Study of Net Zero Carbon Schools in South Jakarta

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Abstract. This study focuses on the analysis of carbon dioxide (CO_2) emissions in two primary schools in Jakarta that implement the concept of net zero carbon, namely SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi. The concept of net zero carbon aims to achieve a balance between the carbon emissions generated and the carbon absorbed or eliminated from the environment. The objective of this study is to evaluate the effectiveness of implementing the net zero carbon concept in these schools and identify the factors that influence CO_2 emissions. Comparative analysis methodology is used in this study by comparing green building criteria, particularly the use of electricity. The data used in this study were collected during April and May 2023. CO_2 emissions are calculated based on the emission factors for electricity set by the Directorate General of Electricity at the Ministry of Energy and Mineral Resources in 2019 for the Jawa-Madura-Bali interconnection system. The research findings indicate higher CO_2 emissions in SDN Grogol Selatan 09 Pagi compared to SDN Ragunan 08 Pagi, which can be attributed to differences in activities and the use of electronic devices. The study reveals that CO_2 emissions in SDN Grogol Selatan 09 Pagi amount to 1917 $kgCO_2/kWh$ (April) and 1444 $kgCO_2/kWh$ (May), while SDN Ragunan 08 Pagi emits 3823 $kgCO_2/kWh$ (April) and 2823 $kgCO_2/kWh$ (May). Factors such as electricity use for lighting, air conditioning, and other electronic equipment contribute to the variation in CO_2 emissions between the two schools. Based on the research results, it is recommended that both schools take measures to improve energy efficiency and reduce CO_2 emissions. Some recommendations include optimizing electricity usage by turning off unused appliances, installing energy-saving lamps, and selecting environmentally friendly electronic equipment. Furthermore, character education and school curricula need to strengthen students' awareness of the importance of environmental conservation and reducing negative impacts on climate change. This study also contributes to the understanding of the implementation of the net zero carbon concept in primary schools. By evaluating CO_2 emissions and identifying influencing factors, schools and governments can take appropriate steps to achieve the goal of net zero carbon. Additionally, this research can serve as a reference for other schools that intend to implement similar concepts to minimize the environmental impact of their daily activities. There are several additional steps that can be taken to enhance energy efficiency and reduce CO_2 emissions in both schools implementing the net zero carbon concept. In conclusion, this study provides insights into CO_2 emissions in primary schools that implement the net zero carbon concept. Through comparative analysis between SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi, the research highlights significant differences in CO_2 emissions resulting from activities and energy usage in these schools. The recommendations and steps outlined are expected to serve as a guide in efforts to improve energy efficiency and reduce CO_2 emissions in net zero carbon schools, while also contributing to global efforts in addressing climate change.

Keywords: CO_2 *, primary school, emissions, green building, net zero carbon.*

1. Introduction

Climate change resulting from increased greenhouse gas (GHG) emissions is a pressing global issue [1]. One sector contributing to GHG emissions is the construction sector, which includes office buildings, residential buildings, and schools. According to data from the International Energy Agency (IEA), the building sector accounted for 39 percent of global GHG emissions in 2018 [2]. Therefore, efforts are needed to reduce the environmental impact of the building sector, including the implementation of the net zero carbon concept.

The net zero carbon concept involves buildings having very low or zero GHG emissions, both during construction and operation [3]. This is achieved by improving energy efficiency and utilizing renewable energy sources. The concept aligns with the UK government's target to achieve net zero carbon by 2050 [4]. Additionally, this concept provides other benefits such as improving the health and comfort of building occupants, saving operational costs, and increasing property value. One type of building that has the potential to implement the net zero carbon concept is schools. Schools are government-owned buildings with high activity levels and play an important role in shaping environmental awareness and the behavior of the younger generation [5]. Therefore, net zero carbon schools can serve as examples and inspiration for the wider community to participate in climate change mitigation efforts.

