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# THE IMPACT OF ELECTRIC VEHICLES IN REDUCING CARBON EMISSION IN METROPOLITAN CITY

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**Abstract:**

**Background:** This comparison of Singapore and Jakarta shows electric vehicles (EVs) can reduce transportation-related carbon emissions, but renewable energy investments are essential. Singapore benefits from lower emissions due to natural gas use, while Jakarta faces traffic and pollution challenges. Effective policies, investment in EV manufacturing, and collaborative strategies are crucial for increasing EV adoption.
**Purpose:** This study aims to find out how the presence of electric vehicles can affect the reduction of carbon emissions in metropolitan cities, especially in Jakarta. This research uses a qualitative descriptive approach.
**Design/methodology/approach:** The data for this research was obtained from various sources, ranging from academic journals, and government and non-government reports, as well as websites that monitor various parameters relating to the two countries and the research being conducted over 12 years (2010-2022).
**Findings/Result:** Findings indicate that average emissions per EV per day in Jakarta are similar to those of Singapore at a value of 3.9245 kgCO2, eq/day as opposed to 6.0403 kgCO2, eq/day for Internal Combustion Engine Vehicle (ICEVs) considering only the emissions with current electricity generation. Adding cradle-to-gate emissions for a service life of 10 years, the value becomes 7.21 kgCO2, eq/day, showing that improvements not only in local renewable energy policy but also in global manufacturing capabilities for EVs are required to make EVs significantly more viable than ICEVs.
**Conclusion:** The comparison between Singapore and Indonesia highlights that while electric vehicles (EVs) can reduce transportation-related carbon emissions, significant investments in renewable energy and supportive policies are crucial for maximizing their benefits.
**Originality/value (State of the art):** This research highlights the comparative viability of electric vehicles (EVs) in reducing transportation-related carbon emissions in Singapore and Indonesia, emphasizing Singapore's advantage due to its reliance on natural gas over coal and oil. Future research directions include analyzing consumer engagement techniques to boost EV adoption in metropolitan areas.

**Keywords:** carbon footprint, electric vehicles, Jakarta, metropolitan, Singapore

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## INTRODUCTION

According to Indonesia's Climate Actions Towards 2030 from the Ministry of Environment and Forestry, Indonesia set a target of 29% emission reduction through its efforts of 41% with international support. This commitment reflects Indonesia's determination to contribute to global efforts to mitigate climate change while acknowledging the challenges it faces as a developing nation. An issue of public concern is carbon emissions from global industries where emissions are generated from industrial sector activities such as the energy, raw materials, and utility sectors (Luo & Tang, 2014).

Today's modern activities are dominated by mobility activities that require transportation. The population of Jakarta ranks 28th out of 781 cities (World Population Review, 2023). With rapid economic growth and rapid urbanization in Indonesia, it is projected that more and more people will require private vehicles for mobility purposes (Asian Development Bank, 2021). Cumulatively, car sales in the domestic market in the January-June 2023 period reached 505,985 units, while in the same period last year the sales were only 475,030 units in Indonesia (Katadata, 2023). This shows that the demand for vehicles from the public rose with the number of sales increasing by around 6.51%.

The carbon footprint of transportation in Jakarta today can be seen in the increasing air pollution. According to CNBC Indonesia (2023), the transportation sector is the largest contributor to carbon emissions in Jakarta at 44% followed by the energy industry 31%, industrial manufacturing 10%, residential sector 14%, and commercial 1%. The number of transportations in Jakarta in 2022 is 26,370,535 units, which include types of transportation 3,766,059 cars, 17,304,447 motorbikes, and 748,395 trucks (Central Bureau of Statistics, 2022). With so much transportation in Jakarta, the streets are very congested, causing a lot of air pollution.

The high mobility of transportation in Jakarta makes the air quality worse today. The Jakarta Environmental Agency (DLH) explains that DKI Jakarta creates 70% (36.2 micrograms/cubic meter) of poor air quality due to transportation, compared to Singapore which only touched 13.3 micrograms. According to Air Quality Index United (2023), Jakarta is currently entering the vulnerable air quality reaching a score of 161 points. Air quality parameters based on AQI US are 1) green (0-50): good, 2) yellow (51-100): moderate, 3) orange (101-150): unhealthy for sensitive groups, 4) red (151-200): unhealthy, 5) purple (201-300): very unhealthy, and 6) maroon (>301): dangerous. Thus, the poor air quality proves Jakarta's carbon footprint is very high.

