed as quantity of fuel used per unit monetary value of fuel purchased for consumption)
X = column vector (n x 1) of total output
Y = column vector (n x 1) of final demand

Following Gay and Proops [9], the vector of total fuel use (i.e., fuel used by producing sectors and final demand for fuels) is given by:

$$\begin{aligned} F &= f + d \\ &= CX + PY \\ &= [C(I-A)^{-1} + P]Y \end{aligned} \tag{1}$$

Total SO_2 emissions from fuel use by producing sectors and final users are given by:

$$E = eF = e[C(I-A)^{-1} + P]Y \tag{2}$$

Denoting $k \equiv e[C(I-A)^{-1} + P]$, Eq. (2) is expressed as:

$$E = kY \tag{3}$$

Note that k is a row vector (1 x n) of total the SO_2 emissions intensity (defined as total direct and indirect SO_2 emissions per unit of final demand). Thus element k_i of vector k represents the total SO_2 emissions intensity of sector i. Following Gay and Proops [9], the total SO_2 production in the economy can be decomposed into three components, i.e., SO_2 production associated with (i) direct consumption demand [hereafter "SO_2(DCD)"], (ii) direct production demand [hereafter "SO_2(DPD)"] and (iii) indirect production demand [hereafter "SO_2(IPD)"]. These are expressed as:

$$SO_2(DCD) = ePY \tag{4}$$

$$SO_2(DPD) = eCY \tag{5}$$

$$SO_2(IPD) = eC(A+A^2+A^3+ ...)Y \tag{6}$$

4. DATA SOURCES AND ASSUMPTIONS

The data used in this study are taken from various published sources; i.e., Biro Pusat Statistik (BPS) [10] for fuel use data for the manufacturing sector; BPS [3, 11 - 13] for fuel use data for the mining and gas industry; BPS [3] and BPS [14] for fuel use data for electricity generation and water supply, respectively; and BPS [11] for agriculture, transport and services. The input-output table used in this study is based on BPS [15]. The sectoral emission factors are taken from AIT[16] and Goto, et al. [17].

The sectoral final demands in 2000 under the "high growth" scenario (which was in fact the official business as usual scenario (BAU) before the economic crisis started) are based on BAPPENAS [8, 18]. The corresponding final demand for electricity by households in 2000 is based on P.T. PLN (PERSERO) (PTP) [4]. The distribution of electricity final demand in 2000 to power generation sectors based on coal, oil, gas/geothermal and hydro is made according to the projected shares of the power generation sectors as given in PTP [4].

According to the International Monetary Fund, the GDP growth in the first half of 1998 was -5% [19]. The decline in economic growth is expected to continue for some years. Since there is not enough information about the future GDP growth rate, the annual growth rate until the year 2000 under the low growth scenario is assumed to remain at -5%. It is also assumed that the distribution of electricity final demand for household from different types of power generation based on fuel use under low growth scenario in 2000 is the same as that in high growth scenario.

It should be noted that following Gay and Proops [9], exports are treated as part of final demand while imports are ignored in this study. If the true picture of the total SO_2 production in the Indonesian economy is to be obtained, then the SO_2 emissions by the Indonesian economy attributable to exports should be subtracted and allocated to the nations importing Indonesian manufactured goods. Conversely, the SO_2 emissions taking place overseas in order to satisfy the Indonesian demand for imports should be added to SO_2 productions in Indonesia. Another assumption made in this study is that sectoral SO_2 intensities in 2000 are the same as that in 1990. The authors use the input-output coefficients of 1990 for assessing the SO_2 production levels in 2000. Although, it is not the ideal approach, this follows the lines of some recent works in the applied literature on I-O analysis [20 - 23].

5. RESULTS AND DISCUSSIONS

Sectoral SO_2 intensities [defined as total SO_2 production (direct as well as indirect) per unit of sectoral final demand] are shown in Table 1. Note that the sectors are presented in the descending order of SO_2 intensity. As can be seen, Oil fired power generation; Coal fired power generation; Textile, wearing apparel and leather; Cement; Basic iron and steel; and Chemicals are the top six sectors in terms of the SO_2 intensity.

