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Impact of lifestyle changes on home energy consumption during pandemic COVID-19 in Indonesia

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ABSTRACT

This study aims to grasp the lifestyle changes in residential buildings related to energy consumption since the emergence of Covid-19 in Indonesia. Data collection through online questionnaires was conducted from more than 1,000 households domiciled in the five largest islands of Indonesia (Sumatra, Java, Kalimantan, Sulawesi, and Papua). Firstly, this article summarizes the results of questionnaire, including the household’s basic information and the lifestyle changes. It is found that more than 89% of families have implemented Work from Home (WFH) affecting other lifestyle changes during the pandemic. Secondly, the Multiple Regression Analysis (MRA) was conducted to find influential factors on electricity use in residential housing. It was found that the number of family members, the use of air conditioning, and the use of kitchen appliances significantly contributed to the increase in electricity during stay homes period. Thirdly, the characteristics and lifestyle attributes are classified, the largest increase occurred in household groups with middle to upper average electricity consumption before the pandemic. Finally, the discussion results are expected to encourage industry and policymakers to implement energy monitors, especially regarding electricity use in residential homes. In addition, periodic surveys of post-occupancy evaluations (POE) in households need to be implemented to obtain detailed data in monitoring people’s lifestyle and energy use behavior. This study can also be used as a report on energy performance in the residential sector to increase awareness of energy savings and encourage the government to develop renewable energy distribution. Especially to avoid an energy crisis due to disasters that force residents to stay at home during a pandemic.

1. Introduction

While researchers and engineers are racing to develop sustainable technology, the Covid-19 pandemic has garnered attention to avoiding the transmission of this new virus since its emergence in China (Novianto et al., 2021; Wu & McGoogan, 2020). The first positive case in Indonesia was found in early March 2020 (Rebecca Ratcliffe, 2020; Susilo et al., 2020). The infection spread quickly, infecting several people due to transmission from overseas travelers (Dyer, 2021). As a response, the Indonesian government adopted the Implementation of Community Activities Restrictions Enforcement (CARE), which was given several levels according to the area scale, forcing the community to work from home as much as possible except for the essential sectors (Permatasari, 2021). Since then, it has been predicted that people’s lifestyles will change drastically due to more stay hours at home. Therefore, increasing electricity consumption is also unavoidable in terms of energy demand.

Energy Consumption (EC) in this article refers to end-use energy used directly by users from electricity, gas, or other energy sources for all needs in the room, such as setting room temperature, lighting, and using other electronic devices. (Lund, 2014; Clarke et al., 2017). In this study, EC is used as a parameter to measure buildings or cities’ performance. The use of gas in Indonesian households is generally for cooking needs, which are dominated by gas cylinders of various sizes with the...
government’s intervention of subsidies, making EC from gas difficult to discuss in this article. Therefore, this study focuses more on Electricity Use (EU).

Even before the pandemic, households were one of the sectors with the largest energy demand in Indonesia, with a distribution of 16%, followed by the transportation sector (40%) and industry (36%) (Ramadani, 2020). Consideringly, in a country with the fourth largest population in the world with a significant increase in population every year, it is predicted that the household sector will continue increasing electricity demand. Power outages that often occur in several areas in Indonesia force some parties to use their generators to maintain the electrical energy supply for households, offices, and industries (Kusuma et al., 2021; Simanjuntak & Louhenapessy, 2021). It is found that the length of the period of doing activities in the homes and the quality of indoor thermal are the main factors that affect electricity consumption (Gao & Novianto, 2018; Tran et al., 2021a). In addition, environmental factors around the house also influence occupants’ satisfaction and preference (Hu & Yoshino, 2012; Novianto et al., 2016).

On the other hand, the standard of living in Indonesia has not undergone many changes in terms of space design and layout for a long time. As a reference, Fig. 1 is a healthy home standard issued by The Ministry of Public Works and Housing in 2012 (Fig. 1a) (Badan, 2011) and 2016 (Fig. 1b) (Kementerian, 2016). However, sanitary still seems like a dirty place that needs to be placed at the back of the house, so to clean ourselves from outside activities, we have to go through the living room and dining room area first.

Therefore, this study is trying to grasp the actual conditions during the implementation of WFH and what things will affect changes in the household energy consumption structure. Factors that affect changes in energy consumption before the pandemic and the situation after the pandemic are analyzed. Therefore, this paper aims at the relationship between the EU and the lifestyle of residents to understand the factors that influence changes in the energy structure of Indonesian housing, as well as provide a correlation analysis model on the situation towards energy conservation strategies. In the end, it is hoped that planners, architects, and policymakers will be able to play an important role in residential house design and standards so that the energy crisis that could worsen the situation can be avoided.

