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Environmental Perspectives of Electric Vehicles in Thailand: Advantages and Challenges

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ABSTRACT

Electric vehicles (EVs) are introduced to the market to reduce the global environmental problems that draw attention to not only the automobile manufacturers, but also the users. To promote the use of EVs, environmental perspectives of EVs from the upstream to downstream must be considered. This study, thus, aims at examining the positive and negative environmental impacts of the EV supply chain, focusing on the production of electric batteries, the vehicle production, the use and maintenance of EVs, and the end-of-life disposal utilizing the analytic hierarchy process (AHP) method. Six interviewees, including consumers, manufacturers, and academic personnel provided data for the analysis. The results reveal that EVs provide a positive environmental impact, specifically in less CO_2 emission and fuel consumption. The management of end-of-life batteries is, in contrast, a major environmental concern, and more research of recycling and disposal of electric batteries should be encouraged to enhance the environmental perspectives of EVs in Thailand.

Keywords: Analytic hierarchy process; Electric vehicle; Environmental impact; Thailand

1. Introduction

The use of combustion cars from the transportation sector increases the greenhouse gas (GHG) emission and leads to environmental effects in today's world. Many countries around the world, as well as Thailand, are attempting to promote the use of electric vehicles (EVs) to deal with the global warming issues and GHG emission. A majority of Thai people are giving attention to this problem, as the rate of EV adoption in Thailand has steadily increased, from 1454 battery EVs (BEVs) in 2018 to 32,081 BEVs in 2022, representing over 200% growth in the past four years [1]. The Thai government launched the “carbon neutrality economy and green manufacturing” campaign, aiming to

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achieve net-zero emissions by 2050 [2]. It is expected that by 2030, 30% of new vehicles produced in Thailand will be zero-emission vehicles (ZEVs) and will become 100% by 2035 [2, 3]. EV battery end-of-life plan and management, charging station subsidization, skilled worker development, special tax rate, and EV package promotion are also among the government plans to enhance EVs in the long-term [2].

Despite being environmentally friendly in the usage stage, it is questioned that EVs have positive impact to the environment in the whole supply chain (i.e., from manufacturing to disposal). Production of electric batteries from the traditioned coal-mining plants generates various emissions, such as carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxide (NO_x) [4]. To promote the use of EVs in Thailand to achieve a sustainable environment, it is important that positive and negative environmental impacts are understood so that effective campaigns can be initiated. This study, therefore, aims to identify key environmental advantages and challenges along the chain of EVs. The importance weight of each impact factor is also calculated utilizing the analytic hierarchy process (AHP) method. It is expected that the study results will provide a better understanding of the environmental impacts of the EV supply chain and guide the government to prioritize the environmental burdens to achieve environmental sustainability and enhance the use of EVs in the long term.

The study reviews environmental impacts of EVs through a number of literatures, both in Thailand and other countries, to extract key environmental advantages (or positive impacts) and challenges (or negative impacts) of EVs and develops the hierarchical model of environmental impact of EVs in Thailand. Interview questions are then set based on the hierarchical model to be used for data collection. Experts in EV manufacturing, academic researchers, and experienced EV users participate in the interviews. The collected data are then analyzed with the AHP method to determine the importance weights of the environmental advantages and challenges of EVs in Thailand. The Thai government and related agencies may use the study results to plan for EV promotion campaigns to raise the EV usage and enhance the environmental sustainability in the long term.

2. Literature Review

Environmental impacts of EV supply chain must be considered to understand the overall impacts. Understanding its whole chain from upstream to downstream helps determine positive and negative sides of EV adoption. Based on a number of EV- and automobile-related literatures, a hierarchical model of environmental impacts of EVs is conceptualized (see Fig. 1).

2.1 Positive environmental-perspective factors

Based on a number of literatures, three key positive environmental impacts of EV supply chain are "less pollution while driving", "less fuel consumption while driving", and "friendly battery type" [4-7]. The "less pollution while driving" impact is confirmed by several studies. Dhar et al. [5], for example, mentioned that EVs improve energy efficiency, reduce air pollutant emissions, and boost the integration of renewable energy. Yagcitekin et al. [7] conducted a case study in Istanbul, Turkey, and concluded that EVs help reduce the CO_2 emission in the transportation sector. Saisirirat et al. [8] stated that 14.09% of GHG emissions can be reduced in Thai transportation through EV adoption. The use of EVs also reduces the demand of petroleum fuel as it is powered by electricity [8]. Spyropoulos et al. [9] stated that it is expected that the emissions of CO_2, dust, and NO_x in Greece will be highly reduced in 2030 through the uses of EVs and green vehicles. Pipitone et al. [10] agreed that the use of EVs should minimize intake of PM 2.5, the acidifying emissions, such as NO_x, NH_3, and SO_2

introduced in the atmosphere, and global warming potential, which expresses the equivalent mass of CO_2 emitted to obtain a product or a service.