The government has provided incentives for the public. To reduce the carbon footprint generated by transportation, PT PLN (Persero) supports the electric transportation ecosystem in Indonesia. However, sales of electric cars in 2020 did not reach the target set by the government and industry, considering that in 2019, 2020, and 2021, the total number of electric cars sold was fewer than 500 units (Indonesian Automobile Industry Data, 2021). The low interest suggests that Indonesia needs an effective strategy to increase the demand for electric cars in Indonesia, especially in Jakarta.

Electric vehicles can help to solve the problem of air pollution in urban areas (Sudjoko et al. 2021). 1 litre of fuel oil (BBM) is equivalent to 1.2 kilowatt hours (kWh) of electricity. The carbon emission of 1 liter of fuel is equivalent to 2.4 kilograms (kg) of CO2e, while 1.2 kWh of electricity is equivalent to 1.02 kg of CO2e (PT PLN, 2023).

Previous research proves from Brockdor and Tanti (2017) that the shift from internal combustion engines to electric vehicles is predicted to shift the threat of emissions from the engine operation phase to the electricity generation phase, with an overall reduction of around 50%. The impact of electric vehicles on the environment can be calculated only based on emissions during electricity generation, which varies from country to country depending on the share of fossil fuels in electricity generation (Kurien & Srivastava, 2020).

## METHODS

The research methodology of this research applies qualitative descriptive approach. This research approach attempts to provide realistic accounts of participants' experiences and perspectives of the topic under investigation, allowing researchers to gain a thorough grasp of it (Sullivan-Bolyai, Bova, Harper, 2005).

The research used qualitative data from various sources, ranging from academic journals, and government and non-government reports, as well as a website that monitors various parameters related to the two countries and the research being conducted over the past 12 years (2010-2022). From these sources, relevant data was processed using equations 1-3 presented in the next section for Electric Vehicle EVs and Internal Combustion Engine Vehicle (ICEVs).

To compare the carbon emissions of electric automobiles and diesel fuel vehicles, the author employs the formula as shown:

ICEV emission ($KgCO_{2,eq}$)/day = (GE*SG*FC*AvgDistYear/365*100*1000) + ($CtG_{ICEV}$/365*ServiceLife) (1)

Where GE, SG, FC, Avg Dist Year, ServiceLife, and $CtG_{ICEV}$ are Gasoline emissions, gasoline specific gravity, ICEV fuel consumption, average distance covered per vehicle per year in each city, the service life of vehicles and Cradle-to-Gate emissions for an ICEV.

EV emission ($KgCO_{2,eq}$)/day =
(EVFC*AvgDistYear/365*1000) +
($CtG_{EV}$/365*ServiceLife) (2)

Where EVFC, $ElecCO_2$, and $CtG_{ICEV}$ are the values for EV energy consumption, grams of $CO_2$ produced by electricity consumption in each city and Cradle-to-Gate emissions for EVs 2. The value of $ElecCO_2$ is determined using Equation 3.

$ElecCO_2$ = CoalRat*OilRat + OilRat*OilEm + GasRat* GasEm (3)

Where CoalRat, OilRat, and GasRat are the ratios of total electricity production in each country from coal, oil, and natural gas respectively, provided in Table 1, while CoalEm, OilEm, and GasEm are the values of emissions in grams of $CO_2$ released per kWh produced of coal, oil, and gas.

The results obtained from this study are presented in tabulated and graphical form to compare the two types of vehicles in each country (Singapore and Jakarta) and discuss the findings in the context of green transportation in metropolitan cities.

The approach taken is comparative between the two cities of Singapore and Jakarta (Indonesia). Researchers compared these two regions in order to see the impact of using electric vehicles from Singapore, which in fact has utilized electric vehicles massively so that it can be a comparison for Jakarta, which is still dominant in using fuel vehicles and producing carbon emissions. Comparative analysis was conducted with several variables including comparison of environmental conditions, policies, and regulations of the two regions, and vehicle types. After the necessary data has been collected, it is necessary to analyse the data, namely summarizing the findings to get a precise and accurate result based on the carbon calculation formula in transportation. The strategy carried out to make a policy for electric vehicles, the strategy can be pursued by drafting a policy direction by paying attention to its harmony with the laws and regulations of the Republic of Indonesia (1945 Constitution). Achievement needs will be adjusted such as the amount of electric vehicle production, electric vehicle support subsidies, and electric vehicle socialization. Research framework in Figure 1.

