# CARBON DIOXIDE (CO2) EMISSIONS BASED ON ENERGY SECTOR DURING COVID-19 PANDEMIC IN INDONESIA

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**Abstract**

Due to the Covid-19 pandemic, all countries globally, including Indonesia, have implemented work from home (WFH) policy to slow down the cases. The WFH policy in Indonesia, which has been implemented since March 2020, brings great effects such as economic downfall, social insecurity, and limited mobility of people. The energy sector including fuel and electricity systems have been significantly affected by the Covid-19 pandemic with changes not only in the total levels of consumption but also the usage patterns. The limitation of people's mobility makes an impact on the $CO_2$ emissions in Indonesia. It is also involved with Indonesia's commitment to reduce carbon emissions in 2030. This study endeavors to analyze the $CO_2$ emissions based on the energy sector such as fuel, electricity, and liquified petroleum gas (LPG) consumption during Covid-19 pandemic. In this study, the $CO_2$ emissions were calculated using a formula based on the amount of fuel, electricity, and LPG consumption by society in October – November 2020. The results show that the $CO_2$ emissions of fuel consumption during WFH slightly decrease by 33%. On the other hand, there was little increase by 20% of the $CO_2$ emissions from electricity and LPG consumption in household sector. It indicates that the $CO_2$ emissions affected by the Covid-19 pandemic, and it involved with Indonesia's NDC with carbon emissions reduction target of 29% in 2030. The Covid-19 pandemic could be as a momentum for Indonesia to rebuild an inclusive, resilient and sustainable strategies. Implementation of green policies such as enhancing public transportation, vehicle usage efficiency, energy-saving electrical appliances, improve planting of trees are highly recommended to reduce the $CO_2$ emissions in Indonesia.

Keywords: $CO_2$ Emissions · Covid-19 Pandemic · Energy Sector · Work from Home

## Introduction

### Background

Global warming and climate change are problems facing humanity around the world. As a densely populated country spread across tropical island chains, Indonesia is considered very vulnerable to the impacts of climate change. $CO_2$ emissions into major anthropogenic greenhouse gases (GHGs) account for 76% of total anthropogenic GHG emissions caused mostly by fossil fuels and industrial processes (IPCC, 2015). In Indonesia, in the energy sector there was an increase in GHG emissions by 2.43% (2000-2015), this increase in emissions occurred due to an increase in energy consumption growth with an average of 2.35% per year (Ministry of Energy and Mineral Resources Indonesia, 2016). The transportation sector has a significant percentage after electricity and heat, which has contributed 7,7 million metric tons of $CO_2$ in producing fuel around 2015- 2016 worldwide (Akinyemi and Ramonu, 2019). Based on National Energy Report (2015), national oil consumption for transportation has always increased from 58 million tons of $CO_2$ in 2000 to 73 million tons in 2007. In 2000 the need for fuel for power generation increased from 124 million SBM to 231 million SBM in 2011, or an average increase per year of 6.5% (Ministry of Energy and Mineral Resources, 2013). It has been a severe challenge to Indonesia with its emerging markets and economics to meet carbon emission targets. Indonesia's national government has ratified Paris Agreement 2015 and committed to reducing greenhouse gas (GHG) emissions by 29% and 41% in business as the usual condition in 2030 and pledged in the Nationally Determined Contribution (NDC) (Apriandi et al., 2017). The contributions in efforts to reduce GHG emissions from forestry (17,2%), energy (11%), agriculture (0,32%), industry (0,10%), and waste (0,38%). Emissions from the energy sector are estimated to make up 58% of Indonesia's emissions in 2030, up from 34%, according to the country's NDC document.