The “less fuel consumption while driving” impact is supported by various studies. Compared to conventional cars, EVs have little or no fuel consumption as they are powered by electricity. This could lead to a decrease in the demand for petroleum products [8]. As a consequence of consuming electricity instead of fuel, EVs emit little to no pollution during the usage stage. Qiao et al. [4] mentioned that EVs emit 24,670 kg CO_2eq every driving cycle, which is approximately 41% less than internal combustion engine (ICE) cars in Beijing in 2020.

The “friendly battery type” impact is confirmed by Lipu et al. [11] that the lithium-ion battery (LIB) is considered an environmentally friendly battery type as its lifespan, setting aside the breakdown, is 8-10 years, while a lead-acid battery only lasts for approximately 2-4 years. Muzir et al. [12] agreed that the life cycles of EV batteries are longer than those of ICE batteries.

2.2 Negative Environmental-Perspective Factors

Three main environmental concerns of the use of EVs are the “management of end-of-life LIB”, “pollution in the manufacturing processes”, and “resource depletion”. The “management of end-of-life LIB” impact is confirmed by various studies. According to Battery Council International [13], recycling LIBs is essential to conserve the materials and resources being used in the manufacturing process as 100% of lead acid batteries used in internal combustion engine vehicles are recyclable. Waste Advantage Magazine [14] mentioned that current LIB end-of-life is yet environmentally friendly, as it contains much more complicated chemistries and a mixture of materials that are harmful to the environment during the disposal processes. Richa et al. [15] added that LIB materials after being disassembled are categorized into two categories: non-reusable and recyclable. However, both raise concerns over environmental impact. Mixed plastics, graphite, and electrolytes are examples of non-reusable materials due to the lack of infrastructure or economic motivation. These materials usually end up in landfills which can take up to several centuries to decompose naturally without any help of technology. The recycling processes of LIB are complicated and require more R&D [16, 17]. LIB is shredded after being burnt or plunged in liquid nitrogen. The hazard primarily comes from the remaining lithium atoms in the anode, which can react violently with moisture. Also, the lithium salts in the electrolyte destabilize and react strongly at high temperatures causing environmental impacts in the long term [16, 17].

The “pollution in the manufacturing processes” impact, especially in the electric battery production, is supported by several literatures. Shu et al. [18] stated that the large-scale production and application of electric vehicle batteries cause environmental pollution. Particularly, the metal materials used in the batteries are harmful to human health and the surrounding ecological system. Earth [19] mentioned that the electric battery production relies on the lithium-ion materials and mining these materials has a high environmental cost that makes the EV manufacturing more energy intensive than that of an ICE vehicle. The EV production incurs additional emissions of, for example, CO_2, SO_x, NO_x, PM 10, and PM 2.5 [20].