Table 2 shows sectoral SO_2 emissions in 1990. Table 3 and Table 4 present the sectoral SO_2 emissions in 2000 under the high growth scenario without and with energy efficiency (EE) improvements in the residential sector respectively while Table 5 and Table 6 show the SO_2 emissions under low growth scenario without and with EE improvements. Total annual SO_2 production from the economy as a whole in 2000 would be more than double of that in 1990 under the high growth scenario: It would increase from 740 million kg in 1990 to 1.614 billion kg in 2000 without EE programs and to 1.589 billion kg with the EE programs. This estimation is somewhat higher than in the study conducted by Shrestha, et al. [24]. The difference could be partly due to the fact that, unlike in the study by Shrestha, et al. [24], sulphur retained in ash of fuels is not considered in this study. Under the low growth scenario, the total SO_2 emission in 2000 is predicted to be 1.166 billion kg without the EE programs while it would be 1.143 billion kg if EE programs are considered. Thus, the improvement in residential sector energy efficiency would avoid 25 million kg of SO_2 production under the high growth scenario which amounts to 1.5% of total SO_2 production by the Indonesian economy in 2000 while in the low growth scenario, the corresponding figure is estimated to be about 23 million kg (i.e., 1.9% of the total SO_2 production in 2000).

Table 1. Sectoral SO_2 intensities in year 1990 (Ranked).

Sector No.[1)]	Sector Name	SO_2 Intensity (g SO_2/US$ at 1990 Prices)
26	Oil fired power generation	153.2
25	Coal fired power generation	89.4
8	Textile, wearing apparel and leather	37.7
17	Cement	32.5
19	Basic iron and steel	23.1
12	Chemicals	22.6
27	Gas/geothermal fired power generation	18.4
28	Hydro power generation	16.6
18	Non metallic mineral products	14.8
30	Water supply	12.6
15	Rubber and plastic wares	12.5
2	Coal	12.2
10	Paper, paper products and cardboard	11.7
11	Fertilizer and pesticide	11.1
21	Fabricated metal products	11.1
13	Petroleum refining	10.1
32	Road transport	8.4
24	Other products	7.8
33	Other transport	7.3
9	Bamboo, wood and rattan products	7.3
16	Clay/ceramics structural products	6.4
31	Construction	6.2
23	Motor vehicle	6.2
20	Non ferrous basic metal	4.2
22	Machinery and apparatus	4.2
6	Manufacture of food	2.7
34	Other services	2.5
7	Beverages and cigarettes	2.4
29	Gas supply	2.4
5	Other mining and quarrying	2.2
1	Agriculture, forestry and fishing	1.0
14	Liquefied of natural gas	0.7
4	Natural gas and geothermal	0.6
3	Crude oil	0.6

[1)]These are the numbers after the aggregation of the sectors in the original I-O table. See Table A1.

Table 2. Sectoral SO_2 production in year 1990 (Ranked).

Sector No.[1)]	Sector Name	SO_2 Production	
		10^3 tons	%
8	Textile, wearing apparel and leather	185.9	25.1
31	Construction	122.9	16.6
34	Other services	98.4	13.3
26	Oil fired power generation	53.9	7.3
6	Manufacture of food	36.8	5.0
32	Road transport	30.3	4.1
12	Chemicals	28.0	3.8
9	Bamboo, wood and rattan products	21.6	2.9
25	Coal fired power generation	21.5	2.9
13	Petroleum refining	21.1	2.8
33	Other transport	19.3	2.6
15	Rubber and plastic wares	18.9	2.5
1	Agriculture, forestry and fishing	11.3	1.5
23	Motor vehicle	11.0	1.5
7	Beverages and cigarettes	8.5	1.1
22	Machinery, electrical machinery and apparatus	8.3	1.1
10	Paper, paper products and cardboard	7.0	0.9
24	Other products	5.4	0.7
3	Crude oil	4.5	0.6
19	Basic iron and steel	3.9	0.5
18	Non metallic mineral products	3.6	0.5
21	Fabricated metal products	3.0	0.4
14	Liquefied of natural gas	2.7	0.4
11	Fertilizer and pesticide	2.4	0.3
28	Hydro power generation	2.1	0.3
20	Non ferrous basic metal	2.0	0.3
2	Coal	1.8	0.2
5	Other mining and quarrying	1.8	0.2
17	Cement	0.9	0.1
27	Gas/geothermal fired power generation	0.9	0.1
30	Water supply	0.8	0.1
16	Clay/ceramics structural products	0.1	0.0
29	Gas supply	0.001	0.0
4	Natural gas and geothermal	0.0	0.0
	Total	740.4	100.0

[1)]New sector numbers after the aggregation. See the footnote in Table A1.