The novel coronavirus has created a disaster at the beginning of 2020. Its impacts are not only in terms of human health but also in planetary health. Aspiring to slow down the spread of the highly contagious Covid-19 virus, governments around the world decided to impose several temporary restrictions such as contact restrictions and distance rules, temporary closure of trade and service companies, and travel restrictions within a country. Since February 2020, concern for the development of actions against Covid-19 has continued to grow in many countries. A research study by Loske (2020) has found that in Germany, freight volume for dry products has been increased in retail logistics depend on strength quantified through the total number of new infections per day. Besides, in the United Kingdom, the Covid-19 pandemic has a significant impact on all aspects, including public and private sector operators, and it requires a fundamental approach to long-term policy for transportation (Vickerman, 2021). In Indonesia, the pandemic has changed the social and economic structure of the people. The policy of work from home (WFH), which has been implemented since March 2020, brings economic downfall, social insecurity, limited of people mobility and unemployment. As many workers are practicing WFH, it is expected that there are changes in terms of $CO_2$ emissions. A report from the Pertamina oil company (2020), noted that in April 2020, the demand for oil for transportation falls 34,6 % compared to a similar variable in February-March 2020. The same fate goes to the demand for oil for industrial purposes, reduced to about 3.18 % in the same period. In contrast, citing katadata.co.id, electricity consumption in July 2020 is the highest since the beginning of the Covid-19 pandemic. The increase was 10% from 58.82 TWh to 64.74 TWh. Like electricity consumption, LPG consumption also increases during WFH. Citing CNBC Indonesia, since the

implementation of WFH policy on March 16, 2020, LPG consumption in the household sector has increased. Subsidies LPG increased by 0.7% from the normal daily consumption of 21.93 thousand metric tons to 22.10 thousand metric tons. Meanwhile, Non- Subsidies LPG increased by 5.4% from the normal daily consumption of 2.05 thousand metric tons to 2.16 metric tons.

Based on study of the Jung et al (2016), found that the outbreaks of a disease can have significant multi-dimensional effects such as economic and environmental consequences. The link between the effects of the pandemic and the economy may vary; the severe rate of infection of Covid-19 has placed 30% of the global population in lockdown, with a country-specific stay-at-home orders (Norouzi et.al, 2020). The impact of Covid-19 mitigation policies on people's movement has also been significant globally, including in Indonesia. In the short term, the energy and electricity systems have been affected by Covid-19 pandemic with changes in consumption and production. In the context of Indonesia, there is still a limited study that explores the amount of $CO_2$ emissions during the Covid-19 pandemic. With this background, this paper seeks to contribute to the understanding of the amount of $CO_2$ emissions in Indonesia based on the energy sector, such as fuel, electricity, and liquified petroleum gas (LPG) consumption during the Covid-19 pandemic. Additionally, this paper's novelty is to analyze the relationship between $CO_2$ emissions during Covid-19 pandemic with the NDC Indonesia carbon emissions reduction target in 2030. Overall, this paper contributes to supporting research about $CO_2$ emissions from the energy sector during Covid-19 pandemic.

## Methodology

The research was conducted in June 2020 – December 2020. Data collection was carried out in October – November 2020 through a questionnaire using the google form that shared to the public by social media. The criteria for the respondents chosen were people who applied work from home, using private transportation, electricity and LPG household during the Covid-19 pandemic. This research used an exploratory and descriptive approach. It explored the oil, electricity, and LPG consumption by Indonesian households during work from home.

### Data Collection Techniques

The following describes the data collection techniques:

The Data of Carbon Emissions

We collected primary and secondary data on carbon emissions. The primary data were collected by surveying respondents through online surveys. The survey was designed in early October and asked respondents to provide information on their activity before the Covid-19 outbreak and during WFH policy, including their ability and instances of working from home. The number of respondents involved in this research is approximately 300 people from different cities in Indonesia. We carefully choose the respondents from those who were practicing WFH. Respondents were then asked such as frequency of weekly travel activity, intensity of private vehicle usage, the total and the cost of oil consumption by different modes of transport (motorcycle and private car) before and during WFH. The number of respondents for vehicle usage was 230 people which was majority from Central Java and DKI Jakarta. The respondent's domicile from Java was higher than the total respondents from out of Java such as Sumatra, Kalimantan, Sulawesi, and Eastern Indonesia. The motorcycle usage was about 65%, the private car

usage was about 24%, and both usages was 11% from the total of respondents. Based on oil consumption surveys, the percentage of female respondent was about 56% and male was about 44%. In addition, the number of respondents for household use of electricity and LPG was 76 people. Respondents came from various regions in Indonesia, including 42 people from Sumatra (covering Aceh, Palembang, Bengkulu, Jambi and Riau), 30 people from Java (covering Jakarta, Tangerang, Bogor, Bekasi, Bandung, Semarang, Yogyakarta, Surabaya), 1 people from West Nusa Tenggara (NTB), and 2 people from South Sulawesi. Some of the components of the questions collected from respondents were self-identification, electricity and LPG consumption (including electrical equipment used, the amount and duration of use) and the amount of electricity tariffs before and during WFH, the use of energy-efficient electrical equipment and energy-saving behavior. It should be noted that the majority of questions in the survey were based on the behavior, condition, and attitudes of the individual respondents.