In Indonesia, the net zero carbon concept has started to be implemented in several schools in Jakarta [6]. In 2022, the Jakarta Provincial Government inaugurated four public schools that have been rehabilitated into net zero carbon buildings, namely SDN 14 Duren Sawit, SDN Grogol Selatan 09, SDN Ragunan 08 Pagi, and SDN 09 Pagi and 11 Sore, as well as SDN Jakarta 96 SMA Negeri. These schools have environmentally friendly designs and facilities, such as green roofs, solar panels, energy-efficient lighting and cooling systems, rainwater and waste treatment systems, and environmental education facilities. Jakarta is the first province in Indonesia to have net zero carbon schools. This study aims to analyze carbon dioxide (CO_2) emissions in two primary schools in Jakarta that implement the net zero carbon concept, namely SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi.

2. Methodology

This study utilizes a comparative analysis method based on green building criteria, particularly focusing on electricity usage. Data collection was conducted during the months of April and May 2023, and calculations were performed using the latest emission factor values or the emission factor values established by the Directorate General of Electricity of the Ministry of Energy and Mineral Resources (KESDM) in the most recent year, which was 0.870 $kgCO_2/kWh$ in 2019. To calculate the concentration of carbon dioxide (CO_2) emissions in the air at SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi, data on the secondary electricity usage by the schools are required. The CO_2 concentration is calculated using the formula equation (1), taking into account the total electricity consumption multiplied by the emission factor.

$$E = \Sigma Ai \times FE \tag{1}$$

Where:
E = Emission load
FE = Emission factor ($kgCO_2/kWh$)
Ai = Total electricity energy consumption

3. Results and Discussion

3.1 Green Building

Green Building or environmentally friendly buildings, are expected to reduce greenhouse gas emissions, one of which is carbon dioxide (CO_2). The aspects or criteria of green building applied to both net-zero carbon schools, SDN Ragunan 08 and SDN Grogol Selatan 09, are expected to reduce the level of CO_2 emissions in the air around the schools, as schools should have good and healthy air quality for the students. **Figure 1** shows the green buildings implemented in SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi.

SDN Grogol Selatan 09 Pagi SDN Ragunan 08 Pagi

Figure 1. Green Building

SDN Grogol Selatan 09 Pagi SDN Ragunan 08 Pagi

Figure 2. Ventilation and Windows in Net Zero Carbon School Spaces

Figure 2 shows the two net-zero carbon schools, SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi, which have green building concepts implemented in their school buildings. These buildings feature ample air ventilation and sufficient room windows. The ventilation and room windows are an implementation of the green building criteria based on the aspects of Energy Efficiency and Conservation, as well as Air Quality and Room Comfort, applied to these two net-zero carbon schools in South Jakarta. The abundance of ventilation and room windows facilitates the entry of sunlight and air into the rooms, thus helping to save energy by reducing the need for artificial lighting and room cooling. Additionally, both SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi also provide solar panels that can be used as an energy source by absorbing sunlight and converting it into electricity. These solar panels automatically activate every day and help conserve the electricity consumption of both net-zero carbon schools.

SDN Ragunan 08 Pagi SDN Grogol Selatan 09 Pagi

Figure 3. Solar Panel

Figure 3 shows the solar panels installed in the two net-zero carbon schools in South Jakarta. SDN Grogol Selatan 09 Pagi has 40 solar panels with a total energy capacity of 21,600 watts, while SDN Ragunan 08 Pagi has 20 solar panels with a total energy capacity of 10,800 watts.

3.2 Calculation of Carbon Dioxide (CO_2)

Emission Concentration The estimation of electricity consumption for indoor lighting, air conditioning (AC), ceiling fans, computers, and printers is only based on school activities, specifically on weekdays (Monday to Friday) during school hours. Therefore, the monthly electricity consumption is multiplied by 20 days.

The usage of indoor lighting in SDN Grogol Selatan 09 Pagi is based on an average daily usage of 1 hour in the morning, except for certain rooms such as the bathroom (24-hour usage) and the school principal's office, teachers' room, and administrative office (6-hour daily usage). The AC usage in the school principal's office, teachers' room, and administrative office is also based on an average daily usage of 6 hours, while other areas such as the library, science laboratory, computer lab, prayer room (mushola), and UKS are only turned on when needed, with an average daily usage of 1 hour. The ceiling fans in the 18 classrooms of SDN Grogol Selatan 09 Pagi are used for an average of 6 hours during class sessions, and the computers and printers in the administrative office are used for an average of 6 hours per day, while in the ANBK room, they are used for 1 hour per day.

