Assessing the Environmental Impact of Electric Vehicles

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Summary

The transportation sector is a major source of greenhouse gas emissions in Indonesia (IESR, 2023). Electric vehicles (EVs) have emerged as a promising option for transitioning towards more sustainable transportation. However, while EVs offer advantages in reducing emissions, challenges remain concerning electricity generation and battery production. Strategies such as circular economy practices and increasing the share of renewable energy can help maximise the environmental benefits of EVs.

Keywords: electric vehicle, environmental impact, life cycle assessment, greenhouse gas, circular economy, renewable energy

Introduction

The escalating impact of greenhouse gas (GHG) emissions on global warming continues to intensify, with transportation emerging as a significant catalyst for these emissions. Globally, the transportation sector caused 8 $GtCO_2e$ in 2022 (IEA, 2023). In Indonesia, the transportation sector is the second-highest source of GHG emissions, contributing 20% of indirect emissions. Among these, road transport takes the lead, contributing 90% of the transportation sector's GHG emissions (IESR, 2023).

The transportation industry heavily relies on fossil fuels like coal, oil, and gas, releasing substantial volumes of GHGs and contributing significantly to creating formidable climate change (Fan et al., 2018). Transportation vehicle releases air pollutants like nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon oxides (CO), ozone, volatile organic compounds (VOC), toxic heavy metals (e.g., lead, mercury), organic pollutants (e.g., dioxins), and particulate matter (PM). These pollutants have detrimental effects on human health, impacting different bodily systems (Kampa & Castanas, 2008). Additionally, transportation noise poses significant health concerns (Kampa & Castanas, 2008).

Hence, it remains imperative to mitigate these environmental impacts and reduce the transportation sector's reliance on conventional fuel sources.

Out of all the best alternatives aimed at mitigating air pollutant emissions originating from conventional vehicles, EVs have emerged as the best option for transitioning towards a more environmentally sustainable transportation, enabling a greater reduction in CO_2 emissions compared to ICEVs.

The number of EVs has increased rapidly in recent years, with electric car sales surpassing 10 million in 2022 globally (IEA, 2023). In Indonesia, there has been a growing trend on the adoption of electric two-wheelers (E2W) on the road. Meanwhile, the average battery electric vehicle (BEV) growth per quarter is around 9,800 for E2Ws and 2,500 for electric cars (E4Ws) (IESR, 2023).

The Government of Indonesia has made substantial efforts to accelerate the adoption of EVs. These include a range of fiscal policies, such as exemptions of EVs from title transfer and ownership fee (*bea balik nama kendaraan bermotor/BBNKB*) and vehicle tax (*pajak kendaraan bermotor/PKB*), as regulated in Act No. 1 year 2022 on Financial

Relations between the Central Government and Regional Governments. In addition, the government has issued several non-fiscal policies in 2022 to further support the use of EVs. These include instructions to adopt EVs as the government's official vehicle, regulations to expand EV conversions beyond the 2W segment (in line with 2020's E2W conversion policy), regulations regarding technical requirements, national EV roadmap, and local content requirement (LCR) guidelines.

From an environmental standpoint, substituting ICEV for EV appears to be a potential step in achieving urban sustainability. Adopting EVs would result in advantages such as decreased air pollution and reduced noise levels in urban settings. Although EVs considerably contribute to reducing emissions, it is also important to investigate their environmental impact. Life-cycle assessment (LCA) is proposed to estimate the environmental effects related to all life-cycle stages of EV, spanning from raw material extraction and processing, manufacturing and assembly, to utilisation and end-of-life (EoL) (ISO, 2006).

To explore the environmental trade-offs of EVs, this op-ed will conduct a comprehensive review of literature sources, specifically focusing on the comparison between EVs and ICEVs in Europe.

Overview of Life Cycle Stages

LCA follows guidelines outlined in ISO 14044, which include:1) Goal and scope definition, 2) Inventory analysis, 3) Impact assessment, and 4) Interpretation (according to goal and scope).