**Data Analysis**

**a. Analysis of $CO_2$ Emissions Based on Fuel Consumption**

In the sectoral approach, the calculation of emissions is based on activities such as energy production, manufacturing, transportation, households, and others. The calculated emission sources include emissions from fuel combustion in each sector and fugitive emissions. The sectoral approach is useful for mitigation policy. The fuel consumption data will be converted to emission factors. In this study, the $CO_2$ emissions were calculated using a formula based on the amount of fuel consumption by each type of vehicle. We used the IPCC Calculation on emission factor to calculate $CO_2$ emissions. Based on this concept, the emission factor of oil's type could be estimated, as in table.

1. The formula of $CO_2$ emissions:

$$\mathbf{CO_2\ Emissions} = k=0nAi \times EF$$

Notes:

Ai: Energy consumption (liter)

EF: Emission Factors (Ton/Gj)

Source: (IPCC, 2006)

*Table* 1. Emission Factors Greenhouse Gases of Several Types of Fuel Products

| Types of Fuel Products | | Emission Factors | | |
|---|---|---|---|---|
| | | $CO_2$ | $CH_4$ | $N_2O$ |
| | | Ton/GJ | g/GJ | g/GJ |
| Fuel | Premium | 0,069 | 5,00 | 0,60 |
| | Bio Premium | 0,062 | 4,75 | 0,57 |
| | Pertamax | 0,069 | 5,00 | 0,60 |
| | Bio Pertamax | 0,062 | 4,75 | 0,57 |
| | Pertamax Plus | 0,069 | 5,00 | 0,60 |
| | Bio Solar | 0,062 | 4,75 | 0,57 |
| | Kerosene | 0,072 | 5,00 | 0,60 |
| | Solar Oil (ADO) | 0,074 | 5,00 | 0,60 |
| | Diesel Oil (IDO) | 0,074 | 5,00 | 0,60 |
| | Combustion Oil (FO) | 0,077 | 5,00 | 0,60 |

**b. Analysis of $CO_2$ Emissions Based on Electricity Consumption**

The $CO_2$ emissions in this study were from household activities classified into two, primary and secondary. The primary is $CO_2$ emissions come from household gas (LPG), while the secondary is $CO_2$ emissions from electricity consumption. The calculation of $CO_2$ emissions was carried out using the following IPCC method:

a. Primary $CO_2$ Emissions

   **$CO_2$ Emissions = EF x Fcy x NCV**

b. Secondary $CO_2$ Emissions

   **$CO_2$ Emissions = EF x Electricity Consumption (KWh)**

c. Total of $CO_2$ Emissions

   **Total of $CO_2$ Emissions = Primary $CO_2$ Emissions + Secondary $CO_2$ Emissions**

Notes:

Fcy: Fuel Consumption (Kg/month)

EF: Emission Factors (Mass/MJ)

NCV: Net Calorific Volume (*energy content*)

Source: (IPCC, 2006)

## Result And Discussion

### 1. The $CO_2$ Emissions Based on Energy Sector During Covid-19 Pandemic

Indonesia's condition with a very dense population affects various sectors, including the increase in the number of vehicles, the demand for energy consumption such as electricity and gas generated from various activities, and others. Household activities have a significant contribution to increase $CO_2$ emissions, as data compiled by the Ministry of Environment and Forestry Indonesia (2012) shows that the energy sector, especially households, is the largest contributor to greenhouse gases. Energy consumption contributes 75% to $CO_2$ emissions. The $CO_2$ emissions affected by many aspects such as number of vehicles, atmosphere, and climate dynamics. Indonesia has enacted emergency response procedures and required people to stay at home instead of going out beginning in March 2020. As a consequence of social distancing, people will travel less, limit motor vehicle usage, and impact fuel consumption. The decline in transportation demand consequently translates to a reduction in energy and fuel demand. Some researchers have been funding the impacts of the Covid-19 outbreaks; a simulation study by Ruiz Estrada et al., (2020) predicts significant drops in tourism and transportation in China due to extensive quarantines. A research study by Arellana et al., (2020) found that in Colombia, at the national and local levels have decreased for vehicles use, giving benefits to the environment. Since mobility had been curtailed due to Covid-19, global oil demand was severely hit, decreasing nearly 15% in the first quarter of 2020. The existence of a social restriction policy by working at home (WFH) in handling the coronavirus disease outbreak is also likely to affect carbon emissions. It is related to the closure of several industries, decreased motorized vehicle use, and decreased fuel consumption. Pertamina oil company (2020), noted that in Indonesia the demand for fuel in big cities such as

Jakarta fell by 59%, Bandung 57%, and Makassar 53%. In contrast, electricity consumption continued to increase during the Covid-19 pandemic.