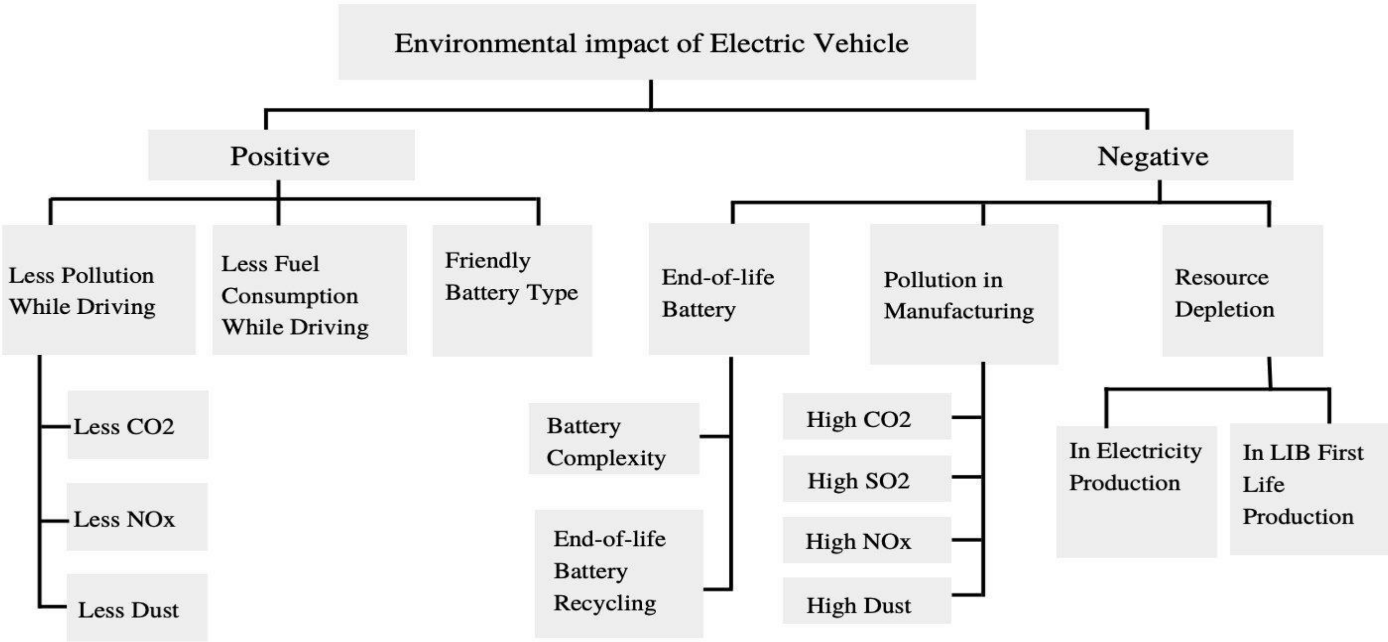

Fig. 1. Hierarchy model of the environmental advantages and challenges of EVs.

The "resource depletion" impact in the electricity production and LIB first life production are mentioned in a number of studies. UNCTAD [21] stated that the demand for raw materials used to manufacture rechargeable batteries will grow rapidly as the importance of oil as a source of energy recedes. For the electric battery production, the demand of raw materials is estimated to increase by factors of 18-20 for lithium, 17-19 for cobalt, 28-31 for nickel, and 15-20 for most other materials from 2020 to 2050. These require a drastic expansion of lithium, cobalt, and nickel supply chains and likely additional resource discovery [22].

3. Materials and Methods

3.1 Overview of analytic hierarchy process

The AHP method is utilized in this study to examine the importance of key factors affecting the environmental impact of the electric vehicle. It supports decision making in a multi-criteria way. It is an effective approach to simplifying complex problems by dividing problems into factors and levels [23]. Factors in the same hierarchy level are compared to determine the most significant factor and choice. Ammarapala et al. [24] concluded its advantages, including ease of use, accuracy of the results, ability to deal with both qualitative and quantitative factors, and ability to test the consistency of the responses.

Several business-related studies have been conducted using the AHP method. Yap et al. [25], for instance, utilized the AHP method for business site selection in Malaysia. Baj-Rogowska [26] selected the IT system to support business operations in the logistics enterprise using the AHP method. Longaray et al. [27] used the AHP method to evaluate the quality of services provided by outsourced companies. Kaewfak et al. [28] applied the AHP method in route selection of coal transportation in Thailand.

The Expert Choice software is used in the AHP analysis in this study (see Fig. 2). The expert interview is used as a data collection method. Each interviewee is asked to provide the score in each pairwise comparison using the scale 1-9, where 1 represents equally important, 5 represents strong importance of a factor over another, and 9 represents extremely strong importance of a factor over another [24].

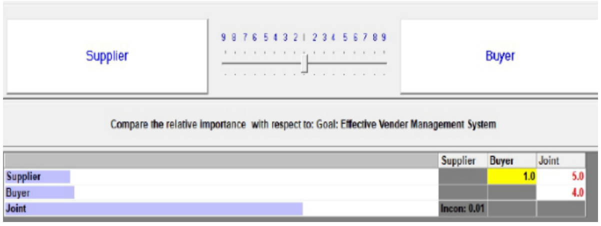

Fig. 2. Example of Expert Choice program.

Six experts are involved in the interviews. Ammarapala et al. [24] and Melon et al. [29] stated that 5-7 experts are reliable for the AHP analysis, since too much data complicates data management, and requires higher costs. Details of experts are as follows:

- Two experts are owners of automobile manufacturing businesses in the transportation industry. One of them has over 27 years of working experience; another one has more than 10 years of working experience.
- Two experts are working in the academic industry. One is a researcher from a top university in Thailand and has been working closely with chemical substances. The other is an adjunct professor who has written a book about EVs.
- Two experts are EV users with over 3 years of experiences and have owned at least two EVs.