Table 3. Sectoral SO_2 production in year 2000 (Ranked) in the high growth scenario without energy efficiency improvements in the residential sector.

Sector No. [1)]	Sector Name	SO_2 Production	
		10^3 tons	%
8	Textile, wearing apparel and leather	504.0	31.2
31	Construction	228.9	14.2
25	Coal fired power generation	112.1	6.9
6	Manufacture of food	99.7	6.2
34	Other services	93.6	5.8
12	Chemicals	75.9	4.7
9	Bamboo, wood and rattan products	58.5	3.6
32	Road transport	56.5	3.5
13	Petroleum refining	53.3	3.3
15	Rubber and plastic wares	51.2	3.2
33	Other transport	36.0	2.2
23	Motor vehicle	29.8	1.8
26	Oil fired power generation	24.5	1.5
7	Beverages and cigarettes	23.0	1.4
22	Machinery, electrical machinery and apparatus	22.6	1.4
10	Paper, paper products and cardboard	19.0	1.2
27	Gas/geothermal fired power generation	18.2	1.1
1	Agriculture, forestry and fishing	15.3	0.9
24	Other products	14.7	0.9
3	Crude oil	11.4	0.7
19	Basic iron and steel	10.7	0.7
18	Non metallic mineral products	9.8	0.6
21	Fabricated metal products	8.0	0.5
14	Liquefied of natural gas	6.9	0.4
11	Fertilizer and pesticide	6.6	0.4
20	Non ferrous basic metal	5.4	0.3
2	Coal	4.8	0.3
5	Other mining and quarrying	4.8	0.3
28	Hydro power generation	4.4	0.3
17	Cement	2.6	0.2
30	Water supply	1.5	0.1
16	Clay/ceramics structural products	0.1	0.0
29	Gas supply	0.01	0.0
4	Natural gas and geothermal	0.0	0.0
	Total	1,613.9	100.0

[1)]New sector numbers after the aggregation. See the footnote in Table A1.

Table 4. Sectoral SO_2 production in year 2000 (Ranked) in the high growth scenario with energy efficiency improvements in the residential sector.

Sector No.[1)]	Sector Name	SO_2 Production	
		10^3 tons	%
8	Textile, wearing apparel and leather	504.0	31.7
31	Construction	229.1	14.4
6	Manufacture of food	99.7	6.3
34	Other services	94.0	5.9
25	Coal fired power generation	93.1	5.9
12	Chemicals	75.9	4.8
9	Bamboo, wood and rattan products	58.5	3.7
32	Road transport	56.5	3.6
13	Petroleum refining	53.3	3.4
15	Rubber and plastic wares	51.2	3.2
33	Other transport	36.0	2.3
23	Motor vehicle	29.8	1.9
22	Machinery, electrical machinery and apparatus	23.8	1.5
7	Beverages and cigarettes	23.0	1.4
26	Oil fired power generation	20.4	1.3
10	Paper, paper products and cardboard	19.0	1.2
1	Agriculture, forestry and fishing	15.3	1.0
27	Gas/geothermal fired power generation	15.1	0.9
24	Other products	14.7	0.9
3	Crude oil	11.4	0.7
19	Basic iron and steel	10.7	0.7
18	Non metallic mineral products	9.8	0.6
21	Fabricated metal products	8.0	0.5
14	Liquefied of natural gas	6.9	0.4
11	Fertilizer and pesticide	6.6	0.4
20	Non ferrous basic metal	5.4	0.3
2	Coal	4.8	0.3
5	Other mining and quarrying	4.8	0.3
28	Hydro power generation	3.7	0.2
17	Cement	2.6	0.2
30	Water supply	1.5	0.1
16	Clay/ceramics structural products	0.1	0.0
29	Gas supply	0.01	0.0
4	Natural gas and geothermal	0.0	0.0
	Total	1,588.6	100.0

[1)]New sector numbers after the aggregation. See the footnote in Table A1.