Mobility and transportation are essential services in every city (Hickman and Banister, 2014). All services are interconnected and are heavily populated, inspires the city to develop various transportation solutions. The impacts of the Covid-19 pandemic on transportation have been evident throughout the world, including Indonesia. According to the result of the questionnaire, in figure 3, explains that 79% of people believe that the implementation of WFH policy has an impact on the reduction of oil consumption by 26% - 50%. The decline of fuel consumption during WFH is close to the low frequency of people leaving the house and mobility using vehicles in a week. Based on this study's results, the fuel consumption of motorcycles has been declined by 35% during WFH. Similar to cars, the fuel consumption of cars has been decreased by 33%. Private car usage in cities fell as more people have been urged to work from home, and WFH has become the new normal for a much larger proportion of workers in the future. In many cases, these are justified based on controlling congestion, pollution and using the proceeds to promote alternative public transport choices. Although road usage did not fall by as much as public transport used during the initial lockdown in the pandemic, reducing pollution in cities during this period was significant.

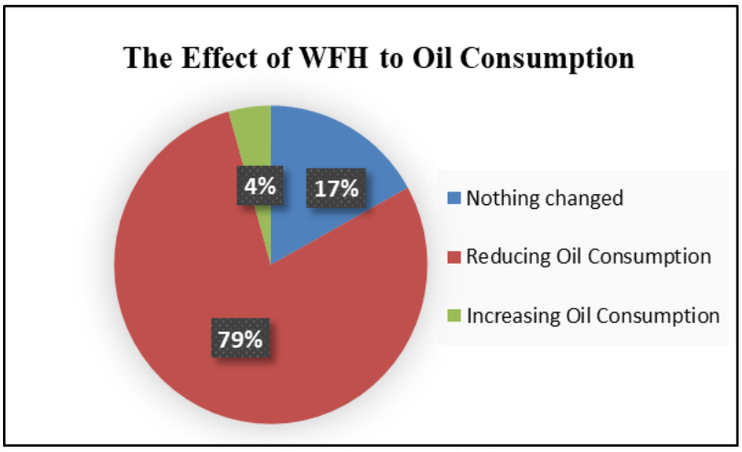


Figure 3. The Effect of WFH on Oil Consumption

According to Muziansyah et.al (2015), the type of vehicle affects the engine capacity, which is the vehicle with large engine sizes consumes much fuel and resulting in large emissions into the atmosphere. The type of fuel has the same emissions, but because the engines that operate the vehicles vary, this can make the number of emissions produced by each vehicle different. Each type of fuel from the vehicle has a different emission factor, and it makes a different number of $CO_2$ emissions (Grelier, 2018). The $CO_2$ emitted by the motorcycles given in Table 2 is lower than the cars before and during WFH. As shown in Table 2, the total number of $CO_2$ emissions of motorcycles and cars before WFH lower than during WFH. During WFH, the total $CO_2$ emissions have changed into 19.120,57 tons/GJ/month or 229.446,8 tons/GJ/year. $CO_2$ emissions decreased between before and during WFH by 9.696,03 tons/GJ/month or 116.352,4 tons/GJ/year or in a percentage decrease of 33%. The declining amount of $CO_2$ emissions during WFH is due to the rapid decrease of fuel consumption during WFH. This is due to significant on human activities outside the home, so people must work from home during the WFH period. The benefits of that reduction include improved air quality and visibility in the cities. However, as Covid-19 restrictions ease, the vehicles will return dominantly and could cause congestion at levels not seen before the outbreak should sensible measures not be introduced.

