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Assessing the Environmental Impact of Electricity Consumption Changes in the Riau Islands During COVID-19

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Abstract
The Riau Islands Province in Indonesia was among the regions impacted by the pandemic, which also influenced electricity usage patterns and subsequently, the environmental impact. To assess these environmental impacts, life cycle assessment (LCA) is an effective tool. This research aimed to evaluate the environmental implications both before and during the COVID-19 pandemic, using SimaPro v.9.1.1.7 software and the Environmental Product Declaration (EPD) database for impact analysis. The inventory data showed that in urban areas like Batam City and Tanjung Pinang City, as well as in Bintan Regency, there was a notable decrease in electricity consumption between 2019 and 2020. Electricity is a crucial energy resource for communities, and this was particularly evident during the COVID-19 pandemic. The Riau Islands Province in Indonesia was among the regions impacted by the pandemic, which also influenced electricity usage patterns and subsequently, the environmental impact. The inventory data showed that in urban areas like Batam City and Tanjung Pinang City, as well as in Bintan Regency, there was a notable decrease in electricity consumption between 2019 and 2020. This reduction led to a significant overall decrease in environmental impact. However, it's important to note that this reduction, brought on by the unpredictable nature of the pandemic, may not be sustainable in the long term.
Keywords: *riau islands province, electricity, life cycle assessment*

Abstrak
Provinsi Kepulauan Riau di Indonesia merupakan salah satu daerah yang terdampak oleh pandemi, yang juga mempengaruhi pola penggunaan listrik dan dampak lingkungan yang menyertainya. Untuk menilai dampak lingkungan tersebut, analisis siklus hidup (*Life Cycle Assessment*/LCA) merupakan alat yang efektif. Penelitian ini bertujuan untuk mengevaluasi implikasi lingkungan sebelum dan selama pandemi COVID-19, menggunakan perangkat lunak SimaPro v.9.1.1.7 dan basis data *Environmental Product Declaration* (EPD) untuk analisis dampak. Data inventaris menunjukkan bahwa di daerah perkotaan seperti Kota Batam, Kota Tanjung Pinang, dan Kabupaten Bintan, terjadi penurunan konsumsi listrik yang signifikan antara tahun 2019 dan 2020. Listrik merupakan sumber energi penting bagi masyarakat, dan hal ini menjadi sangat nyata selama pandemi COVID-19. Penurunan ini menyebabkan pengurangan dampak lingkungan secara keseluruhan. Namun, penting untuk dicatat bahwa penurunan ini, yang disebabkan oleh ketidakpastian alam pandemi, mungkin tidak berkelanjutan dalam jangka panjang.
Kata Kunci: *provinsi kepulauan riau, listrik, analisis siklus hidup*

1. Introduction

The Riau Islands Province, situated as a pivotal hub in Indonesia, is renowned for its role as both an industrial center and a key player in international trade, particularly in exports. This province's strategic significance is largely attributed to its prime location along major international trade routes, acting as a vital gateway in the region. Its geographical positioning, sharing borders with both Singapore and Malaysia, places the Riau Islands at the crossroads of significant maritime trade pathways. This unique location enhances the province's role in facilitating regional trade interactions and fostering economic interdependencies among these neighboring nations. As a result, the Riau Islands Province not only serves as a critical point for the movement of goods and services within Southeast Asia but also as a conduit for broader international trade flows. Its ports and industrial zones are bustling with activities, connecting various trade networks and serving as a linchpin for economic exchanges. The province's proximity to

major international markets like Singapore and Malaysia further amplifies its importance, allowing it to capitalize on the trade opportunities and economic partnerships that arise from this strategic positioning.

In late December 2019, the initial cases of COVID-19 were identified in Wuhan, China, and by January 26, 2020, the virus had spread to multiple regions [1], [2]. Studies during the pandemic have reported an increase in electricity bills, attributed to the virus's impact [1]–[5]. Studies during the pandemic have reported an increase in electricity bills, attributed to the virus's impact [6], [7]. In Indonesia, the spread of COVID-19 brought about issues related to surges in public electricity bills. These were primarily due to lifestyle changes, with people spending more time at home, leading to increased home activities and subsequently higher electricity demand [8], [9]. This demand surge necessitated an augmented electricity supply to maintain system stability and fulfill consumer electrical energy needs. Consequently, managing the inconsistent annual electrical power needs, especially during the pandemic, became a significant challenge.