2. Methodology

The theoretical framework of this study can be shown in Fig. 2 following. This study aims to investigate Home Electricity Use (HEU) and its response to CARE due to the Covid-19 pandemic in Indonesia. Data mining through social media was carried out in the early stages to formulate matters of concern for users during the CARE period. An online questionnaire was designed to target young families in Indonesia from identified keywords. The feedback results are divided into several areas based on the geographic location and local urban climate. Data on lifestyle changes are then correlated with changes in HEU during WFH. From this exploratory analysis, the influential factors on HEU and household classification based on energy-related behavior can be determined.

2.1. Data mining

Due to the different policies of each region, collecting data that represents each area became a concern so that they are representative of the actual situation in the community. For that reason, the data mining method is carried out to formulate questions and hypotheses about the things that have a high probability of influencing citizen lifestyle changes (Munawir et al., 2019). Crawling data through social media accounts (Twitter) using the RapidMiner Tool, which detects things related to the pandemic in Indonesia descriptively. The keywords used are WFH, the impact of Covid-19, and PSBB (the first version of CARE in Indonesian). The data collected is based on keywords searched through

![Fig. 1. Healthy Home Standard Model.](image-url)

(a) Simple Healthy Instant Home Floor Plan (Remodeling from Kementerian PU Badan) (b) Basic Healthy Home Floor Plan (Remodelling from Kementerian Penelitian dan Pengembangan Pusat Penelitian dan Pengembangan Permukiman, 2011)
the analysis process of text from Tweets.

Refers to Fig. 3, the corpus data for the keyword "WFH" found 25,396 words, 4,001 unique words, 0.158 vocabulary density, 23,151 readability index, and 60.2 average words per sentence. As a result, the linkage of each word based on keywords can be drawn a phrase (The phrases tool shows repeating sequences of words organized by frequency of repetition or number of words in each repeated phrase). Therefore, it is found that the impact of covid for workers is salaries cut, an increase in electricity expenditure and the internet expenditure due to the implementation of WFH. Meanwhile, the corpus of the "Covid-19 impacts" tweet document with 1,048 tweets contained 25,345 words and 3,960 unique words, 0.156 vocabulary density, 23,548 readability index, and 61.5 average words per sentence. Meanwhile, the corpus in the tweeted document with the keyword "PSBB" contains 7,444 words, 2,495 unique words, 0.335 vocabulary density, 23,369 readability index, 30.9 average words per sentence.

The sampling is done through three levels to get more representative data from questionnaires. The questionnaire targets all 34 provinces in Indonesia spread across the archipelago at the first level. At the second level, the survey targeted respondents who live in urban areas or city capitals so that the data is expected to represent the conditions of policy implementation. At the third level, filtering is carried out on feedback data that is not filled in completely. Finally, a total of 525 feedback that represents households is obtained.

2.2. Investigation method

The survey through questionnaires was conducted online to a total of 1,196 households, targeted especially the productive age group from all across the Indonesian archipelago. Geographically, the archipelagic of Indonesia stretches along the equator with a tropical climate with an average air temperature of 23 degrees to 28 degrees Celsius, with a fairly high humidity every year between 65% to 90%. Table 1 shows the characteristics of each island area based on the Köppen-Geiger climate
classification (Rubel & Kott, 2010) and the amount of feedback obtained in this study. In this research, the Indonesian archipelago is divided into five areas based on the presence of the larger islands. First, ST refers to all provinces within Sumatra Island and the surrounding islands. Likewise with Java (JW), Kalimantan (KM), Sulawesi (SW) and Papua (PP).

Table 1 also describes the number of feedback response rates. The survey was conducted online with the target family (head of household/housewife) from all over Indonesia. With household’s population of 73,066,900, a margin error of 5% and a confidence level of 95% are used in this study. With an estimated response rate of 35%, it requires feedback from about 1,100 households. Although the response rate is low in some areas, results such as stay become more representative for a very short survey period.