Table 2. $CO_2$ Emissions Each Type of Fuel Before and During WFH

| Condition | Type of Vehicle | Type of Fuel | Fuel Consumption (Ton/GJ/Month) | $CO_2$ Emissions (Ton/GJ/Month) | $CO_2$ Emissions (Ton/GJ/Year) |
|---|---|---|---|---|---|
| **Before WFH** | **Motorcycle** | Premium | 829,66 | 686,95 | 8.243,50 |
| | | Pertalite | 911,66 | 6.104,48 | 73.253,70 |
| | | Pertamax | 823,23 | 3.674,90 | 44.098,78 |
| | **Total of $CO_2$ Emissions of Motorcycle** | | | 10.466,324 | 125.595,982 |
| | **Car** | Premium | 0 | 0 | 0 |
| | | Solar | 5273,84 | 2.341,59 | 28.099,02 |
| | | Pertalite | 3858,91 | 11.244,86 | 134.938,40 |
| | | Pertamax | 4519,75 | 4.763,82 | 57.165,80 |
| | **Total of $CO_2$ Emissions of Car** | | | 18.350,262 | 220.203,22 |
| **Total of $CO_2$ Emissions Motorcycle and Car** | | | | **28.816,60** | **345.799,20** |
| **During WFH** | **Motorcycle** | Premium | 626,68 | 518,891 | 6.226,69 |
| | | Pertalite | 562,75 | 3.768,17 | 45.218,09 |
| | | Pertamax | 553,11 | 2.469,08 | 29.629 |
| | **Total of $CO_2$ Emissions of Motorcycle** | | | 6.756,148 | 81.073,782 |
| | **Car** | Premium | 0 | 0 | 0 |
| | | Solar | 3215,76 | 1.427,80 | 17.133,57 |
| | | Pertalite | 2669,08 | 7.777,70 | 93.332,39 |
| | | Pertamax | 2997,08 | 3.158,92 | 37.907,07 |
| | **Total of $CO_2$ Emissions of Car** | | | 12.364,418 | 148.373,03 |
| **Total of $CO_2$ Emissions Motorcycle and Car** | | | | **19.120,57** | **229.446,80** |

As shown in Table 3, each region of Indonesia has different $CO_2$ emissions before and during WFH. The result shows that Java is the highest region of decreasing $CO_2$ emissions before and during WFH, significantly decreasing by 36%. Followed by Kalimantan decline by 32% and Sulawesi decrease by 28%. The lowest region of declining $CO_2$ emissions was in Sumatera fall by 22%, and Maluku Nusa Tenggara Papua decrease by 21%. The changes in $CO_2$ emissions in each region due to the changes in the amount of fuel consumption. As a result, the fuel consumption in Java Island has the most significant changes than other regions. Besides Indonesia, other countries like Brazil also have been impacted by Covid-19, which is the density of road traffic, and economic activity has reduced during lockdown (Dantas et.al, 2020). According to Rayash and Dincer (2020), the global mobility trend showed that declined rapidly since March 2020 in several world cities such as Tokyo, Amsterdam, London, New York, and Istanbul. Hence, the $CO_2$ emissions has been decreased significantly due to the decline of mobility. Governments should provide subsidies to maintain the system supply to avoid crowdedness and promote active transport by allocating less-used street space to cyclists and pedestrians. The report from Oxford Analytica, carbon emissions will diminish because of prolonged disruptions to economic activity. The longer this crisis persists, the more profound the short-term carbon impact will be in life.

Table 3. The $CO_2$ Emissions Each Region of Indonesia

| Region | Type of vehicle | Type of Fuel | $CO_2$ Emissions Before WFH (Ton/GJ/Year) | $CO_2$ Emissions During WFH (Ton/GJ/Year) |
|---|---|---|---|---|
| **Sumatera** | **Motorcycle** | Premium | 532,53 | 266,26 |
| | | Pertalite | 3.584 | 2.026,47 |
| | | Pertamax | 837,38 | 358,87 |
| | **Car** | Pertalite | 18.539,7 | 15.550,2 |
| | **Total** | | **23.493** | **18.201** |
| **Java** | **Motorcycle** | Premium | 2.396,38 | 1.331,32 |
| | | Pertalite | 51.506,3 | 31.538,3 |
| | | Pertamax | 36.218,1 | 23.174 |
| | **Car** | Solar | 32.382,4 | 17.133,6 |
| | | Pertalite | 86.711,1 | 58.616,9 |
| | | Pertamax | 61.965,2 | 40.306,69 |
| | **Total** | | **271.179** | **172.100** |
| **Kalimantan** | **Motorcycle** | Premium | 665,66 | 665,66 |
| | | Pertalite | 8.254,21 | 5.263,56 |
| | | Pertamax | 4.304,15 | 3.106,69 |
| | **Car** | Pertalite | 13.637,4 | 9.091,6 |
| | **Total** | | **26.861** | **18.127** |
| **Sulawesi** | **Motorcycle** | Premium | 2.236,63 | 2.236,63 |
| | | Pertalite | 1.794,39 | 1.196,26 |
| | | Pertamax | 478,50 | 478,50 |
| | **Car** | Pertalite | 3.349,54 | 1.674,77 |
| | **Total** | | **7.859** | **5.586** |
| **Maluku, Nusa Tenggara, and Papua** | **Motorcycle** | Premium | 2.396,38 | 1.717,41 |
| | | Pertalite | 6.934,73 | 5.263,56 |
| | | Pertamax | 1.650,84 | 1.794,39 |
| | **Car** | Pertalite | 4.545,8 | 3.349,54 |
| | **Total** | | **15.527** | **12.124** |