During the COVID-19 pandemic, with most of the population restricted to their homes, there was a noticeable increase in the use of various electronic devices. This uptick was marked by a heightened reliance on air conditioners, televisions, computers, and even motor vehicles for short local trips. Such changes in daily habits led to a significant rise in energy consumption within households. The prolonged and intensified use of air conditioners, driven by the need for comfort while staying indoors, especially in warmer climates, contributed heavily to this surge. Similarly, increased screen time, whether for entertainment, remote work, or online education, resulted in higher usage of televisions and computers [10]–[12]. This escalated utilization of electronic devices and vehicles had a direct and substantial impact on the environment, particularly in terms of greenhouse gas emissions. Each of these devices, when powered on, consumes electricity, much of which is generated from fossil fuels in many regions. The burning of these fuels releases a considerable amount of carbon dioxide, a primary greenhouse gas, into the atmosphere. Moreover, the increase in the use of motor vehicles, even if limited to local areas, added to the carbon footprint. Short trips, often undertaken multiple times a day, accumulated to contribute significantly to overall vehicle emissions. This is particularly relevant in urban areas where the density of vehicles is high.

The correlation between this increased consumption of energy and the rise in carbon emissions is clear and direct. The more electricity and fossil fuels consumed by households and individuals for powering various devices and vehicles, the greater the volume of carbon emissions released into the atmosphere. This pattern of high energy consumption and its consequent impact on carbon emissions highlights a critical aspect of consumer behavior, especially in times of crisis such as a pandemic, where the shift in lifestyle and activity patterns can have far-reaching environmental impacts.

The concept of environmentally friendly products focuses on reducing environmental impact to enhance quality of life, understand product sustainability, and efficiently use resources throughout the product lifecycle. One method to assess product sustainability during the COVID-19 pandemic is through Life Cycle Assessment (LCA) [13]. LCA is a methodology that involves detailed data collection, assessment, and evaluation of all environmental impacts associated with products, processes, and activities. This study aims to explore the environmental impact of electricity usage in the Riau Islands Province during and prior to the COVID-19 pandemic, utilizing LCA to evaluate the impact of electricity distribution activities. The study's scope includes data from 2019 and 2020, marking its temporal limitations.

2. Material and Methods

The Life Cycle Assessment (LCA) methodology used in this study to compare the environmental impacts of different electricity usage scenarios adheres to the standards set by ISO 14040-1997. The LCA process is methodically divided into four phases: goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact analysis (LCIA), and interpretation of results.

1. **Goal and Scope Definition:** This phase involves defining the study's objectives and establishing the scope of the assessment. It sets the context for the LCA, specifying the electricity usage scenarios to be evaluated and outlining the system boundaries and underlying assumptions.
2. **Life Cycle Inventory Analysis:** During the LCI stage, there is a comprehensive collection of data focusing on the amount of electrical energy utilized in each scenario. This phase entails a detailed inventory of necessary data during two specific periods: during the COVID-19 pandemic and before its onset. The data is predominantly sourced from the Central Statistics Agency for the Riau Islands Province (**Figure 1**) for the years 2020 and 2021 as secondary information.
3. **Life Cycle Impact Analysis:** In the LCIA phase, the environmental impacts of each electricity usage scenario, based on the LCI stage data, are quantified [13], [14]. This step involves assessing

the different environmental impacts associated with the consumption of electrical energy in each scenario. The categories of impact assessment are determined based on the study's limitations and the significant environmental impact categories of electrical energy use.

4. **Interpretation of Results:** The final phase of the LCA is the analysis and interpretation of the results obtained from the LCIA. This stage aims to comprehensively understand the environmental performance of each electricity usage scenario, identifying the most sustainable option based on the findings.

For processing and analyzing the data, all gathered information is inputted into SimaPro software v.9.1.1.7. The analysis then proceeds using the 2018 Environmental Product Declaration (EPD) method. The study employs the latest eco-inventory database [15], ensuring that the assessment is grounded in current and relevant environmental data. This structured LCA approach allows for an in-depth and systematic evaluation of the environmental impacts of different electricity usage scenarios. The analysis provides crucial insights into the sustainability of these scenarios, guiding informed decision-making for environmentally responsible electricity consumption, particularly in the context of changing patterns during the COVID-19 pandemic.