## RESULTS

In the pursuit of increasing sustainable development in urban environments, a solution frequently brought up is the use of electric vehicles (EVs) in place of conventional, hydrocarbon-fuelled vehicles to reduce $CO_2$ emissions that frequently plague metropolitan cities. EVs are promising a reduction in carbon emissions through zero-use emissions, emissions coming from the operating lifetime of the vehicle. However, even during their service life, EVs indirectly contribute to the carbon footprint of a country since most countries of the world still utilize fossil fuel for their energy generation, which is required to power cities and the prospective EVs that are to substitute conventional vehicles. To illustrate this, a comparative study between the emissions of a conventional vehicle (henceforth referred to as ICEV (Internal Combustion Engine Vehicle) and an EV on a daily and yearly basis is carried out for the most congested region of Indonesia, its capital, Jakarta. Following this study, a comparison of the same metrics is done with Singapore to shed light on the differences between developing and developed nations' emissions with low reliance on renewable energy sources. For the calculation of carbon emissions for both vehicles in both countries, several assumptions were made to simplify calculations.

1. The energy used to recharge an electric vehicle assumes a ratio equivalent to the entire country's energy generation ratio between non-renewable and renewable energy sources.
2. The average fuel/energy consumption remains constant.
3. Service life of 10 years within which the production emissions are spread.
4. No battery degradation in EVs.
5. For Singapore, the fuel consumption was found by dividing the total gasoline (The Global Economy, n.d.) used by the country in a day by the product of the total number of ICEV private vehicles and the average distance driven per day.

**Jakarta and Its Environment**

Jakarta is the capital of Indonesia, with a population of 10.56 million (Jakarta Investment Centre, 2023) as of 2020, concentrated in an area of 664 square kilometres. This results in a very high population density of 15904 people/square km. This, in conjunction with the approximately 21.9 million vehicles in 2018 (CEIC, 2018), out of which 4.14 million were passenger cars (CEIC, 2018), creates an environment where air pollution is very high. With an average value of 110 on the Air Quality Index (AQI), Jakarta's air quality falls in the category of 'Unhealthy for sensitive groups' category, with some places within the centre of the city reaching as high as 155, which puts that area in the 'Unhealthy' category (The World Air Quality Project, 2023). Air quality severely impacts human health, as outlined by (Thurston et al. 2017) in their review of the adverse effects of air pollution on the human body. This is also an adversary to the SDG goals set by the United Nations, specifically SDG 3, "Good health and well-being".

Additional air pollution comes from the release of pollutants due to energy generation. Currently, Indonesia's energy production comes primarily from hydrocarbon-based fuels, with 87.5% coming from a combination of coal (42.38%), oil (31.4%), and natural gas (13.92%) in 2022 (Indonesian Ministry of Energy and Mineral Resources, 2022). From the total energy demands of the country of 2714 TWh, electricity accounts for 333.54 TWh, a share of 12.2%, with the production mix shifting from the primary energy generation presented previously to a split of 61.55% coal, 17% gas, and only 1.83% oil (Ritchie et al. 2022).