Table 5. Sectoral SO_2 production in year 2000 (Ranked) in the low growth scenario without energy efficiency improvements in the residential sector.

Sector No. [1)]	Sector Name	SO_2 Production	
		10^3 tons	%
8	Textile, wearing apparel and leather	358.3	30.7
31	Construction	161.8	13.9
25	Coal fired power generation	96.1	8.2
6	Manufacture of food	71.9	6.2
34	Other services	58.0	5.0
12	Chemicals	53.9	4.6
9	Bamboo, wood and rattan products	41.9	3.6
32	Road transport	40.4	3.5
13	Petroleum refining	38.0	3.3
15	Rubber and plastic wares	36.5	3.1
33	Other transport	25.6	2.2
23	Motor vehicle	21.2	1.8
26	Oil fired power generation	21.0	1.8
22	Machinery, electrical machinery and apparatus	16.2	1.4
7	Beverages and cigarettes	16.1	1.4
27	Gas/geothermal fired power generation	15.6	1.3
10	Paper, paper products and cardboard	13.4	1.1
1	Agriculture, forestry and fishing	12.8	1.1
24	Other products	10.4	0.9
3	Crude oil	9.0	0.8
19	Basic iron and steel	7.6	0.7
18	Non metallic mineral products	7.0	0.6
21	Fabricated metal products	5.7	0.5
14	Liquefied of natural gas	5.0	0.4
11	Fertilizer and pesticide	4.7	0.4
20	Non ferrous basic metal	3.8	0.3
28	Hydro power generation	3.8	0.3
2	Coal	3.4	0.3
5	Other mining and quarrying	3.4	0.3
17	Cement	1.9	0.2
30	Water supply	1.1	0.1
16	Clay/ceramics structural products	0.1	0.0
29	Gas supply	0.004	0.0
4	Natural gas and geothermal	0.0	0.0
	Total	1,165.6	100.0

[1)]New sector numbers after the aggregation. See the footnote in Table A1.

Table 6. Sectoral SO_2 production in year 2000 (Ranked) in the low growth scenario with energy efficiency improvements in the residential sector.

Sector No.[1)]	Sector Name	SO_2 Production	
		10^3 tons	%
8	Textile, wearing apparel and leather	358.3	31.3
31	Construction	161.9	14.2
25	Coal fired power generation	79.7	7.0
6	Manufacture of food	71.9	6.3
34	Other services	58.3	5.1
12	Chemicals	53.9	4.7
9	Bamboo, wood and rattan products	41.9	3.7
32	Road transport	40.4	3.5
13	Petroleum refining	38.0	3.3
15	Rubber and plastic wares	36.5	3.2
33	Other transport	25.6	2.2
23	Motor vehicle	21.2	1.9
26	Oil fired power generation	17.5	1.5
22	Machinery, electrical machinery and apparatus	17.1	1.5
7	Beverages and cigarettes	16.1	1.4
10	Paper, paper products and cardboard	13.4	1.2
27	Gas/geothermal fired power generation	12.9	1.1
1	Agriculture, forestry and fishing	12.8	1.1
24	Other products	10.4	0.9
3	Crude oil	9.0	0.8
19	Basic iron and steel	7.6	0.7
18	Non metallic mineral products	7.0	0.6
21	Fabricated metal products	5.7	0.5
14	Liquefied of natural gas	5.0	0.4
11	Fertilizer and pesticide	4.7	0.4
20	Non ferrous basic metal	3.8	0.3
2	Coal	3.4	0.3
5	Other mining and quarrying	3.4	0.3
28	Hydro power generation	3.1	0.3
17	Cement	1.9	0.2
30	Water supply	1.1	0.1
16	Clay/ceramics structural products	0.1	0.0
29	Gas supply	0.004	0.0
4	Natural gas and geothermal	0.0	0.0
	Total	1,143.6	100.0

[1)]New sector numbers after the aggregation. See the footnote in Table A1.