### Table 1
Island Characteristic Information.

| Area & label | Climate characteristic | Population (person)/ no. of household | Area (km²)/ density (person/ km²) | Total feedback (response rate) | Valid feedback |
|-------------|------------------------|--------------------------------------|----------------------------------|-------------------------------|----------------|
| Sumatera and surrounding islands (ST) | Af – wet equatorial climate Am – tropical monsoon and trade-wind littoral climate (few areas in northern & southern) | 59,196,800/ 14,713,647 | 473,481/ 125 | 245 (0.0017) | 112 |
| Java, Bali, Timor and surrounding islands (JW) | Af – wet equatorial climate (few areas in western) | 166,803,900/ 47,759,670 | 138,794/ 1,202 | 725 (0.0015) | 322 |
| Kalimantan and surrounding islands (KM) | Af – wet equatorial climate Am – tropical monsoon and trade-wind littoral climate (few areas in southern) | 16,432,900/ 4,517,118 | 539,237/ 30 | 86 (0.0019) | 42 |
| Sulawesi, Halmahera, and surrounding islands (SW) | Af – wet equatorial climate Am – tropical monsoon and trade-wind littoral climate (few areas in southern) | 19,751,300/ 5,383,486 | 249,100/ 79 | 98 (0.0018) | 28 |
| Papua and surrounding islands (PP) | Af – wet equatorial climate Am – tropical monsoon and trade-wind littoral climate (few areas in southern) | 7,418,500/ 632,979 | 415,100/ 18 | 42 (0.0066) | 21 |
| Total | | 269,603,400/ 73,066,900 | 1,815,712/ 148 | 1196 | 525 |

### Table 2
Questionnaire Contents.

| No | Categories | Contents | Number of questions |
|----|------------|----------|-------------------|
| 1  | Basic Information | Age, gender, domicile, family structure, household composition, household income, occupation, etc. | 8 |
| 2  | Building Information | Building type, orientation, floor area, floor number, construction year, building status, period of stay, etc. | 8 |
| 3  | Living Environment Condition | Living environment evaluation, thermal comfort level, temperature, humidity, ventilation, noise, disturbance, environmental preference, air conditioning system, etc. | 16 |
| 4  | Lifestyle | Period use of room/space, the use of space (before-during) WFH, period use of electronic equipment, etc. | 10 |
| 5  | About WFH | Period of WFH, work style before WFH, reason of WFH, change during WFH, renovation during WFH, opinion on policy during WFH, etc. | 66 |
| 6  | Energy use | Electricity use, gas use, water use, energy equipment, etc. | 8 |

2.3. Questionnaire contents

Regarding the contents of the questionnaire, it is described in Table 2. This survey is divided into six categories which are predicted to have a significant influence on energy demand in residential homes (Novianto, Gao, et al., 2015; Novianto, Kano, et al., 2015; Zheng et al., 2016), including Basic Information; Building Information; Living Environment Condition; Lifestyle; About WFH; and Energy Use Information, with total 116 questions.

The limitation during the data mining and online questionnaires is that due to the pandemic situation, all participating respondents are those who are quite familiar with the use of internet-connected devices. Therefore, the questionnaire is difficult to reflect conditions in areas with lower internet access.

3. Result of questionnaire

The location and percentage of feedback from the survey questionnaire are presented in Fig. 4. It can be seen that in East Java Province of Java Island, which is the home base of the research team, has the largest feedback, followed by DKI Jakarta Province. In addition, West Kalimantan Province of Kalimantan Island and South Sulawesi Province of Sulawesi Island also contributed the highest feedback. The survey was conducted for two weeks, from the mid of December 2021 to the end of December 2021.

The feedback with no answers for the whole related questions are deleted in the process of data filtering. The questionnaire contains detailed information based on the characteristics of buildings, occupants’ lifestyles, and ownership of home appliances/electronic devices from total of all 34 provinces in Indonesia. The size of the interval is determined based on the population size, standard deviation, and 95% confidence level. After the filtering process, 525 valid feedbacks were obtained and summarized in Table 3.

The result showed that the largest percentage of householders (head of family) were from the group age of 31 to 35 years (38.1%) classified as a young family and productive age groups familiar with the internet. By the results on family size, the feedback is dominated by four family members (25.5%) which is dominated by the composition of father-mother-two children (24.2%), followed by two family members (23%) which is dominated by couples (11.1%). In addition, results such as stay year period, employment status, and total family income are also
In terms of building type, the results show that the composition of detached houses is still dominant in most urban areas in Indonesia, with about 86.5% of feedback. As for the building construction year, most of the buildings are aged between 10 to 20 years (35.1%). In addition, concerning the building direction related to the opening, the result shows that mainly dominated by the east and south directions, which are 25.1% and 24.8%, respectively. It seems that the people are quite aware of the need for morning sunlight and response to avoid the heat of the hot equatorial climate where the sun gets throughout the year. Concerning house size, there is a fairly large gap related to the house floor area. Although the percentage of house floor area is dominated by groups with a total floor area of more than 90 sqm, a fairly large percentage also occurs among those with an area between 21-30 sqm. Refers to the result of house type before, most of the houses are landed houses which tend to have a varied land and floor area compared to the types of multi-dwelling such as apartments or flats.