Figure 1. Study Area in Riau Islands Province
Source: [16]

3. Results and Discussion

This research focuses on assessing the environmental impact associated with electricity usage in the Riau Islands Province, both before and during the COVID-19 pandemic. The study utilizes secondary data, which was obtained from the central statistical agency for the years 2019 and 2020. The data collected is annual, providing insights into the yearly energy usage measured in kilowatt-hours (kWh). The scope of this study encompasses the entire process of electricity consumption by customers in the Riau Islands Province, as illustrated in **Figure 2**. This comprehensive approach allows for a detailed analysis of how electricity usage patterns and their environmental impacts have evolved in response to the pandemic.

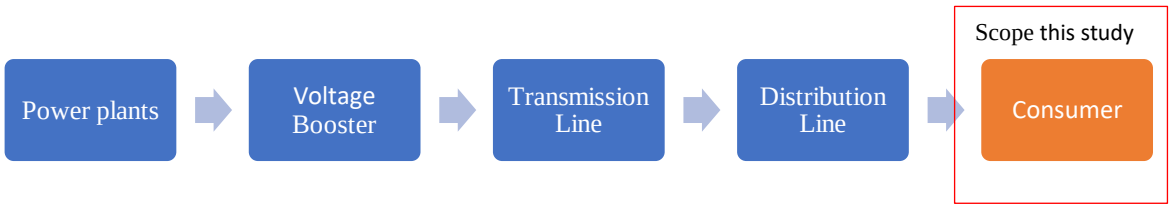

Figure 2. Scope in LCA Analysis of Electrical Energy Consumption in Riau Islands Province

Amidst Indonesia's slowing economic growth and the implementation of social restriction policies to curb the spread of the COVID-19 virus, the Riau Islands' economy also witnessed a significant downturn. The region's economy contracted by -6.6% year-on-year (yoy) in the second quarter of 2020, a stark decline compared to the first quarter of the same year, which saw a growth of 2.06% yoy [17]. Its downturn in the Riau Islands' economy mirrored the national trend, as the entire country experienced economic contraction during this period. Concurrent with the economic downturn in the Riau Islands was a decrease in energy

demand. As shown in **Table 1**, electricity consumption in urban areas such as Batam City, Tanjung Pinang City, and Bintan Regency tended to decrease. The data presented in **Table 1**, which outlines the electricity consumption in these areas, was utilized as part of the inventory for the LCA) analysis. This data helps in understanding the correlation between the economic contraction due to the pandemic and its subsequent impact on electricity consumption patterns in the Riau Islands.

Table 1. Recapitulation of Electrical Energy Consumption in Riau Islands Province before and during the COVID-19 pandemic

Regency/Municipality	Total Electrical Energy Consumption (kWh)	
	2019[1]	2020[2]
Karimun	218,419,826	220,174,115
Bintan	224,684,294	219,042,788
Natuna	52,639,161	56,857,004
Lingga	37,240,017	41,504,788
Anambas (Archipelago)	25,455,656	28,329,572
Batam	2,460,987,735	2,443,268,000[3]
Tanjung Pinang	316,152,636	311,086,994

[1][18]; [2][19], [3][20]

The largest decrease in electricity consumption in Bintan City reached -2.58% compared to Tanjung Pinang City and Batam City, which decreased not too far (**Figure 3**). Other island regions such as Karimun, Natuna, Lingga, and Anambas tend to increase. The number of tourists before COVID-19 in 2019 was 1,094,442 visitors, while during COVID-19 in 2020, the number of tourists decreased by approx. 81.49% to 202,583 visitors [21]. During Covid-19 pandemic tourism activities, all tourists who come from abroad are absent since the border is closed. Usually, Singaporean tourists come on weekends, and Chinese tourists come with the tour as a group on weekdays when COVID-19 is not there [21]. Decreasing hotel occupancy rates and liner tourism activities with reduced consumption of electrical energy in the community. The tourism sector significantly impacts environmental conditions so that the consumption of community needs is reduced [13], [22]; this includes electricity consumption.

The Batam City Government recorded around 1900 SME players who significantly impacted the Covid-19 pandemic [23]. The impact felt by SMEs in Batam City was a decrease in turnover influenced by declining demand and constraints on raw materials due to a large-scale social restriction system. Changes may also influence this decrease in consumer behavior by limiting physical interaction and staying at home. The need for food and electricity must be met in daily activities at home. The use of electrical energy previously consumed mainly outside the home now tends to be greater during a pandemic. The decrease in electrical energy consumption in urban areas can occur in public facilities such as airports, schools, and others. Visiting activities by air in Batam City also experienced a decrease in visitors by -99.92% [24]. Several studies also reported that online learning activities were still running during the Covid-19 pandemic in Batam City [25]–[27].