WFH policy that began to be implemented by the Government of Indonesia since the first positive case of Covid-19 was confirmed in Indonesia made changes in various sectors, not least in the energy sector. When the community is required to do activities at home, resulting in community mobility outside the home becomes remarkably decreased, causing fuel consumption to decrease. Meanwhile, household electricity and LPG consumption increased during the implementation of the WFH policy. This is because activities at home encourage people to cook more often and use other electronic equipment that is usually used when outdoors. In addition, studies on energy consumption patterns also reveal that electricity and LPG are the main energies used in the household sector. While the main factors that affect total energy consumption in the household sector are the cost of energy consumed and the number of family members contained in a household (G & N, 2019).

Government policies in an effort to stop the spread of positive cases of Covid-19 have changed the pattern of energy demand around the world. Many international borders are closed, there are restrictions on people's mobility, causing a decrease in the amount of transportation and changing energy consumption patterns (Quéré et al., 2020). The survey results on respondents in this study showed that 81% of the 76 respondents stated

that there are differences and increases in electricity and LPG consumption's household during the implementation of WFH, as shown in figure 4.

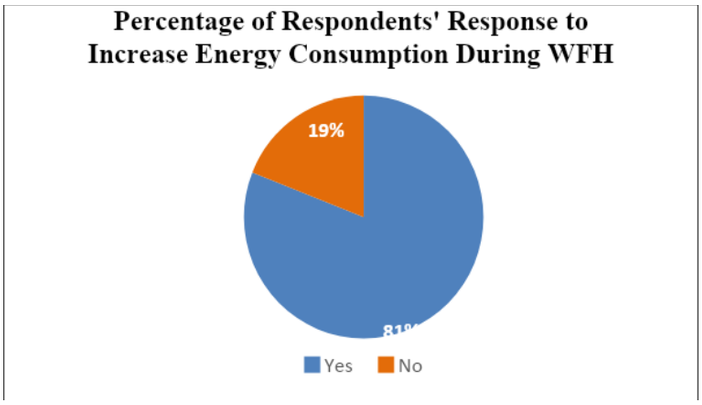


Figure 4. Percentage of respondents' response to increasing energy consumption during WFH

Based on the results of calculations obtained from a sample of respondents per region showed that there is a difference between electricity and LPG consumption's household at the time before the implementation of WFH policy and at the time of implementation of WFH policy. It will also affect the total emissions produced by each individual/month. Tables 4 and 5 show the emissions average against differences in electricity consumption and household LPG before the implementation of WFH policy and at the time of implementation of WFH policy divided into four regions. Besides that, not only in Indonesia, electricity use during the Covid-19 pandemic in European countries has also increased during the lockdown policy, impacting population activities that have changed electricity consumption. For countries that enforce lockdown policies strictly, electricity consumption is increased much from the time before the Covid-19 pandemic. It indicates that the lockdown policy changes the consumption profiles on the one hand. On the other hand, these profile changes can also reflect the effects of different approaches to dealing with the pandemic on people's activities (Bahmanyar et al., 2020). In Lagos, Nigeria there was also a significant increase in electricity consumption by 49% during the period of total lockdown in the household sector (Edomah & Ndulue, 2020).