On the other hand, the usage of indoor lighting in SDN Ragunan 08 Pagi is based on an average daily usage of 1 hour when natural sunlight is insufficient through the ventilation or room windows in the morning, and the bathroom lights that are on for 24 hours. The AC usage in the school principal's office, vice principal's office, teachers' room, administrative office, library, health unit (UKS), guidance and counseling room (BK), and reception room is based on an average daily usage of 6 hours on school days, except for the science laboratory and computer lab, which are only turned on during class sessions for 1 hour. The ceiling fans are used for an average of 6 hours per day, while computers and printers are used for an average of 1 hour per day, only when needed.

Table 1 shows the calculation of electricity consumption for outdoor lighting in both schools, which is on every day for the entire month with an average daily usage of 12 hours, only during the night. Therefore, the electricity consumption for outdoor lighting can be multiplied by 30 days of usage in a month. **Table 1** provides a comparison of estimated CO_2 concentration in the air surrounding and SDNGrogol Selatan 09 Pagi and SDN Ragunan 08 Pagi.

Table 1. CO_2 Emissions Estimate

Electronic Devices	**SDN Grogol Selatan 09 Pagi**			**SDN Ragunan 08 Pagi**		
	Quantity	**Electrical Energy Consumption (kWh/Month)**	**CO_2 Emissions (kgCO$_2$/kWh**	**Quantity**	**Electrical Energy Consumption (kWh/Month)**	**CO_2 Emissions (kgCO$_2$/kWh**
Lamp	224	215	187	217	202	176
AC	17	385	335	21	748	651
Fan	42	232	202	54	1508	1312
Computer Printer	8	22	19	7	25	22
TOTAL		**854**	**743**		**2483**	**2160**

Based on the calculations, **Table 1** shows the estimation of CO_2 emissions generated from a portion of the electrical energy used for electronic devices such as lamps, air conditioners, fans, computers, and printers in SDN Grogol Selatan 09, with a CO_2 concentration of 743 kg CO_2/kWh and SDN Ragunan 08, with a CO_2 concentration of 2160 kg CO_2/kWh. The estimated CO_2 emissions value in SDN Grogol Selatan 09 Pagi is smaller compared to SDN Ragunan 08, mainly due to the smaller school area of approximately 1,905 m², whereas SDN Ragunan 08 Pagi has an area of approximately 5,660 m².

This difference in size leads to lower requirements and usage of electronic devices. Meanwhile, the calculation of CO_2 emissions based on the monthly electricity consumption of all electronic devices used in SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi during April and May 2023 can be seen in **Table 2.**

Table 2. Monthly CO_2 Emissions from Electricity Usage

Month	SDN Grogol Selatan 09 Pagi		SDN Ragunan 08 Pagi	
	Monthly Energy Consumption (kWh)	CO_2 Emissions ($kgCO_2/kWh$)	Monthly Energy Consumption (kWh)	CO_2 Emissions ($kgCO_2/kWh$)
April	2204	1917	4359	3823
May	1660	1444	2823	2456

As seen in **Table 2**, the electricity consumption and CO_2 emissions in April are higher compared to May. This could be attributed to the fact that in April 2023, there was a holiday period for the celebration of Eid al-Fitr, which took place from April 17th to April 26th, resulting in the staff and school guards not controlling or turning off the outdoor lights during the holiday. The CO_2 emissions in SDN Grogol Selatan 09 Pagi have lower concentrations, specifically 1917$kgCO_2/kWh$ in April and 1444$kgCO_2/kWh$ in May 2023. Compared to SDN Ragunan 08 Pagi, which has concentrations of 3823 $kgCO_2/kWh$ in April and 2456 $kgCO_2/kWh$ in May 2023. This difference is due to the smaller size of SDN Grogol Selatan 09 Pagi, resulting in less energy usage and fewer electronic devices, thus leading to lower calculated CO_2 emissions. **Figure 4** shows a graph comparing the CO_2 emissions between the two net-zero carbon schools in South Jakarta, namely SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi.