The six largest SO_2 producing sectors (i.e., Textile, wearing apparel and leather; Construction; Other services; Oil fired power generation; Manufacture of food; and Road transport) account for over 71% of total SO_2 production in 1990 (Table 2). In 2000, the six largest SO_2 producing sectors would be the same as in 1990 except for Oil fired power generation and Road transport which would be replaced by Coal fired power generation and Chemicals in both scenarios whether or not EE programs were considered. The share of the six largest sectors in total SO_2 reduction from the economy due to EE programs in 2000 under both scenarios would be about 72.7%.

Total SO_2 production (direct and indirect) from electricity generation sectors (i.e., Coal-, oil-, gas/geothermal- based power generation) was 78 million kg (i.e. ,10.6% of total SO_2 production) in 1990. Under the high growth scenario, it would increase to 159 million kg (i.e. 9.9% of total SO_2 production in 2000 without EE programs and to 132 million kg (i.e., 8.3% of total SO_2 production) with EE programs. In the low growth scenario, the total SO_2 production (direct and indirect) from electricity generation sector in 2000 would be 137 million kg (i.e., 11.7% of total SO_2 production) without EE programs and 113 thousand tons with EE programs (i.e., 9.9% of total SO_2 production).

The share of energy intensive sectors (i.e., Coal-, oil-, gas/geothermal- based power generation; Chemicals; Basic iron and steel; Cement; and Textile, wearing apparel and leather) in total SO_2 production was 39.8% in 1990 while the corresponding figures in 2000 under the high growth scenario with and without EE programs are estimated to be 45.4% and 46.3% respectively. In the low growth scenario, the corresponding figures in 2000 are estimated to be 46.5% and 47.5% with and without EE programs, respectively. This clearly shows the growing roles of these sectors in SO_2 emissions in the country.

Table 7 presents the breakdown of total SO_2 production by the Indonesian economy in terms of SO_2 productions associated with DCD, DPD and IPD for fuels. As can be seen, in 1990, IPD for fuels accounted for the highest share (62.9%) in total SO_2 production and was followed by DPD (35.2%) and DCD (1.9%). In 2000, the share of IPD in total SO_2 production would decline to about 60% under both the high growth scenarios (i.e., without and with EE programs), while that of DCD would increase from 1.9% in 1990 to 2.2% in 2000. The share of DPD would increase from 35.2% in 1990 to around 37.6% in 2000 without the EE programs and to 37.1% with these programs under the high growth scenario. In the low growth scenario, the share of DPD would be 37.1% with EE programs and 37.2% without these programs. The share of DCD in total SO_2 production in 2000 in the low growth scenarios would be 2.7% with the EE programs and 2.6% without the programs.

Table 7. SO_2 production associated with various demand categories, in million kg.

Demand Category	SO_2 Production in Year 1990	SO_2 Production in Year 2000 in the High Growth Scenario		SO_2 Production in Year 2000 in the Low Growth Scenario	
		Without EEIP[a]	With EEIP[a]	Without EEIP[a]	With EEIP[a]
Direct Consumption Demand	14.1	35.7	35.7	30.6	30.6
Direct Production Demand	260.9	607.3	588.7	433.6	423.9
Indirect Production Demand	465.4	970.9	964.2	701.4	689.1
Total	740.4	1,613.9	1,588.6	1,165.6	1,143.6

[a] EEIP = energy efficiency improvement programs

6. CONCLUSIONS AND FINAL REMARKS

This paper has estimated the effect of energy efficiency improvements in the residential sector on the total and sectoral emissions of SO_2 from the Indonesian economy in the year 2000 under high and low growth rates by using the framework of input-output analysis. The results show that the SO_2 production from the Indonesian economy in 2000 under the high growth scenario would be 1.614 billion kg without EE programs and 1.589 billion kg with EE programs as compared to 740 million kg in 1990. Thus, about 25 million kg of SO_2 emissions (i.e., approximately 1.6% of total SO_2 emissions) would be avoided through the residential sector EE programs in 2000. In the low growth scenario, the total SO_2 production in 2000 with and without EE programs would be 1.144 billion kg and 1.166 billion kg, respectively. Six sectors, i.e., Textile, wearing apparel and leather; Construction; Manufacture of food; Coal fired power generation; Other services; and Chemicals would contribute to about 72.7% of the total SO_2 mitigation in 2000 under both high and low growth scenarios. The study also shows that more than 60% of the total SO_2 emissions in Indonesia in 1990 and 2000 are found to be associated with the indirect production demand for fuels.