On the other hand, the working pattern in the household is also presented in Table 3. About 74.9% are households with both parents working. Related to the working situation before the pandemic, about 72.9% of the feedback stated that they had to leave home to work before the pandemic. The situation changed significantly when the virus outbreak occurred, more than 90% of household were forced to WFH. Regarding the WFH period, about 50.2% of households have carried out WFH in the last two years, since the first lockdown was announced by the local government in April 2020 (H. Saputra & Salma, 2020).

The questionnaire also included questions related to the changing level of activities compared with the situation before WFH. From the results in Fig. 5, it was found that 87.1% of the respondents admitted that the use of the internet at home had increased. In addition, home activities such as cooking (73.6%), cleaning the house (56.6%), sunbathing (43.8%), and using AC (46%) were also felt by most of the respondents had increased. In contrast, 93.2% of respondents felt that the outdoor activities had decreased, followed by 61% of respondents who found it difficult to concentrate working during WFH, and 45.8% of respondents’ productivity had decreased, affected the difficulties to manage working hours, about 47.6% of respondents.

Regarding household consumption expenses, Fig. 6 shows changes in the level of consumption during the WFH period qualitatively. The largest percentage of respondents felt the increase in the need for raw food. Since the outdoor activities were limited, forcing households to have enough food stock during the stay home period, about 29.3% (10-50% increase from before WFH), 18.9% (50-100% increase from before WFH), and 8.6% (an increase of more than 100%). While Fig. 7 shows the changes in the level of use of home electronic appliances. Increased kitchen activities affected the use period of the cooking stove between 1-3 hours per day to more than 12 hours per day. In addition, along with the implementation of WFH, the use of computers also tends to increase with the largest number of feedbacks, followed by electronic devices related to thermal comforts such as air conditioners and electric fans.

4. Influential factors analysis

In order to find the contribution of each factor influencing the changes in household electricity consumption, the Multiple Regression Analysis (MRA) method used IBM SPSS 26. MRA models examine the correlation of two or more independent variables with the dependent variable (Kutner et al., 2004; Xie et al., 2011). Referring to Eq.1, changes in various types of lifestyles are independent variables that affect electricity consumption as the dependent variable. Due to the differences in regulations applied in each region, this study assumes that each major islands of Indonesia have a close relationship. Therefore, the MRA is carried out based on the groups of the islands of Java, Sumatra, Kalimantan, Sulawesi, and Papua.

\[ Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_n X_{in} + \varepsilon_i \]  

(1)

where,

- \( Y_i \) = dependent variable for the i-th observation, for \( i = 1, \ldots, n \).
- \( X_{i1}, X_{i2}, \ldots, X_{in} \) = independent variable
- \( \beta_0, \beta_1, \ldots, \beta_n \) = regression coefficients
- \( \varepsilon_i \) = the errors for the i-th observation.

With \( \varepsilon \) as the dependent variable for WFH.

In Table 4, the empirical equation from MRA results of each dependent variable based on the distribution of the areas is described. The formula in the equation column shows predictions of lifestyle factors, building conditions, and the living environment that affected the HEU before and during the pandemic.

As a result, the validation models in Fig. 8 show the comparison between the survey results (x-axis) and the prediction results by MRA (y-axis). The MRA was conducted with the Stepwise method, which allows...
the models containing significant predictors values to be obtained (Whittingham et al., 2006). A higher $R^2$ (maximum value 1.00) indicates the empirical regression equation has a high predictive ability. Each $R^2$ in each graph shows the difference between before the pandemic and the situation when the pandemic occurred.