Table 4. Average $CO_2$ Emissions from Household Electricity Consumption

| No | Regions | Average $CO_2$ Emissions | |
|---|---|---|---|
| | | Before WFH | During WFH |
| 1 | Sumatera | 6,1188816 tons $CO_2$/ individual/month | 6,5681268 tons $CO_2$/ individual/month |
| 2 | Jawa | 2,1659526 tons $CO_2$/ individual/month | 2,5870902 tons $CO_2$/ individual/month |
| 3 | NTB | 2,5573152 tons $CO_2$/ individual/month | 3,3043104 tons $CO_2$/ individual/month |
| 4 | Sulawesi | 1,8608184 tons $CO_2$/ individual/month | 3,5815752 tons $CO_2$/ individual/month |

Table 5. Average $CO_2$ Emissions from Household LPG Consumption

| No | Regions | Average $CO_2$ Emissions | |
|---|---|---|---|
| | | **Before WFH** | **During WFH** |
| 1 | Sumatera | 0,00924291 tons $CO_2$/ individual/month | 0,00962803 tons $CO_2$/ individual/month |
| 2 | Jawa | 0,00847267 tons $CO_2$/ individual/month | 0,00693218 tons $CO_2$/ individual/month |
| 3 | NTB | 0,00616194 tons $CO_2$/ individual/month | 0,00693218 tons $CO_2$/ individual/month |
| 4 | Sulawesi | 0,00924291 tons $CO_2$/ individual/month | 0,010783 tons $CO_2$/ individual/month |

**The $CO_2$ Emissions During Covid-19 Pandemic Related to The Indonesia Carbon Emissions Reduction Target in 2030**

The increase in population and income will increase energy utilization. Thus, resulting in $CO_2$ emissions from energy utilization also increased which also has an impact on the increase of environmental problems. The problem of climate change is a reality faced by the whole world, including Indonesia. The resulting impact is a domino effect that lasts across territorial boundaries and time. Indonesia's participation in the Paris agreement encourages Indonesia to be involved in efforts to reduce emissions through NDC's of 29% (Business as Usual) and 41% (International assistance) in 2030. NDC is a commitment containing the contribution of each member country to reduce GHG emissions. It requires a separate effort for Indonesia, considering Indonesia is one of the countries with the world's most extensive carbon absorption. However, on the other hand, deforestation and land-use change are still happening massively (Aisya, 2019).

The changes brought by the Covid-19 outbreak are widespread and unparalleled (Dewi et al, 2020). The impact of Covid-19 is an interdisciplinary discussed topic in social sciences. This evidence suggests that the government's request to 'stay at home' has been heeded. The coronavirus outbreak led to the emptying of streets and public spaces, whether by partial lockdown or by personal responses. According to this study, the Covid-19 pandemic in Indonesia has been impacted by changes in $CO_2$ emissions in the energy sector (fuel, electricity, and LPG consumption). For instance, the demand for fuel in Indonesia has decreased during WFH due to limited vehicle mobility. It impacts on the changes of $CO_2$ emissions from fuel consumption has been decreased by 33% during WFH.

The outbreak of the Covid-19 in various countries carried out regional quarantine policies to prevent the spread of infection. It has resulted in lower energy consumption and reduced emissions in the first quarter of 2020 (International Energy Agency, 2020). But on the other hand, due to a policy that requires people to do activities at home to break the chain of transmission of Covid-19, this leads to an increase in the amount of electricity and LPG consumption in the household sector. It shows that the changes in $CO_2$ emissions based on fuel consumption during pandemic contributes a little to the decreasing of $CO_2$ emission target on NDC Indonesia. In contrast, the changes in $CO_2$ emissions from electricity and LPG consumption encourage the increase of $CO_2$ emissions. According to this research, the changes of $CO_2$ emissions based on the energy sector during the Covid-19 pandemic did not have a massive effect related to the emission

reduction target and still far away from the target on NDC Indonesia in 2030. The lockdown policy leads to a substantial reduction of transport and economic activities, resulting in an 8% reduction in GHG emission compared to 2019. However, $CO_2$ emissions from transport are expecting to rise again with the increasing economic activities. The world globally has to reduce emissions by almost the same amount as during the pandemic. However, on figure 5, it can be shown that transport emissions reduction of China, Japan, and India compared to the largest global $CO_2$ emitters is only between 1% and 2% against last year in the same period (Dalkmann, 2020).