The environmental impact calculations carried out using the SimaPro Software indicated a decrease in most environmental impacts, with the exceptions being ozone layer depletion and photochemical oxidant formation, as detailed in **Table 2**. Overall, the reduction in environmental impacts attributed to decreased electricity use was found to be minimal. The rate of environmental mitigation showed only a slight decrease, ranging from 0.36 – 0.98%. This modest reduction underscores the fact that the environmental impact reductions observed during the pandemic are not substantial indicators of sustainable development. The findings suggest that while there were some decreases in environmental impacts due to changes in electricity consumption patterns during the pandemic, these changes were not significant enough to contribute markedly to sustainability goals. This highlights the need for more targeted and substantial measures to achieve meaningful environmental sustainability.

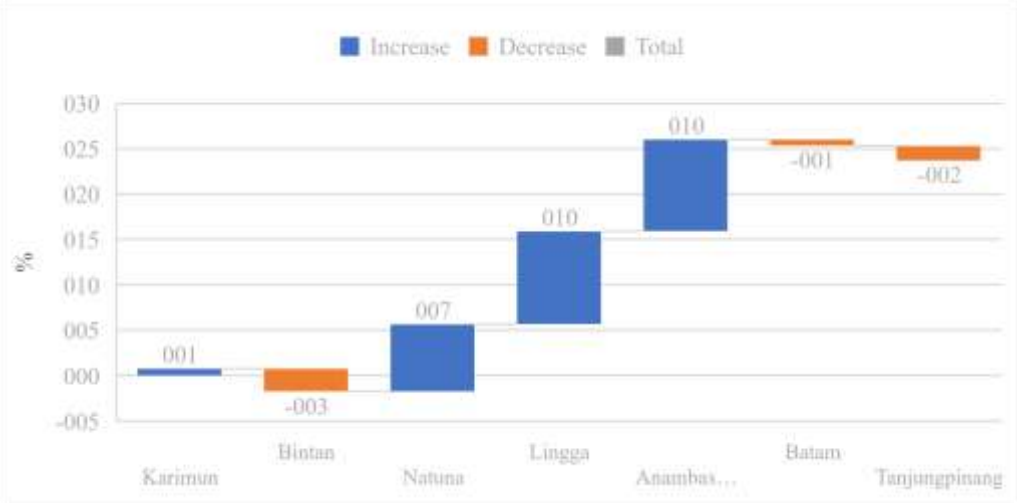

Figure 3. Comparison of Electrical Energy Consumption Before and during the COVID-19 Pandemic in Riau Islands Province

The environmental impact of electricity uses in the Riau Islands Province, as detailed in the provided table for the years 2019 and 2020, shows a range of reductions across several impact categories, although some remained unchanged. There was no observed reduction in acidification and ozone layer depletion, with the figures for sulfur dioxide and CFC-11 equivalents staying constant at 1,550,000 kg and 110 kg, respectively. Notably, there were slight improvements in other areas: the emissions related to eutrophication decreased marginally by 0.54%, while global warming potential saw a reduction of 0.57%, indicating a small step forward in reducing the carbon footprint of the province. The data also illustrates a reduction in the impact of photochemical oxidation and abiotic depletion of both elements and fossil fuels, with the latter showing a decrease in usage by 0.55%. Additionally, water scarcity impacts were slightly mitigated, with a 0.36% decrease in water usage. These marginal yet positive changes reflect a trend towards more sustainable electricity use in the region, although the stabilization in certain categories underscores areas where further efforts are necessary.

Table 2. Results of calculating the environmental impact of electricity use in the Riau Islands Province

Impact category	Unit	2019	2020	Reduction (%)
Acidification (fate not incl.)	kg SO_2 eq	15500000	15500000	0.00
Eutrophication	kg PO_4 eq	18600000	18500000	0.54
Global warming (GWP100a)	kg CO_2 eq	3530000000	3510000000	0.57
Photochemical oxidation	kg NMVOC	1030000	1020000	0.98
Abiotic depletion, elements	kg Sb eq	5120	5100	0.39
Abiotic depletion, fossil fuels	MJ	36800000000	3.66E+10	0.55
Water scarcity	m^3 eq	565000000	563000000	0.36
Ozone layer depletion (ODP)	kg CFC-11 eq	110	110	0.00

The difference in the total weight of the environmental impact caused by electricity use is not too much different during the pandemic and before the pandemic (**Figure 4**). The previous study also mentioned that Batam City could increase greenhouse gas emissions and air pollution before the Covid-19 pandemic [28]–[30]. As a result of social restrictions, there is a possibility that there will be a proven reduction in environmental impacts. Still, the reduction in environmental impacts from electricity use is not too significant. Research on air pollution concentrations in China was conducted by [31], there was a very diverse decrease in air pollution during the lockdown.