Based on Table 4 and Fig. 8 (a), in the case of Java Island and its surrounding (JW), before the pandemic, the influential factors in residential electricity consumption: 1) the number of AC ownership; 2) manufacture year of AC; 3) use period of electric fan; 4) water consumption; 5) household income; 6) noise disturbance level. However, during the WFH period, the factors that contribute to the monthly electricity consumption are: 1) the number of AC ownership; 2) use period of electric fan; 3) manufacture year of AC; 4) internet use; 5) household income; 6) gas consumption; 7) outdoor activities; 8) family size. The number of AC units, the use of the electric fan, and household income were found not to change the position of the influential factors in home electricity consumption. On the other hand, internet use become one of the significant factors affecting home electricity. It may not be classified as having a direct impact on consuming electricity since the devices are non-high consuming appliances. However, it can indicate that during pandemics, the use of the internet from home by various devices such as smartphones, computers, and TV are highly increased. In the year 2020, total internet penetration has grown by 9.2%, linear with social media users that increased by 9.8% (Ramadhan, 2020). In addition, gas consumption also has increased during WFH. This is also confirmed that the use of kitchen equipment becomes intense during WFH, especially for cooking activities. While outdoor activities and family numbers also become significant factors in changing home electricity consumption. The decreased outdoor activities affected the whole family member to stay at home more than before the pandemic. This phenomenon also happened in countries that implemented WFH, more than 80% of people reduced their outdoor activities, especially for elders (de Haas et al., 2020)(Rovira-Vizcaíno et al., 2021)

| Table 3 | Results on Household Characteristic. |
|---------|-------------------------------------|
| No.     | Category                             | Unit     | Result summary |
| 1.      | Household basic information          |          |               |
|         | Participant age                      | years old|                |
|         | %                                    | Less than| 21-25         |
|         | %                                    | 20      | 26-30         |
|         |                                      | 31-35   | 36-40         |
|         |                                      | 41-45   | 46-50         |
|         |                                      | 51-60   | More than 60  |
| 2.      | Family size                          | person  |                |
|         | %                                    | 1       | 2             |
|         | %                                    | 3       | 4             |
|         |                                      | Parents | Parents +1child|
|         |                                      | Parents +2child|
| 3.      | Period of stay                       | years   |                |
|         | %                                    | Less than 1| 1–3         |
|         |                                      | 4–6    | 7–10          |
|         |                                      | 11–15 | 16–20         |
|         |                                      | 21–30 | More than 30  |
| 4.      | Status of employment                 | -       | Edu           |
|         |                                      | Gov    | Stu           |
|         |                                      | Emp    | Pri           |
|         |                                      | Med    | Agr           |
|         |                                      | Other  |
| 5.      | Household total income               | -       | Under Min.    |
|         |                                      | Std. Min. Wages | 8          |
|         |                                      | Above Std. Min. Wages | 31.7    |
|         |                                      | 7.5    | 16             |
|         |                                      |        | 2               |
|         |                                      |        | 3.2          |
|         |                                      |        | 4.9            |
| Building characteristic               | -       | Multi-dwelling | Detached house  |
|         |                                      | 13.5   | 86.5          |
| 2.      | Building construction year           | -       | ~1980         | 1980–1990 |
|         |                                      |        | 1990–2000     | 2000–2010 |
|         |                                      |        | 2010–         | Uncertain |
| 3.      | Opening direction                    | -       | West          | South   |
|         |                                      |        | East           | North   |
|         |                                      |        | Other          |
| 4.      | Floor size                          | sqm    | 21–30         | 31–40   |
|         |                                      |        | 41–50         | 51–60   |
|         |                                      |        | 61–70         | 71–80   |
|         |                                      |        | 81–90         | More than 90 |
| Work style and about WFH             | -       | Yes           | No          |
| 2.      | WFH even before Covid-19             | -       | Yes           | No      |
|         |                                      |        | Sometimes     | WFH     |
| 3.      | WFH since Covid-19                   | -       | Yes           | No      |
| 4.      | WFH period                          | Month  | Less than 12  | 12–18  |
|         |                                      |        | 19–24         | 25–30   |
|         |                                      |        | More than 30  |

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consumption becomes the second influential factor indicating the increase of cooking activities during the stay home period. The use of AC also became less influential in this case. A previous study found that in terms of cost and energy use, using room AC for continuous hours will increase efficiency (Karali et al., 2020; Tran et al., 2021b). This result also confirmed in Fig. 7 that there is a high percentage of households stated the increased use of AC between 1-3 hours to more than 10 hours daily compared to before WFH.