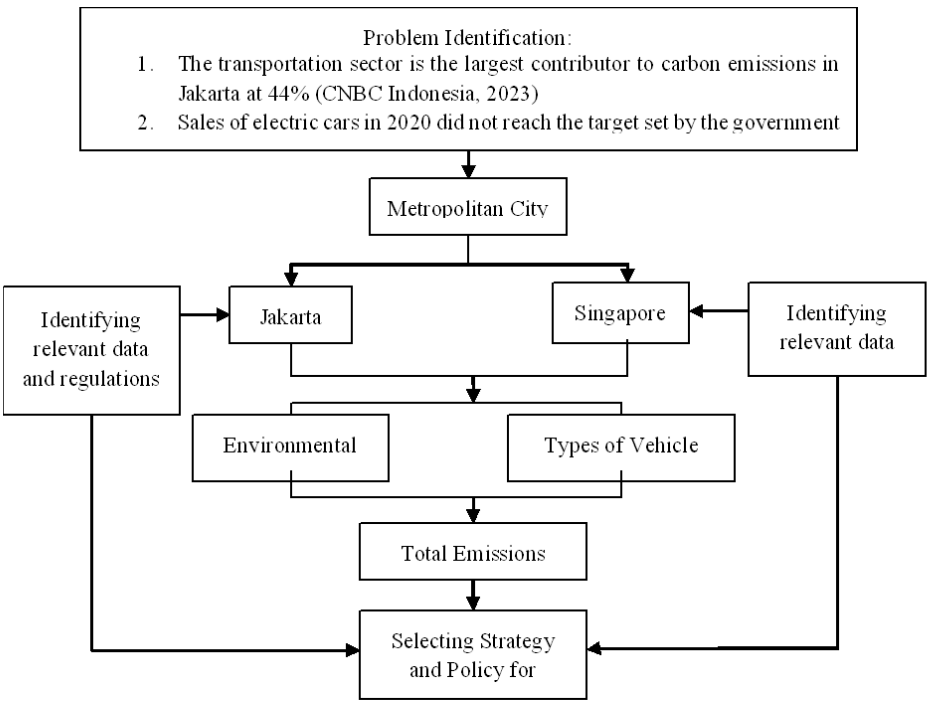


Figure 1. Research framework

**Singapore and Its Environment**

Singapore is a nation with a population of 5.64 million as of 2022 concentrated in an area of 742 square kilometres, resulting in a very high population density of 7601 people per square kilometre (National Population and Talent Division, 2022). Singapore's GDP per capita has grown exponentially over the intervening 58 years since its independence, growing from $516 in 1965 to $82807 in 2022 according to the World Bank (World Bank, 2022). Correspondingly, the energy demands of the country have increased by 18 times, from just 48 TWh in 1965 to 879 TWh in 2022 (Ritchie et al. 2022). Electricity generation in 2022 accounts only for 51 TWh out of the total primary energy demands of the country.

Despite the high reliance on fossil fuels and only 1.2% of its vehicle fleet being electric, Singapore still maintains a relatively low AQI between 40 and 75 depending on the area (Air Quality Index Project, 2023) That is due to very stringent measures by the government to curb emissions (Molina et al. 2019).

**Comparison of The Two Cities and Types of Vehicles**

Table 1 lists the electricity requirements of Indonesia and Singapore in 2022 and the split by generation type while Figure 1 diagrammatically illustrates the disparity in electricity requirements and generation. The result of Figure 2 shows the quantitative comparison of the two vehicles uses the metric of kilogram equivalent of CO2 released per day ($kgCO_{2, eq}$/day) to compare the vehicles. As the various types of vehicles used, the exact number of each type, and their fuel economy would be challenging to quantify, average values were utilized for a meaningful comparison. Table 2 presents the values of fuel consumption and the number of vehicles used for the analysis of the two types of vehicles in each country. The total number of vehicles in Jakarta was extrapolated using an average growth rate of 6% from the 2018 data obtained from the CEIC report, with the number of EVs estimated at 0.02% of the total passenger car fleet in Jakarta, which would equate to about 15% of the total EVs on the road in Indonesia as reported by IESR (IESR, 2023). The Singaporean EV fleet uses a value of 1.2% of all total passenger cars as obtained from the report summarising the total number of cars by type in Singapore produced by the Land Transport Authority of Singapore (Land Transport Authority, 2022).

The Table 2 shows about the calculation of emissions, where the values for the release of $CO_2$ per fuel type and per kWh of electricity produced are required. Values for the grams of $CO_2$ released in the atmosphere per kWh of electricity produced per fuel type were obtained from the research of (Rahman et al. 2021). Values for the specific gravity and emission of gasoline, which is used as the sole fuel type in the comparison as it is the primary fuel type of 4-wheeled vehicles used in the ICEVs in Jakarta (75%) (Lestari et al. 2022) and Singapore, were obtained from the paper of (Setiawan et al. 2022). The average distance travelled in the city of Jakarta and Singapore per year was obtained from (Dewi et al. 2023) and (Wang et al. 2019). All the values as mentioned above are presented in Table 3 below. Data below based on Handbook of energy & Economic Statistic of Indonesia by Minister of Energy and Mineral Resources Regulation (2018).