It can be seen that the use of electricity has the most significant global warming impact weight than other impacts (**Figure 4**). It reduces the impact of climate change due to the need to be suppressed because it has long-term effects. Climate change creates the emergence of new viruses such as Covid-19 because it is caused by global warming, which eventually causes the earth's heat, impacting many animals migrating to places that are not their original habitats, which can be overcome [32], [33].

To address the issue of rising electricity bills and to promote environmentally friendly electricity usage, the implementation of renewable energy sources, such as solar power, is recommended. An effective alternative to conventional power sources, solar energy offers a sustainable and cost-effective solution. For instance, in Batam City, solar power has already been employed on a small scale in applications like simple automation systems, including automatic handwashing equipment [34]. The procurement of solar panels as a source of electrical energy is expected to provide a simple solution to prevent the spread of the virus and make the environment clean and energy efficient. Post COVID-19, it is crucial for policies to focus on enhancing the infrastructure for renewable energy sources like solar power. The government could incentivize the installation of solar panels in both residential and commercial sectors, encouraging widespread adoption.

Policies should also facilitate research and development in renewable energy technologies to make them more accessible and cost-effective. Furthermore, educating the public about the benefits of renewable energy and providing financial assistance or subsidies for solar panel installations could accelerate the transition towards a more sustainable and resilient energy system. These asset will not only contribute to environmental sustainability but also help in adaptation future challenges [35]–[37] related to energy consumption and public health.

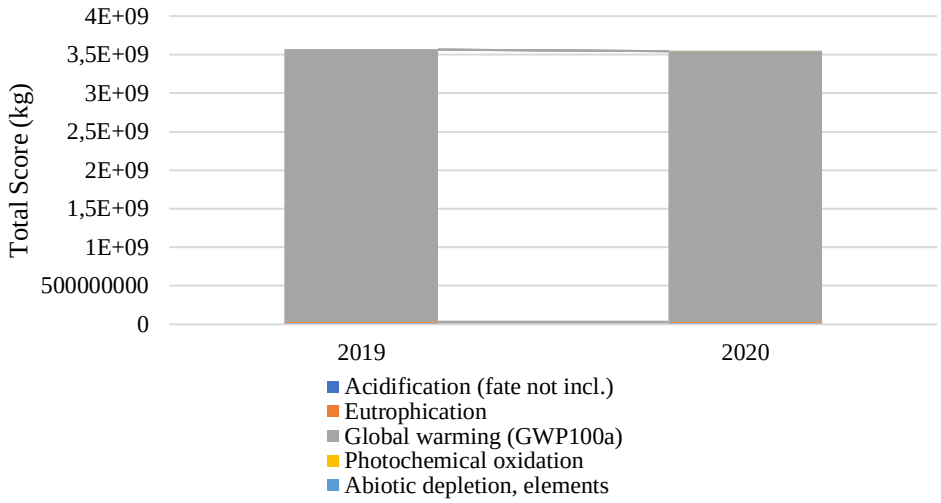

Figure 4. Total Environmental Impact Weights Before and During the COVID19 Pandemic in Riau Islands Province

4. Conclusion

In the Riau Islands Province, the environmental impacts from electricity use show both steady and declining trends from 2019 to 2020. Acidification and ozone layer impact numbers held steady, with no reduction in sulfur dioxide or CFC-11 emissions. However, the region did see a small decrease in eutrophication by 0.54% and global warming impacts by 0.57%. Other areas of improvement include a 0.98% reduction in substances that contribute to photochemical smog, a 0.39% decrease in the depletion of elements, and a 0.55% decline in the use of fossil fuels. Water scarcity impacts also fell slightly by 0.36%. This was evident from the observed decrease in total electrical energy consumption across the province. However, when analyzing the environmental impacts through Life Cycle Assessment (LCA), it was found that the reduction in these impacts was relatively insignificant. Consequently, the decrease in environmental impact observed during the COVID-19 pandemic does not equate to a sustainable or long-term reduction in environmental impact. This suggests that while changes in consumption patterns during the pandemic led to some immediate reductions in environmental impact, these changes were not substantial enough to contribute significantly to long-term environmental sustainability.

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