On the other hand, Fig. 8 (c) shows the case of Kalimantan Island and its surrounding (KM), 1) daily stay period; 2) humidity comfort level; 3) AC temperature setting; 4) cooking period; 5) insect disturbance; and 6) cooking stove use, are factors that contributed to the increase of electricity consumption respectively before the pandemic. While during the pandemic, the composition of influential factors become: 1) clean water consumption; 2) daily stay period; 3) humidity comfort level; 4) AC cleaning period; 5) cooking stove use; 6) noise level; 7) shop online, 8) oven use, 9) sunbath, and 10) indoor airflow quality, since the pandemic. Unlike the two cases before, clean water consumption levels

![Fig. 5. Change on the Home Activity.](image)

![Fig. 6. Change on Consumption Expense.](image)
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and indoor airflow quality, are indicated to be directly correlated with urban water pipe infrastructure. Housing are driven by water pumps using electricity due to inadequate bathing activities. Most of the clean water supply systems in residential according to Fig. 5, 27.5% of the households indicated an increase in temperature and humidity in Kalimantan which are relatively higher than in Java may be one of the reasons since these areas are closer to equatorial. Even before the pandemic, the daily stay period was a significant factor affecting home energy consumption, and this factor remained during the pandemic. In addition, both parents be due to the gap in oil prices between the western and eastern parts of Indonesia (Himawan, 2017). In the SW region showed the largest increase in electricity consumption per household by region in the comparison between before and during the pandemic which affect the use of more home electronic appliances. The use of electric fans disappeared from the list of factors that influenced home electricity consumption before the pandemic. Since the pandemic, these have changed to 1) insect disturbance; 2) transport cost; 3) gasoline cost; 4) work both; and 5) outdoor noise level. The pandemic is forcing people to spend more time at home, along with that, their sensitivity to the indoor environment and surrounding are also expected to increase during their stay home period. Natural ventilation may be one of the efforts to move indoor air to make it healthier and minimize virus transmission. However, hot and humid climates are also giving the best environment for insects (mosquitoes) to enter the buildings, becoming a disturbance to people’s comfort level. On the other hand, transportation costs and gasoline costs from private vehicles contribute negatively to household energy consumption. This indicated the situation where households reduced outdoor activities due to the virus outbreak. Finally, Fig. 8 (e) presents the case of Papua Island and its surrounding (PP) were, 1) insect disturbance; 2) electric fan use; 3) noise level are factors that influenced home electricity consumption before the pandemic. Since the pandemic, these have changed to 1) insect disturbance; 2) transport cost; 3) gasoline cost; 4) work both; and 6) noise quality. Insect disturbance plays the same way with the condition during the pandemic. The use of electric fans disappeared from the list of factors that affect household consumption, replaced by the cost of transport and gasoline consumption. Similar to the case of SW, transportation costs and gasoline costs contribute significant roles in home energy. This may be due to the gap in oil prices between the western and eastern parts of Indonesia (Himawan, 2017). In addition, both parents’ work shows the linear impact on the increase in energy consumption. This may relate to the more working activities that happen in the home during the pandemic which affect the use of more home electronic appliances. In general, Fig. 9 shows monthly electricity consumption per household by region in the comparison between before and during the WPHI. On average, electricity consumption in JW is the largest compared to other islands. Meanwhile, the results of the questionnaire analysis for the SW region showed the largest increase in electricity consumption per month compared to before the pandemic period, approximately 74.1%, which is 197.7 kWh per household, followed by ST (31.3%), JW (24.8%), PP (24.7%), and KM (8.7%). On the other hand, based on the energy consumption data extracted from the Ministry of Energy and Mineral Resources (ESDM) (Gatrik, 2021) and the number of households from Statistics Census Indonesia (BPS) (Badan Pusat Statistik, 2020), in

Table 4

Empirical model regression analysis.

| Area   | Equation                                                                 | Dependent variables                                                                 |
|--------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| JW     | \[ Y = -515.5 + 94X_1 + 52.5X_2 + 38.6X_3 + 126.7X_4 + 33X_5 + 47.5X_6 + 1462.3 + 116.4X_8 + 68.1X_9 + 99.2X_10 + 69.4X_11 + 76.1X_12 + 223X_13 + 247.8X_14 + 34.4X_15 \] | \( X_1 \): AC no. \( X_2 \): Fan use \( X_3 \): AC year \( X_4 \): Internet \( X_5 \): Cooking \( X_6 \): Shop online \( X_7 \): Humidity \( X_8 \): Insect \( X_9 \): Water use \( X_{10} \): Temperature \( X_{11} \): Water use \( X_{12} \): Transport cost \( X_{13} \): Gas cost \( X_{14} \): Gasoline cost \( X_{15} \): Work both |
| ST     | \[ Y = -141.2 - 73.9X_1 + 133.3X_2 + 65.6X_3 \] | | |
| KM     | \[ Y = -233.5 + 169.7X_4 + 162.4X_5 - 79.8X_6 \] | | |
| SW     | \[ Y = -406.3 + 223.6X_7 + 99.2X_8 + 79.8X_9 - 194.5X_{10} + 124.5X_{11} + 269.6X_{12} + 265.8X_{13} + 169.7X_{14} + 116.4X_{15} \] | | |
| PP     | \[ Y = 126.7X_1 + 182.3X_2 + 124.5X_3 + 38.6X_4 \] | | |