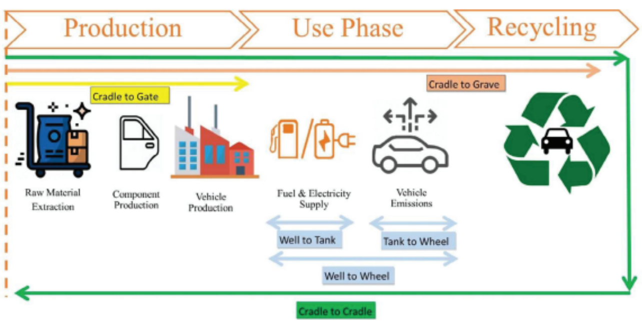

Fig. 1 Representation of different stages of LCA for EV (Source: Verma et al., 2021)

The life cycle of an electric vehicle (EV) can be divided into three main stages: production, use, and recycling (Fig. 1). The production phase encompasses everything from raw material extraction to vehicle assembly before delivery to consumers (Messagie et al., 2010). The utilisation phase, commonly referred to as the Well-to-Wheel (WTW) phase, consists of the fuel and electricity production or Well-to-Tank (WTT) phase and operation of the EVs or Tank-to-Wheel (TTW) phase (Hill et al., 2023). As for last, the recycling phase consists of the EV's end-of-life scenarios, such as disposal to landfill, component re-using, and materials recycling (Hill et al., 2023).

Environmental Impact of EV

1. Production Phase

When it comes to examining the GHG emissions from comparable-sized battery electric vehicles (BEVs) and EVs in the production phase, including those originating from raw material supply, the LCA consistently indicated that the production of BEVs has a larger environmental impact than that of ICEVs (Ellingsen et al., 2016; Kim et al., 2016). The notable contrast between BEVs and ICEVs in terms of production energy requirements primarily stems from the vehicle battery. The entirety of battery production contributes to approximately 33-44% of the total emissions generated in the production of BEVs (Ellingsen & Hung, 2018).

Raw materials processing involves resource-heavy steps like extraction, separation, and refining, which consume significant amounts of water, energy, and substances like ammonia (Massari & Ruberti, 2013; Larcher & Tarascon, 2014; Dunn et al., 2015). Another significant contributor to GHG arises from direct CO_2 emissions and perfluorocarbons produced during aluminium manufacturing. BEVs utilise larger amounts of aluminium to lighten the vehicle components, resulting in comparatively higher GHG emissions during production.

The use of specialised lightweight materials in BEVs aims to enhance energy efficiency during operation, enabling longer travel distances on a single charge (Romare & Dahllöf, 2017). However, the production of these materials, at times, can generate more GHG compared to materials used in ICEV due to the heightened demand for energy-intensive manufacturing processes (European Environment Agency, 2018). Other than the said effects, other byproducts produced during the raw material process may contain hazardous substances and toxins, leading to detrimental effects such as eutrophication, acidification of water bodies and wetlands, soil contamination with heavy metals, soil erosion, and loss of biodiversity.

Another point needs to be noted is that the production of EV specifically for EV batteries, relies heavily on rare earth metals and minerals. Responsible sourcing and recycling initiatives are crucial to mitigate the environmental impact of mining and reduce the depletion of valuable resources. The European Union through Regulation (EU) 2023.1542 concerning Batteries and Waste Batteries has set a mandatory battery due diligence policy for economic operators to identify and mitigate the environmental risks associated with raw materials used in battery manufacturing.

2. Utilisation/Operational Phase
Most LCA indicates that the WTW GHG emissions per kilometre travelled by BEVs in Europe are lower compared to those of ICEVs and hybrid vehicles. The WTW emissions of a mid-sized BEV ranged between 60–76g of CO_2eq/km, a significant 47% to 58% lower than emissions of an average mid-sized passenger ICEV in 2015, which stood at 143g of CO_2eq/km (European Environment Agency, 2018; Nordelöf et al., 2014).

The emissions of various GHGs and air pollutants per unit of electricity generated vary depending on the source of electricity generation.

It is important to note that GHG emissions of typical BEVs WTW charged using coal-generated electricity are similar to or exceed those of an equivalent ICEV, which ranges between 139–175g of CO_2eq/km. However, charging BEVs with other fossil fuel types results in slightly lower GHG emissions compared to ICEVs (Nordelöf et al., 2014). In contrast, a BEV charged with wind power would exhibit WTW GHG emissions of merely 1-2 grams of CO_2eq/km. It is also worth mentioning that the generation of electricity to power vehicles is accountable for emitting PM, NO_x, SO_2, and other air pollutants other than GHG. Meanwhile, the operation of BEVs produces no air pollutants through tailpipe exhaust. However, they still emit non-exhaust PM from brake systems and road friction.