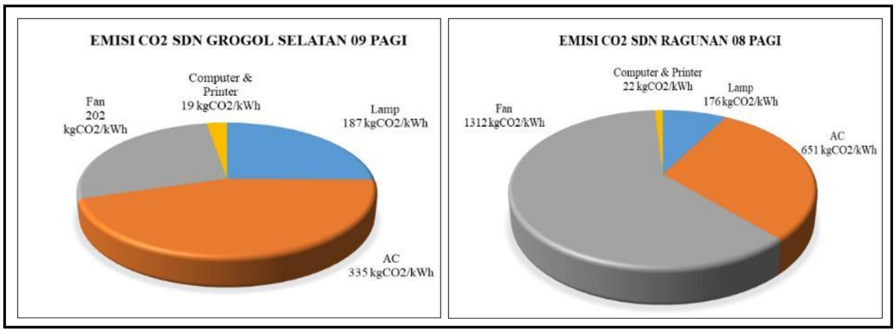

Figure 4. Comparison Graph of CO_2 Emissions

3.3. Issues and Challenges:

The implementation of the net zero carbon concept in schools is one of the efforts to reduce greenhouse gas emissions and contribute to climate change mitigation. However, this concept also faces various technical, economic, social, and political issues and challenges. Some of the identified problems and challenges are as follows:

a. Availability and affordability of renewable energy sources that can reliably and efficiently meet the energy needs of schools [7]. This is related to infrastructure, costs, regulations, and market readiness for renewable energy sources.

b. The need to improve energy efficiency and reduce energy consumption in schools through behavior change, management, and maintenance [8]. This requires education, participation, and motivation from all stakeholders in schools, including students, teachers, staff, parents, and the surrounding community.

c. Limited budget and resources to build, renovate, or operate zero-carbon schools [9]. This requires support and incentives from the government, private sector, and donors to finance the initial investment and operation of zero-carbon schools.

d. Uncertainty and instability of policies related to targets, standards, and mechanisms for net zero carbon [2]. This impacts the level of trust and commitment of building sector actors to implement the net zero carbon concept.

3.4 Impacts and Consequences:

CO_2 emissions from electricity use in schools have significant impacts and consequences on the environment and climate. Some of the identified impacts and consequences are as follows:

a. CO_2 is a major greenhouse gas that causes global warming and climate change. CO_2 emissions from the building sector, including schools, accounted for 39 percent of global greenhouse gas emissions in 2018 [10]. Climate change can result in various negative impacts, such as increased air temperatures, reduced rainfall, increased frequency and intensity of natural disasters, decreased agricultural productivity, spread of diseases, and ecosystem damage.

b. CO_2 emissions from electricity use in schools also impact local air quality. CO_2 can react with other compounds in the air, such as nitrogen oxides (NOx) and sulfur dioxide (SO_2), which originate from the combustion of fossil fuels, forming surface ozone (O_3) and fine particles ($PM_{2.5}$). Surface ozone and $PM_{2.5}$ can cause respiratory disturbances, eye irritation, headaches, heart diseases, and lung cancer [11].

c. CO_2 emissions from electricity use in schools contribute to the dependence on fossil fuels, particularly coal, which remains the primary source of electricity in Indonesia. Dependence on fossil fuels can lead to various consequences, such as price fluctuations, supply instability, social conflicts, and environmental damage from coal mining and combustion.

4. Conclusion and Recommendations

Based on the research conducted in two primary schools in Jakarta implementing the net zero carbon concept, namely SDN Grogol Selatan 09 Pagi and SDN Ragunan 08 Pagi, it can be concluded that the difference in activities and electronic device usage affects the level of carbon dioxide (CO_2) emissions in both schools. SDN Ragunan 08 Pagi has higher CO_2 emissions compared to SDN Grogol Selatan 09 Pagi. Based on the research findings, several recommendations can be provided to enhance energy efficiency and reduce CO_2 emissions in net zero carbon schools:

1. Energy Audit: Conduct a detailed energy audit in both schools to identify areas where energy wastage or inefficient energy use occurs. By identifying these areas, specific improvement measures can be taken to optimize energy use.
2. Awareness Enhancement: Increase awareness among students, teachers, and school staff about the importance of CO_2 emissions reduction and sustainability. This can be done through education, campaigns, and activities that promote sustainable practices in daily school life.
3. Energy Efficiency Improvement: Implement more efficient technologies and practices in energy use at school, such as using energy-efficient electrical equipment, optimizing temperature and lighting settings, and adopting smart energy management systems.
4. Renewable Energy: Harness renewable energy sources, such as solar panels or wind power, to meet the school's energy needs. Installing renewable energy systems in schools can reduce dependence on conventional energy sources that contribute to CO_2 emissions.
5. Monitoring and Reporting: Implement an effective monitoring and reporting system to regularly track and measure CO_2 emissions in the school. This data can be used to identify trends, evaluate the effectiveness of mitigation measures, and identify further improvement opportunities.
6. Collaboration and Networking: Build collaborations with other educational institutions, government entities, and relevant organizations to share knowledge, experiences, and resources in developing net zero carbon schools. Such networks can provide support, guidance, and inspiration for other schools interested in implementing similar concepts.

By implementing these recommendations, net zero carbon schools can optimize energy use, reduce CO_2 emissions, and become inspirational examples for the wider community in addressing climate change and maintaining environmental sustainability.

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References:

[1] M. Shen, W. Huang, M. Chen, B. Song, G. Zeng, and Y. Zhang, "Microplastic Crisis: Unignorable Contributions to Global Greenhouse Gas Emissions and Climate Change," J. Clean. Prod., vol. 254, pp. 120138, 2020, doi: 10.1016/j.jclepro.2020.120138.

[2] KA Ali, MI Ahmad, and Y. Yusup, "Issues, Impacts, and Mitigation of Carbon Dioxide Emissions in the Building Sector," Sustain., vol. 12, no. 18, 2020, doi: 10.3390/SU12187427.

[3] U. Iyer-Raniga, "Zero Energy in the Built Environment: A Holistic Understanding," Appl. Sci., vol. 9, no. 16, 2019, doi: 10.3390/app9163375.

[4] C. Action, N. Zero, and C. Buildings, "From Thousands," pp. 1–52.

[5] R. Djuwita and A. Benyamin, "Teaching Pro-Environmental Behavior: A Challenge in Indonesian Schools," Psychol. Res. Urban Soc., vol. 2, no. 1, p. 26, 2019, doi: 10.7454/proust.v2i1.48.

[6] Oswar Mungkasa, "Realizing Low Carbon Cities: Contributions to the Development of Indonesian Urban and the Archipelago Capital," no. April, 2022.

[7] M. Gaeta, C. N. Businge, and A. Gelmini, "Achieving Net Zero Emissions in Italy by 2050: Challenges and Opportunities," Energies, vol. 15, no. 1, 2022, doi: 10.3390/en15010046.

[8] A. J. Nathanael, K. Kannaiyan, A. K. Kunhiraman, S. Ramakrishna, and V. Kumaravel, "Global Opportunities and Challenges on Net-Zero CO_2 Emissions towards a Sustainable Future," React. Chem. Eng., vol. 6, no. 12, pp. 2226–2247, 2021, doi: 10.1039/d1re00233c.

[9] L. Wang, X. Yan, M. Fang, H. Song, and J. Hu, "A Systematic Design Framework for Zero Carbon Campuses: Investigating the Shanghai Jiao Tong University Fahua Campus Case," Sustain., vol. 15, no. 10, 2023, doi: 10.3390/su15107975.

[10] EB Agyekum, MNS Ansah, and KB Afornu, "Nuclear Energy for Sustainable Development: SWOT Analysis on Ghana's Nuclear Agenda," Energy Reports, vol. 6, July 2015, pp. 107–115, 2020, doi: 10.1016/j.egyr.2019.11.163.

[11] IL Bart, "Urban Sprawl and Climate Change: Statistical Exploration of Causes and Effects, with Policy Options for the EU," Land Use Policy, vol. 27, no. 2, pp. 283–292, 2010, doi: 10.1016/j.landusepol.2009.03.003.