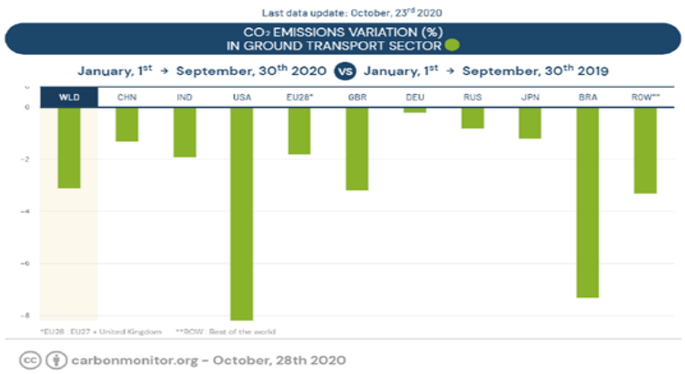


Figure 5. $CO_2$ Emissions Variation in Ground Transport Sector in Some Countries (Sources: Dalkmann, 2020)

The Covid-19 pandemic could be as a momentum for Indonesia to rebuild sustainable strategies and maintain the environment's quality. However, post-Covid-19 will increase energy consumption and impact $CO_2$ emissions. Thus, the right effort and strategies are needed in arranged environmental policies. There are some policy recommendations to maintain $CO_2$ emissions from fuel consumption in the post-Covid-19 period. The first is the transformation of transportation, which priority for humanity and the environment. This policy, called humanitarian transportation, includes some aspects such as healthy, clean, comfortable, and justify. The green economy's implementation is needed, which includes low carbon, resource-efficient, and socially inclusive. Also, in the household sector, several policy recommendations can be applied by the community, including the utilization of Rooftop Solar Power Plants (PLTS), the efficiency of the use of electrical energy and LPG, using energy-saving electrical appliances and greening the household sector by increasing the planting of trees and ornamental plants that can help absorb $CO_2$.

In an attempt to contribute to the global endeavor of limiting the increase in global temperatures by the middle of the century to 2°C, Indonesia has pledged to reach development using a low-carbon approach 2020 – 2045 (Ministry of National Development Planning Indonesia, 2019). Indonesia has various energy sector mitigation options that could achieve reduction emission targets, such as energy efficiency usage, renewable energy, clean energy, electric vehicle, public transportation, vehicle usage efficiency and the use of nuclear power. These options can be considered part of low carbon energy system energy. In a country with limited wealth, mitigation actions' economic impact is an essential factor in selecting and eventually implementing these options. Several studies have discussed future options for energy systems in Indonesia, and they concluded that low carbon technologies bring multiple benefits, such as the reduction in the primary energy supply and reductions in $CO_2$ and air pollutants. While some studies have addressed Indonesia's future energy scenarios, there have been no attempts to assess its NDC. Energy consumption has grown with population and

economic growth. Indonesia is endowed with a wide range of energy resources include oil, gas, and coal have been intensively exploited to meet domestic and export demands. The prices of renewable energy cannot compete with subsidized fossil fuel energy.

The increase of $CO_2$ emissions can be reduced by utilizing environment-friendly energy sources and technology such as using low carbon energy sources and increasing energy technology efficiency. Transport is crucial for sustainable development, including poverty reduction, economic diversification, and human well-being, and its central role in modern economies and societies has been brought to the fore due to the Covid-19 pandemic. Short-term reductions in greenhouse gas emissions and other pollutants are also evident, but prior experience shows that these are rapidly reversed when the situation returns to normal unless structural changes take place. The transformation can lead to such changes in transport. Existing challenges, such as GHG emissions, urban pollution, and lack of access in rural areas, which have been brought to the fore by the pandemic, should be addressed in a sustainable manner and in line with the "avoid, shift, and improve" approach. The Covid-19 pandemic should be taken as a chance to accelerate a transition to sustainable transport systems and solutions in support of the implementation of the 2030 Agenda and the Paris Agreement on climate change.

## Conclusion

The Covid-19 pandemic affects the amount of $CO_2$ emissions based on fuel, electricity, and LPG consumption during WFH policy. The $CO_2$ emissions based on energy sector during the Covid-19 pandemic shown an opposite result between fuel consumption with electricity and LPG consumption. The $CO_2$ emissions from fuel consumption during WFH have been declined about 33%. On the other hand, the $CO_2$ emissions increased by 20% based on electricity and LPG consumption during WFH. Implementation of some green strategies such as enhancing public transportation, vehicle usage efficiency, energy-saving electrical appliances, improve planting of trees are needed to pursue Indonesia's carbon emission reduction target in 2030.

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