Table 1. Electricity generation by source (TWh) in Indonesia and Singapore 2022

| Electricity generation source | Indonesia (TWh) | Singapore (TWh) |
|---|---|---|
| Coal | 205.3 | 0 |
| Oil | 6.1 | 2 |
| Gas | 56.7 | 48.2 |
| Renewables | 33.4 | 0.8839 |
| Total | 333.54 | 51.39 |

Table 2. Fuel consumption and number of vehicles per type in Jakarta and Singapore (2022)

| Variable (unit) | Electric Vehicles (EV) | Internal Combustion Engine Vehicles (ICEVs) |
|---|---|---|
| Fuel Consumption (EV:kWh/km - ICEV:L/100km) | 0.185 | 8.1 (Jakarta)<br>6.24 (Singapore) |
| Number of cars (2022) | 1043 (Jakarta - calculated)<br>7836 (Singapore - calculated) | 5.23 million (Jakarta) (estimated)<br>645130 (Singapore) |

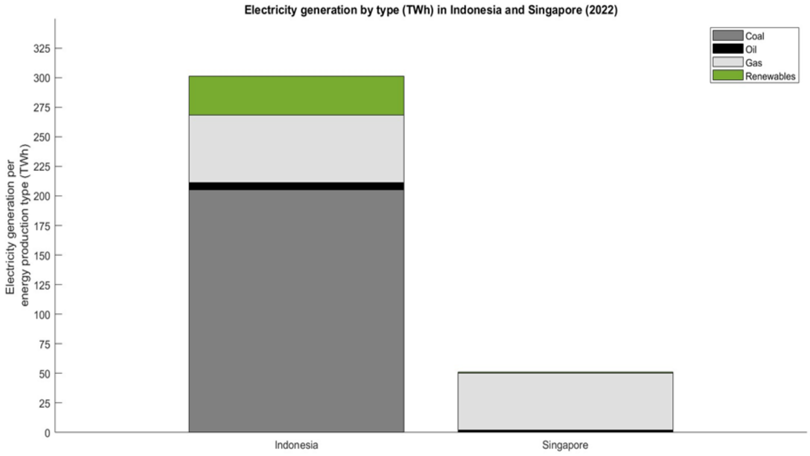


Figure 2. Electricity generation by type (TWh) in Indonesia and Singapore 2022

Table 3 shows the data to find the $CO_2$ emissions for ICEVs, equation 1 was used including their Cradle-to-gate emissions which are spread throughout the effective service life of the vehicle and added to the emissions per day, while equation 2 was used to find the effective $CO_2$ emissions for EVs by also taking into account the cradle-to-gate (or production) emissions according to a study by (Qiao et al. 2019) in the overall emissions of EVs and ICEVs during their lifetime in China.

The resulting value provides a total emission in grams of $CO_2$ released per kWh generated. The results are shown below in Table 4 and Figure 3 for both types and countries by using the formula as shown in the research method.

From the results, clearly Singapore is more environmentally friendly in terms of emissions from electricity production, relying purely on natural gas that has lower emission levels than both the coal and oil that Indonesia relies on. Additionally, the lower number of vehicles contributes to the far better AQI in Singapore.

However, as Figure 3 shows, the emissions from EVs are lower in Singapore with a value of 3.59 $kgCO_{2, eq}$/day than in Indonesia which has a value of 3.924 $kgCO_{2, eq}$/day. Despite the higher average distance driven by Singaporean citizens, the use of natural gas with lower emissions per kWh contributes to the lower emissions for EVs. This shows that Indonesia must reduce its dependency on the “dirtier” fossil fuels such as coal and oil and move to cleaner energy sources, ideally renewable. Despite this, the performance of EVs compared to ICEVs for both countries is far superior, with a decrease in emissions of 35% in Indonesia and 65% in Singapore. Additionally, high emissions per day are added due to the production emissions of EVs. For both countries, the average daily emissions for EVs have almost half their contribution come from the production emissions that are spread out throughout the service life of the vehicle. Therefore, for more efficient EV adoption, the manufacturing emissions of EVs must be lowered through more advanced technologies for the viability of EVs to increase.

This analysis, however, does not consider the disposal emissions for either type of vehicle or as mentioned at the beginning of the section, makes assumptions that would need to be addressed for a fully accurate analysis. However, despite these, for the increased adoption of EVs, steps towards higher reliance on reliable energy sources are required, as well as more sophisticated capabilities to reduce cradle-to-gate emissions.

**Recommendations for Scaling Up Electric Vehicles to Reduce Carbon Emissions**

Indonesia can learn from other countries that have shifted from conventional to electric vehicles by integrating electric vehicle-related policies into the national transportation policy. Several studies found that the increase in EV sales since 2009 was mainly due to policy support from the government in the early stages of EV market penetration, such as in China and Norway (Mathisen & Terje, 2020).

