Building Electricity Consumption as an Indicator of Indirect Carbon Dioxide Emissions

S Ma’ mun¹, Sukirman, A E Alel and M Hasanah

Department of Chemical Engineering, Universitas Islam Indonesia
Jl. Kaliurang Km. 14.5, Yogyakarta 55501, Indonesia
sholeh.mamun@uii.ac.id

Abstract. The global CO₂ emissions have continually increased from year to year and reached 32 Gt in 2010. The increased CO₂ emissions may lead to a higher temperature and cause climate change on a global scale. Building energy-using equipment in Indonesia continuously increases annually leading to increasing indirect CO₂ emissions from the buildings. The objective of this study is to measure the indirect CO₂ emissions from the Faculty of Industrial Technology (FIT), Universitas Islam Indonesia (UII) Yogyakarta, Indonesia. The research data were taken from the electricity consumption by reading the electric meter at specified time intervals for 7 weeks from 26 September to 13 November 2016. The amount of electricity consumption indirectly indicates the amount of CO₂ emission in the FIT where the FIT has consumed the electricity of 18.6 kWh/day corresponding to the average indirect CO₂ emission of 15.9 kg CO₂-eq/day. The results obtained would, therefore, give some recommendations to the FIT to take some policy actions related to the indirect CO₂ emission by improving energy management system to minimize the indirect CO₂ emission in the FIT.

1. Introduction

Greenhouse gases such as carbon dioxide (CO₂) absorb heat emitted from Earth’s surface. Increases in concentrations of these gases in the atmosphere cause Earth to warm by trapping more of this heat. Continued emissions of these gases will cause global warming which in turn cause climate change. Various climate models estimate that the global average temperature may rise by about 1.4 to 5.8 °C by the year 2100 [1, 2]. However, long-term climate change over many decades will depend mainly on the total amount of CO₂ and other greenhouse gases emitted from human activities. The CO₂ emissions tend to rise from year to year. In 2005, CO₂ emissions reached 26.3 Gt and rose to 32 Gt in 2010 [3] where building sector was responsible for 40% of the global energy consumption and one third of the global GHG emissions [4-6]. As the global CO₂ emissions continue to increase, the total CO₂ emissions in Indonesia also increased from 356 Mt in 2004 to 453 Mt in 2014 [7].

A previous study by [8] calculated the total emissions of CO₂ caused by energy consumption in four types of hotels in Taiwan. As the result, CO₂ emissions are produced more by the hotel with highest facilities and services, and the electricity use is the highest and main contributor of the CO₂ emissions in hotel building. Indonesia is one of developing countries that has big populations where the amount of inhabitant increase gradually year by year and most of the people in Indonesia prefer living in urban area. There were significant differences in household energy use between household in urban and nonurban areas, where such differences are, according to [9], driven part by contextual factors such as population density that indirectly affects the energy use. Building energy-using equipment and energy consumption in Indonesia continuously increase annually. This, therefore, increases the indirect CO₂ emissions from the buildings due to using electrical energy generated by the fossil-fuel-based power plants [10]. In 2014, Perusahaan Listrik Negara (PLN), the Indonesian state-owned electricity company, provides national electricity with the total installed capacity of 51.62 GW and
93.2% of which are the fossil-fuel-based power plants such as steam, gas, and diesel power plants. The total CO₂ emissions from these electricity generation activities were 128 Mt of CO₂-eq [11]. This present study aims to measure the indirect CO₂ emissions from Faculty of Industrial Technology (FIT), Universitas Islam Indonesia (UII) Yogyakarta, Indonesia by measuring the electricity use for a period of time. The results could be used for electricity utilization management in the faculty as an effort to decrease a number of CO₂ emissions in the FIT UII Yogyakarta, Indonesia.

2. Methods
The methodology used in this research was by reading the electricity meters as an indicator of energy consumption from the electricity consumed by the FIT at specified time intervals, i.e. every three hours, for 12 hours from 06:00 am to 06.00 pm in seven weeks (49 days). The electricity meters were monitored both during the busy days and also during the weekends or holidays. The amount of electricity consumed indirectly indicates the total amount of CO₂ emission caused by the activities in the FIT UII Yogyakarta.

3. Results and Discussion
The objective of this research is to measure the indirect CO₂ emission from the electricity consumption in FIT buildings in the period of time. The data were taken from three electricity meters for seven weeks (49 days) starting from 26 September 2016 at 09.00 am to 13 November 2016 at 06.00 pm. The 1st electricity meter is used to calculate the electricity consumed for teaching activities including the laboratory works, the 2nd meter is for the sports center, and the 3rd meter is for street lighting. The electricity meters were read every 3 hours from 06:00 am to 06.00 pm and divided into two periods of time to compare the electricity consumption during both normal day and exam term as described in table 1. The total data collected for 49 days were 238 data and those were presented in figure 1.