Note that this study has estimated the level of SO_2 emission avoided with the use of efficient electrical appliances in the residential sector only. The level of emissions avoided would obviously be higher if energy efficiency improvements in manufacturing and other sectors were also considered. Further research in this area would be interesting.

7. REFERENCES

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8. APPENDIX

Modification of Existing Indonesian Input-Output Table

The original Indonesian I-O table with 161 sectors [15] was aggregated into 34 sectors for the purpose of the present study. The Electricity and Gas sector was disaggregated into two separate sectors, i.e., Electricity sector and Gas sector. The Electricity sector was then further disaggregated into four sectors, i.e., Coal fired power generation, Oil fired power generation, Gas/ geothermal fired power generation and Hydropower generation.

The non-energy sectors were aggregated as shown in Table A1, where the new names and numbers of the sectors after the aggregation are presented along with the corresponding sector numbers before aggregation, i.e., in the original input-output table of Bira Pusat Statistik [15].

Table A1. Final demand of the 34 sectors of the Indonesian economy.

Sector Name[1]	Corresponding Sectors in the Original I-O Table as in [7]	New Sector No.[2]	Final Demand at 1990 Prices (10^6 US$)				
			1990	2000 with High Growth Scenario		2000 with Low Growth Scenario	
				Without EEIP[3]	With EEIP[3]	Without EEIP[3]	With EEIP[3]
Agriculture, forestry and fishing	1-31,44	1	11,123	15,121	15,121	12,756	12,756
Coal	32	2	144	390	390	277	277
Crude oil	33	3	7,740	19,605	19,605	14,928	14,928
Natural gas and geothermal	34	4	0	0	0	0	0
Other mining and quarrying	35-43	5	799	2,165	2,165	1,540	1,540
Manufacture of food	45-61	6	13,811	37,450	37,450	26,639	26,639
Beverages and cigarettes	62-65	7	3,480	9,435	9,435	6,711	6,711
Textile, wearing apparel and leather	66-73	8	4,928	13,363	13,363	9,505	9,505
Bamboo, wood and rattan products	74-79	9	2,976	8,070	8,070	5,740	5,740
Paper, paper products and cardboard	80-83	10	596	1,615	1,615	1,149	1,149
Fertilizer and pesticide	85-86	11	219	594	594	422	422
Chemicals	84,87-93	12	1,237	3,355	3,355	2,387	2,387
Petroleum refining	94	13	2,090	5,293	5,293	3,765	3,765
Liquefied of natural gas	95	14	3,958	10,025	10,025	7,131	7,131
Rubber and plastic wares	96-99	15	1,512	4,102	4,102	2,918	2,918
Clay/ceramics structural products	102	16	8	23	23	16	16
Cement	103	17	29	80	80	57	57
Non metallic mineral products	100,101,104	18	244	661	661	470	470
Basic iron and steel	105-106	19	171	465	465	331	331
Non ferrous basic metal	107-108	20	474	1,284	1,284	914	914
Fabricated metal products	109-112	21	267	725	725	516	516
Machinery and apparatus	113-120	22	2,005	5,437	5,725	3,867	4,072
Motor vehicle	123-124	23	1,776	4,815	4,815	3,425	3,425
Other products	121,122,125-131	24	693	1,880	1,880	1,337	1,337
Coal fired power generation	132	25	240	1,254	1,041	1,075	892
Oil fired power generation	132	26	352	160	133	137	114
Gas/geothermal fired power generation	132	27	47	987	819	846	702
Hydro power generation	132	28	128	267	222	229	190
Gas supply	132	29	2	3	3	2	2
Water supply	133	30	64	119	119	85	85
Construction	134-138	31	19,697	36,692	36,721	26,100	26,120
Road transport	143	32	3,628	6,759	6,759	4,808	4,808
Other transport	142,144-146	33	2,644	4,924	4,924	3,503	3,503
Other services	139-141,147-161	34	38,735	36,845	36,989	22,836	22,960

[1] It refers to the sector name after the aggregation of the original 161 sectors into 34 sectors.

[2] It refers to the new number of a sector in the 34 sector I-O table derived from the aggregation of the relevant sectors in the original 161 sector I-O table.

[3] EEIP = energy efficiency improvement programs