Meanwhile, in the case of Sulawesi Island and its surrounding (SW) in Fig. 8 (d), the factors that influence the home electricity consumption are: 1) outdoor air quality; and 2) family number. Which then during the pandemic turned into 1) insect disturbance; 2) transport cost; 3) gasoline cost; 4) work both; and 5) outdoor noise level. The pandemic is forcing people to spend more time at home, along with that, their sensitivity to the indoor environment and surrounding are also expected to increase during their stay home period. Natural ventilation may be one of the efforts to move indoor air to make it healthier and minimize virus transmission. However, hot and humid climates are also giving the best environment for insects (mosquitoes) to enter the buildings, becoming a disturbance to people’s comfort level. On the other hand, transportation costs and gasoline costs from private vehicles contribute negatively to household energy consumption. This indicated the situation where households reduced outdoor activities due to the virus outbreak.
the year of 2019, the household in Indonesia spent 329 KWh per month has increased only 5 KWh per month from the year before, with the assumption of 4.1% increase of household by 2020. It is hard to conclude that the increased amount is related to the pandemic since there is no significant change between the two. In addition, due to the activity restriction announced in May 2020, the implementation of WFH was starting later and sporadically. Although, based on the questionnaire in this study, the average consumption of Indonesian households reached...
an increase of approximately 32.7% compared to the consumption before the pandemic.

In briefly refer to Fig. 10, the family group with consumption between 60 to 130 KWh has the highest percentage number of respondents, which is 18.6%. In general, the distribution of households with electricity consumption is between 60 to 340 KWh. However, households with monthly average consumption of 470 to 540 KWh experienced the biggest increase during the pandemic, which was 50.9% feedback compared to the situation before the pandemic. By this figure, we can claim that the households with a higher electricity consumption group have a bigger increase in consumption during the pandemic. Similarly, in terms of gas consumption in Fig. 11, it shows that households with higher gas consumption experienced a higher increase even though the number of households in these groups was smaller.

In order to grasp the households’ attributes by the increased levels, Fig. 12 shows the group analysis results based on 5 classifications: 1) increased by more than 100%, 2) increased between 50 to 100%, 3) increased by 10 to 50%, 4) no significant increase, and 5) decreased. Some significant factors that highly affect the changes in electricity consumption in the previous section are included which are: the number of family members, years of stay, family income, number of AC units, AC performance, electric fan use, rice cooker use, oven/microwave use, gas consumption, and water consumption. Those household attributes were translated into numerical scales, then distributed to 6 levels of radar graphs. For example, Fig. 12 (a) shows A Group which is composed of households with family number more than 4 people, year of stay more than 10 years, with household total income is upper standard minimum wage, with AC ownership of more than 2 units, with rarely doing the AC maintenance, with more than 4 unit of electric fan ownership, with intensive use of rice cooker and microwave, and an indication of higher gas and water consumption a month. Regarding the total electricity consumption of each household group, Fig. 13 shows the monthly average electricity consumption comparison between the situation before the pandemic and during the pandemic.

The family attributes including the number of families, years of stay in the current house, and family income remarkably affect the energy consumption pattern in all groups. Previous study found that larger family size tends to spend more energy per household compared to smaller family size but in terms of EU per person it shows high efficiency since the share of space and home electronic appliances (Tran et al., 2021b). However, during the pandemic situation where all family members are forced to WFH the electricity use escalated to more than 100% (A Group). Mentioning about household stay year, it can be indicated that the longer family stays in the current house the greater number of home appliances ownership. In addition, families with higher incomes also tend to be less worried about electricity consumption. This financial confidence is also shown in the increase of electricity consumption, although it is not always linear to the increased levels (A, B, C Group). In contrast, households with income below the local minimum wage showed decreased electricity consumption during the pandemic (E Group). Probably, their attention and financial concern are focused on the uncertain situation due to the pandemic.

Policymakers must put more concern on the household groups with specified characteristics and lifestyle attributes mentioned above, because the households have the potential to consume electricity more than double at any time when they are facing a critical situation, such as pandemic and other disasters.

5. Conclusion and recommendation

In this paper, the electricity consumption is taken as a parameter in household energy consumption to reveal the occupant’s lifestyle and building characteristics and any possibilities that change the consumption during the virus outbreak in residential buildings. From this study, it can be concluded as follows.