Table 3. Additional parameters required for carbon emission evaluation (MEMR, R., 2018)

| Variable (unit) | Value |
|---|---|
| Crude Oil CO2 equivalent emissions (gCO2/kWh) | 600 |
| Coal CO2 equivalent emissions (gCO2/kWh) | 920 |
| Natural Gas CO2 equivalent emissions (gCO2/kWh) | 400 |
| Gasoline CO2 equivalent emissions (gCO2/kg) | 3172.31 |
| EV cradle-to-gate CO2 equivalent emissions (kg CO2) | 11992 |
| ICEVcradle-to-gate CO2 equivalent emissions (kg CO2) | 9744 |
| Gasoline specific gravity (kg/L) | 0.715 |
| Average distance travelled by a vehicle per year (km) - Jakarta | 12000 |
| Average distance travelled by a vehicle per year (km) - Singapore | 17800 |
| Effective service life (years) | 10 |

Table 4. Resulting emissions per country

| Property | Indonesia | Singapore |
|---|---|---|
| $gCO_2$/kWh | 645.24 | 397.92 |
| EV emissions (Service Life)/EV emissions (Total) ($kgCO_{2,eq}$)/day | 3.9245 / 7.211 | 3.59 / 6.8766 |
| ICEV emissions (Service Life)/ICEV emissions (Total) ($kgCO_{2,eq}$)/day | 6.0403 / 8.7098 | 10.2964 / 12.9660 |

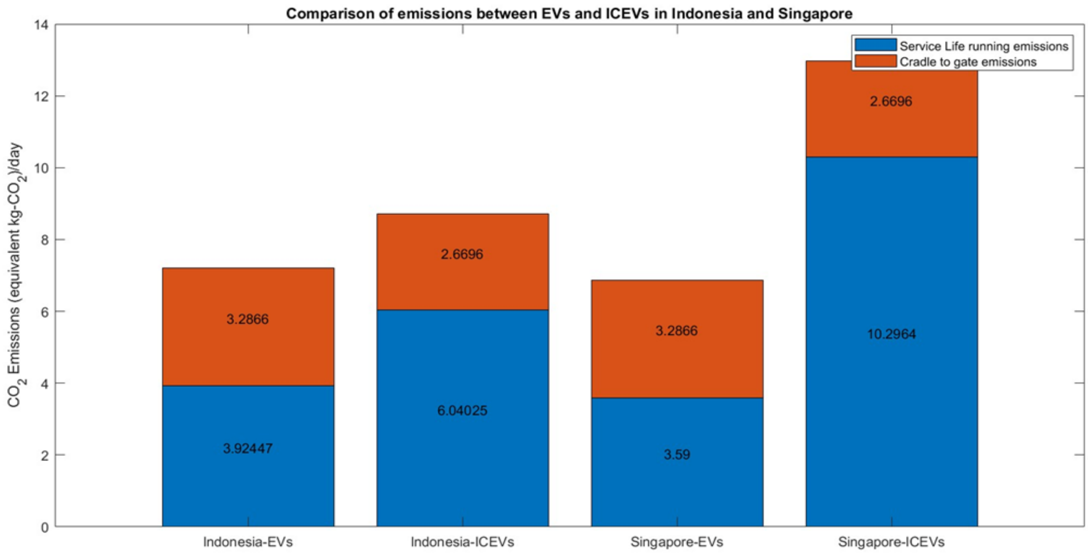


Figure 3. Comparison of emissions between EVs and ICEVs in Indonesia and Singapore

Electric vehicles are considered the most promising alternative to internal combustion engine vehicles for a cleaner transportation sector (Casals, 2016). Electric cars are more environmentally friendly than ICEVs. Overall, EVs can reduce emissions by 36% just by replacing ICEVs (Xu et al. 2020). Even from a life cycle point of view, EVs' greenhouse gas emissions are about 29% lower than ICEVs (Qiao et al. 2020).

**Policy**

There is a need for clear derivatives from Presidential Regulation Number 55 of 2019, issued on August 12th, regarding the acceleration of the Electric Vehicle Program, which is considered to potentially usher in the era of electric vehicles in Indonesia. These derivative regulations are expected to serve as legal guidelines for investors aiming to enter Indonesia, providing legal certainty for the development of their investments. These derivative regulations are anticipated to provide more detailed explanations about hybrid technology and production incentives. They will be issued by relevant ministries and institutions in collaboration with the business world and academia.