By knowing that a significant portion of emissions during the utilisation phase originates from the WTT phase, which is heavily influenced by the energy mix. It is crucial for nations to shift to renewable energy. Several countries have ambitious plans in increasing renewable energy share in their energy mix target, such as The European Union with a minimum of 42.5% of renewable energy share in 2030.

3. End-of-life Phase (Material Recycling)
According to Tagliaferri et al. (2016), climate change impacts during the end-of-life stage are comparable for both BEVs and ICEVs. Studies indicate that the disposal of batteries at the end of life for EV contributes to end-of-life GHG, accounting for approximately 14–23% (Ellingsen et al., 2016).

To support the development of circular economy and allow a more resource-efficient use of raw materials, the European Union (EU), through Regulation 2023/1542 on Batteries and Waste Batteries, has set mandatory recycled content targets for 2031, accounting for 16%, 85%, 6%, and 6% for cobalt, lead, lithium, and nickel respectively.

Apart from that, producers should finance the costs of collecting, treating, and recycling all collected batteries, carrying out compositional surveys of mixed collected municipal waste, reporting on batteries and waste batteries, and providing information to end-users on their proper use and disposal. These extended producer responsibility (EPR) rules aim to enhance environmental protection by ensuring high rates of separate battery collection and efficient recycling.

What Can Be Done to Reduce the Environmental Impact of EV

1. Circular Economy Practice

Reducing resource usage in raw material supply can be achieved through recycling. Manufacturing primary aluminium demands roughly 20 times more energy compared to recycling scrap aluminium (IEA 2000a, 200b). Utilising recycled materials for the entire battery production process could potentially cut GHG emissions by up to 50% (Dunn et al., 2015). Battery reuse can involve direct incorporation into electric vehicles or repurposing for alternative applications, such as energy storage. Strategies like battery reuse, remanufacture, functionalisation, and recycling are integral to the circular economy, substantially reducing the environmental impact during the end-of-life stage while also gaining monetary benefit.

Numerous countries have expressed concerns over the detrimental effects of electric vehicle batteries. The European Parliament and The Council of EU passed a new battery regulation under Regulation (EU) 2023/1542 that extends producer responsibility and requires due diligence of supply chains to assess social and environmental risks. The Regulation also sets an ambitious target on the collection rate for portable batteries and LMT (Light means of transport) batteries, as well as imposes obligations on end-users to discard waste batteries separately after detaching them from the used appliances.

In Washington, D.C., a state law has been enacted necessitating EPR for both disposable and rechargeable batteries. Concurrently, Indonesia, being among global primary nickel reserves, has not set any regulation pertaining to the handling and recycling of electric vehicle battery waste.

2. Increasing Share of Renewable Energy in Energy Mix

Air pollution and GHG emissions linked to electricity generation are contingent upon the energy mix at the time and place of vehicle manufacturing, presenting opportunities to reduce GHG emissions by transitioning into a decarbonised electricity grid. Currently, BEV components are manufactured separately in various locations, but the majority of battery production, which is the most energy-intensive stage, is done in China, South Korea, and Japan, where electricity generation exhibits relatively high carbon intensity (Ellingsen & Hung, 2018).

Effective approach in reducing emissions involves increasing the use of renewable energy in BEV production. The reduction could be achieved through several possible scenarios, including shifting key battery manufacturing hubs toward countries favouring renewable energy, alongside the anticipated advancements in the adoption of low-carbon electricity and emissions reduction in existing manufacturing locations. Transitioning into renewable energy sources would also result in further reductions in per-kilometre emissions of WTT associated with BEVs.

In parallel with Indonesia's plan to increase EV adoption, the country has pledged to increase renewable energy share in the energy mix through Government Regulation No. 79 /2014 on the National Energy Policy, targeting at least 23% in 2025 and 31% in 2050 for the renewable energy share in the national energy mix. Despite the target, the realisation of renewable energy growth remains low, with only less than a 10% contribution to the primary energy mix.

Conclusion

The transition from ICEV to EV is a pivotal step to mitigate the environmental impact of the transportation sector. EVs offer significant advantages, such as a notable reduction in GHG emissions during the operation, contributing to improved air quality. However, challenges persist particularly in the production phase, especially the production of EV batteries, whose environmental impact outweighs that of ICEVs. Efforts to minimise the environmental impact of EVs should focus on improving the sustainability of raw material usage, battery production, and end-of-life disposal. Additionally, transitioning toward a higher share of renewable energy in the electricity grid will maximise the benefits of EVs and reduce emissions associated with their use.

Disclaimer

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