1. Based on the results in this paper, it was found that there is a significant shift of factors affecting residential electricity consumption between the situation before the pandemic and during the pandemic. In Java and Sumatra, the factors affecting changes in electricity consumption during the pandemic are dominated by the lifestyle-related to the use of household appliances and attributes of the family. Meanwhile, in Kalimantan, Sulawesi, and Papua, the influential factor is dominated by the quality of the environment, both indoor and outdoor. Considering that Java is one of the most populous islands in the world (D. D. Saputra & Budiarti, 2018), as well as the location of the main cities of Indonesia, the urban and economic development is also the most advanced compared to other islands, followed by cities in Sumatra. This affects the level of convenience in owning household appliances, but on the other hand, the sharp increase in energy consumption must also become a concern. The application of dynamic pricing and energy monitoring systems with IoT that can control people’s lifestyles on using appliances is urgently needed in densely populated areas. Even so, cities outside Java also show a trend to follow the development of developed cities in Java. Urban energy planning infrastructure from renewable energy resources must be carried out immediately in response to the fast population growth. Besides, the equatorial, which is exposed to sunlight every month, the archipelago, which is full of wind and sea, can be the solution for renewable energy resources that can be distributed throughout the city, suburban and rural areas.

2. Based on the increase rate, by island area, the average monthly electricity consumption in Java (JW) was the highest both before the pandemic (653 KWh per household) and during the pandemic (814 KWh per household), which is almost 4 times the average electricity consumption of Kalimantan (KM), and more than two times the national average electricity consumption in 2019 and 2020. According to National Electricity Statistics (Gatrik, 2021), the national electrification ratio is still 99.2%, with the highest is Bali (100%) and the lowest is East Nusa Tenggara with a ratio of 87.6%. If the ratio has reached 100% for all regions of Indonesia, the electricity consumption rate, and the increase during the pandemic in other regions could be equivalent to the average of Java and Bali. If the composition of electricity sources still relies on natural oil and coal, the sustainability and resilience of the energy supply in Indonesia could be critical.

3. Based on the types of lifestyle changes obtained from the questionnaire results, it shows that the residential building has turned into...
the center of all activities with the help of the internet which provides various options one of them is by doing remote work. In critical situations, from the results of the analysis, it was found that more than 90% of households did WFH. On one hand, the increase in energy consumption in residential buildings is inevitable, but on the other hand, energy consumption in the transportation sector is much lower (Fig. 3). The electricity-based transportation system can be a potential solution in the sudden crisis situation, making it possible to shift energy supply quickly to reduce the wider economic impact. It is estimated that even though the pandemic is over, most people will continue to work remotely because they are adapted to it. This moment is an opportunity for policymakers to go towards a green economy and as an opportunity for designers, industry, architects, to develop green technology in residential architecture.

4. By matching the results of the regression analysis and data on the rate of increase in household electricity consumption, it revealed the characteristics and information of each household group which is useful to establish regulations for classifying household levels so that frequent electrical blackouts can be avoided. In addition, this information is also useful for occupants to conduct simulation of their electricity consumption as well as implement low energy lifestyles related to the use of appliances. In the near future, HEMS is also deemed necessary to be adopted in the residential communities so that the need for electricity, the importance of energy savings combined with the use of renewable energy can be achieved by the country with the fourth largest population in the world.

5. Through this study, it can be confirmed that the use of AC in hot humid tropical climates for room cooling like in Indonesia is indispensable. AC is also a factor that has a significant positive effect on
the increase in household electricity consumption. From the results of this research, it is necessary to develop AC technology that can adapt to conditions during a pandemic without reducing its efficiency because ventilation is also a critical factor to avoid virus transmission in the family or larger groups. On the other hand, the use of kitchen appliances such as rice cookers, ovens, microwaves, and cooking stoves also indicate a significant lifestyle change during the WFH period. These results are different from similar studies conducted previously (Novianto, 2016; Novianto, Gao, et al., 2015; Novianto, Kano, et al., 2015; Tran et al., 2021b; Wang et al., 2016; Zheng et al., 2016) where energy consumption is heavily influenced by building characteristics such as floor area, building direction and building construction year.

Further, field measurement related to the use of home appliances in several types of residential buildings during the pandemic and self-quarantine will be conducted to break down the energy consumption based on use and find the correlation with thermal comfort related to the change of room function.

Declaration of Competing Interest

The authors declare no conflict of interest.

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