Looking at the demand aspect, the government has the capacity to aid in boosting the utilization of electric vehicles powered by batteries while ensuring the contentment of existing technology adopters. For newcomers, the government can hasten the uptake of electric vehicles by implementing regulations that reserve specific zones exclusively for these vehicles. Moreover, the government can extend financial incentives such as subsidies on purchases, lowered interest rates on loans, reduced initial payments, and tax cuts on vehicles. Educative and public awareness campaigns are also vital in fostering societal consciousness about environmentally friendly vehicle technology. Consequently, the approval of these types of vehicles by the public can grow. The government also has the potential to do away with emission testing policies for electric vehicles and make it easier for essential infrastructure to be constructed to facilitate public use of electric vehicles for commuting. Naturally, as the public's contentment with electric vehicles increases, the potential for expanding their utilization within the community also grows.

**Collaboration with Businesses and Inventors for Electric Vehicles**

Business actors and inventors of electric vehicles in developing their business ideas certainly need legal protection so that the inventions developed are not copied by other parties (Subekti et al. 2021). This is because the development of electric vehicle technology can lead to commercial progress (Pilkington, 2006).

Currently, climate change mitigation is strongly influenced by technology (Sohag et al. 2015). Sudjoko's research (2021) explains that the use of energy for electric vehicles can be 3-5 times more efficient than conventional vehicles. This proves that it is effective to reduce air pollution and accelerate the utilization of new renewable energy. The government needs to provide opportunities for the private sector to develop supporting infrastructure for electric vehicles which aims to help technology penetration in Indonesian society (Nur, 2021). Economic instruments should also be complements to ensure energy conservation and emission reduction results (Sudarmaji et al. 2022). Thus, this collaboration will increase public awareness of the importance of climate change carbon emissions through the maximum use of electric vehicles.

**Managerial Implication**

This study contributes to our understanding of the impact of electric vehicles on carbon emissions reduction. This critical understanding aids to aligning the steps that must be taken to attain sustainable development goals. It should be emphasised that encouraging the development of electric vehicles in Indonesia not only ensures a qualitative rise in profit vehicle sales, but also a step towards reducing the carbon footprint caused by fossil fuel transportation. As a result, governments should consider investing in electric car projects to improve environmental sustainability and avert global warming. Policies are also needed to improve coordination between Indonesian environmental protection and the UN so that the conflicting synergies between these two forces can converge and improve the UN framework (Nogueira et al. 2022).

This study emphasises the importance of research in contributing to reflection on the optimal road to net zero emissions, which must be sustainable and represent not only the development of electric vehicles, but also concerns for social, environmental, and economic justice. This deepens the relationship between carbon footprint reduction and automobiles by emphasising the necessity for academic research into the impact of electric vehicles.

The goal of the Jakarta-Singapore comparison is to establish a sustainable foundation (social, environmental, and economic) that can be clearly compared. It is intended that Jakarta can learn from Singapore's efforts to promote electric vehicles and its social approach. Based on this foundation, electric vehicle efforts that focus more on the welfare of society in general rather than just the amount of progress in economic growth can be created. Therefore, it is important to expand the study of carbon emissions to include the analysis of electric vehicles, to which this analysis contributes, thereby reducing the dearth of studies linking these two themes.

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

Comparing these two countries proves that electric vehicles are a viable solution for reducing transportation-related carbon emissions. Singapore has a lower carbon emission value for EVs despite longer average distances covered on average due to its reliance on natural gas instead of coal and oil as is the case with Indonesia, however, both cities need enormous improvements in their renewable energy investments to make EVs worthwhile.

Furthermore, global investing in the improved manufacturing of EVs and their components is required to reduce their production emissions. In contrast, Jakarta faces greater challenges in managing traffic congestion and air pollution caused by the massive use of conventional vehicles, resulting in a modest difference in carbon footprint between the two types of vehicles. This comparison also shows the policy differences between the two, proving that policy is one of the most important elements for scaling up electric vehicles in Indonesia. In addition, collaborative strategies with electric automotive businesses and investors also support the increase of electric vehicles in the Indonesian market.

### Recommendations

Future research might analyse consumer engagement techniques to raise interest in electric vehicles in metropolitan areas to better further examination of their influence on carbon emissions. This is critical to convincing people to switch to environmentally friendly and sustainable products.

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