Table 1. The electricity meter reading activity from 26 September to 13 November 2016.

| Date                   | Reading Interval | Comment                                                                 |
|------------------------|------------------|--------------------------------------------------------------------------|
| 26-09-2016 to 23-10-2016 | 3 hours          | Teaching period: classrooms, laboratories, offices, corridors, sport centers and street lighting |
| 24-10-2016 to 04-11-2016 | 3 hours          | mid-term exam period: classrooms, offices, corridors, sport centers and street lighting |
| 05-11-2016 to 13-11-2016 | 3 hours          | teaching period: classrooms, laboratories, offices, corridors, sport centers and street lighting |

CO₂ emissions may come from power plants from the combustion process of fuels which are used in, such as coal, natural gas, LNG, HSD (High-Speed Diesel), and MFO (Marine Fuel Oil). The CO₂ emission is calculated by the following equation [12]:

\[
\text{CO}_2 \text{ emitted (kg CO}_2\text{)} = (\text{Grid Emission Factor}) \times (\text{kWh})
\]

(1)

Grid emission factor (GEF) is defined as the intensity of CO₂ emissions per electricity energy unit in grid/transmission system (kg CO₂-eq/kWh). With the total amount of national CO₂ emissions of 201 Mt in 2015, it was obtained the national average GEF of 0.867 kg CO₂-eq/kWh. However, the GEF for Java-Bali region is a bit lower than the national GEF, i.e. 0.857 kg CO₂-eq/kWh. Since UII is located
in Yogyakarta, a part of Java Island, thus the CO$_2$ emitted from the fossil-fuel-based power plants for the Java-Bali interconnection can be calculated by using equation (1) with the GEF for the Java-Bali transmission system. By use of equation (1), the amount of CO$_2$ emissions contributed indirectly by the FIT-UII from the electricity use can then be measured. Figure 1 shows the total electricity use measured by the three electricity meters in the FIT. Due to the difference in electricity need for each day, the data seem to be fluctuating. During the meter reading periods, it was found the electrical shut down several times, thereby it caused the electricity use decreased significantly. Moreover, the student’s activities in the evening would also contribute the large amount of kWh. In general, the electricity consumption reached the minimum during weekends because of no teaching and laboratory work activities.

Figure 1. Daily electricity consumptions and corresponding CO$_2$ emissions at the FIT UII Yogyakarta, Indonesia from 26 September to 13 November 2016.

The electricity consumption, as well as the corresponding CO$_2$ emissions during 5 working days and weekends for 7 weeks, are depicted in figure 2. It can be seen that the increase of electricity use in the building would also escalate the CO$_2$ emissions. According to the data, the highest CO$_2$ emissions happened in the working days, i.e. Monday to Friday. The teaching and laboratory activities had already begun in September and finished in the beginning of December 2016. Moreover, some sport competition events were held in the sports center. Those activities have significantly increased the electricity consumption in the FIT. It can also be seen from the figure that the use of electricity during the mid-term exam (weeks 5 and 6) are almost similar to those during the teaching periods. This indicates that the use of electricity in the classrooms for mid-term exam purpose were very significant because there were no laboratory work activities.

The accumulative electricity consumption and corresponding CO$_2$ emissions at the FIT UII Yogyakarta are shown in figure 3. It can be seen that the electricity consumption, as well as the CO$_2$ emissions during the day (06:00 am – 06:00 pm), accounts for about 56.4% where the peak occurred at 09:00 am till 03.00 pm, i.e. 30.9%, while the lowest occurred in the early morning (06:00 pm – 09:00 pm) and in the late afternoon (03:00 pm – 06:00 pm) where the activities begin and finish. The accumulative electricity consumption for 7 weeks from 26 September to 13 November 2016 at the FIT UII Yogyakarta were 912 kWh (18.6 kWh/day) with the indirect CO$_2$ emissions of 781 kg CO$_2$-eq (15.9 kg CO$_2$-eq/day). The current results were a bit lower compared to those reported by [10] where they measured the electricity consumption at the FIT in April 2016 for 30 days with the average daily electricity usage of 20.3 kWh and the indirect CO$_2$ emissions of 17.2 kg CO$_2$-eq/day. To minimize the
energy consumption and CO₂ emissions, the FIT is planning to install a solar panel with a design capacity of 10 kW. Moreover, all old lamps have been replaced by the LED lamps in all rooms at the FIT as well as installing air conditioners (ACs) with low energy consumption. These actions have indeed slightly reduced the electricity consumption and CO₂ emissions in the FIT UII Yogyakarta and thus contribute to achieving the national target to reduce 26% of the CO₂ emissions by 2020 [13].

Figure 2. The electricity consumptions and corresponding CO₂ emissions during working days and weekends at the FIT UII Yogyakarta, Indonesia for 7 weeks from 26 Sept to 13 Nov 2016.

Figure 3. (1): Accumulative electricity use and (2): accumulative CO₂ emissions at the FIT UII Yogyakarta, Indonesia for 7 weeks.

4. Conclusion
The indirect CO₂ emission at the FIT UII Yogyakarta was measured by determining the electricity consumption for 7 weeks from 26 September to 13 November 2016. The results indicated that the average indirect CO₂ emission was 15.9 kg CO₂-eq/day resulted from 18.6 kWh electricity consumed per day. The FIT has taken some actions to improve energy management system to minimize the indirect CO₂ emission in the FIT.
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