3.2 Data collection

Interviews were conducted to gather information from experts to be used with the AHP analysis. Each expert was asked to rate his/her opinions on a number of pairs of factors or sub-factors, pair-by-pair, using the Saaty score (see Table 1). For example, the interviewee was asked to compare the importance of less pollution while driving and friendly battery type of LIB. If the interviewee considers the less pollution while driving as having extremely most importance in being environmentally friendly, he/she then gives the score of the less pollution while driving of 9. This, vice versa, gives the score of the *friendly* battery type of 1/9 (see Table 2). Sub-factors are also compared in each hierarchy level, pair-by-pair, using the scale 1 to 9. For instance, if the interviewee considers the "less CO_2" as having equal importance to the "less NOx", he/she then gives the score of 1 to both of them.

Table 1. Saaty score for the AHP analysis [24].

Scale	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment favor one factor over another
5	Essential or strong importance	Experience and judgment strongly favor one factor over another
7	Very strong importance	A factor is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence of favoring one factor over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate value	Intermediate values when compromise is needed

Table 2. Example of the interview scores.

Factor	Score		
	Less CO2	Less NOx	Less Dust
Less CO2	-	9	3
Less NOx	1/9	-	1/6
Less Dust	1/3	6	-

4. Results and Discussion

Data collected from the interviewees are analyzed with AHP to examine the importance of each factor and sub-factor in the environmental perspective of EVs. For each interviewee, the importance weights of factors and sub-factors in each level are calculated and confirmed with the consistency ratio (CR) values [24]. If the RI values are not in the acceptable ranges, the expert is requested to reconsider the scores of factors or sub-factors to adjust the CR values before the importance weights are finalized. The accepted importance weights of factors and sub-factors from six interviewees are then normalized using the geometric mean to achieve the final hierarchical model of environmental impact of EVs. The flow diagram of the AHP analysis is as shown in Fig. 3.

The analysis results (see Fig. 4) show that majority of experts agree that the use of EVs provide positive impacts to the environment with the importance weight of 87.8%. The key positive impact is "less pollution while driving" (importance weight of 72%), especially in CO_2 reduction. This is consistent with Vidhi and Shrivastava [30] that EVs help reduce air pollution and CO_2 emissions in India in the long run. Qiao et al. [4] added that the life cycle of an EV's GHG emissions are 29% lower than those of conventional cars.

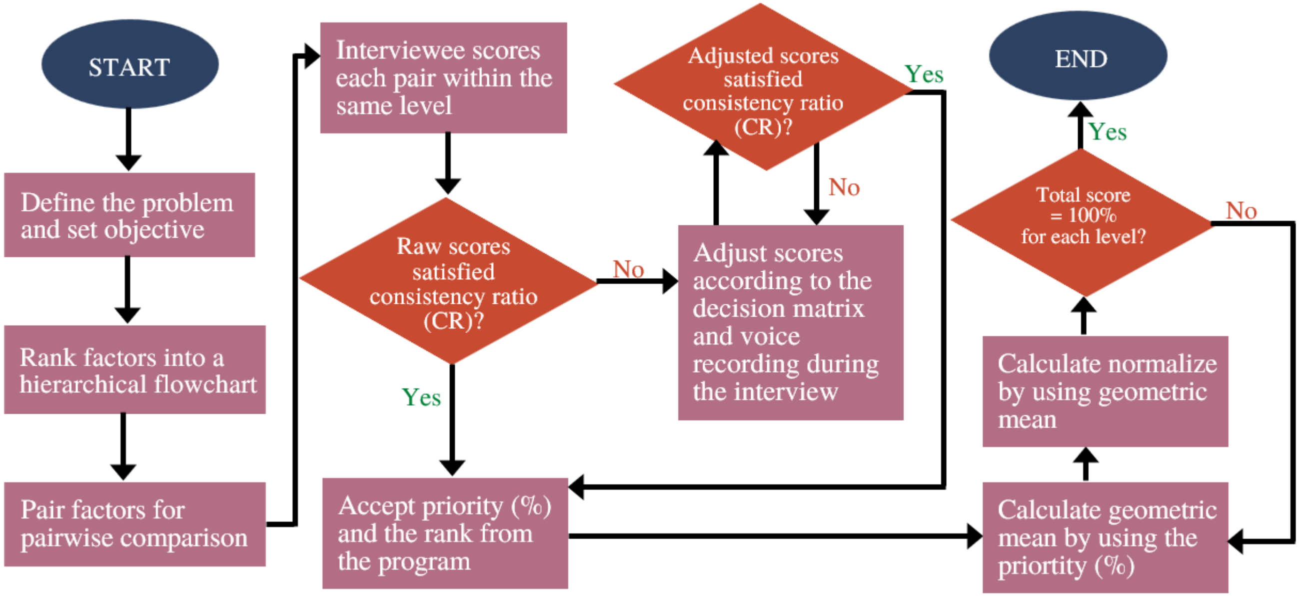

Fig. 3. Flow diagram of the AHP analysis.

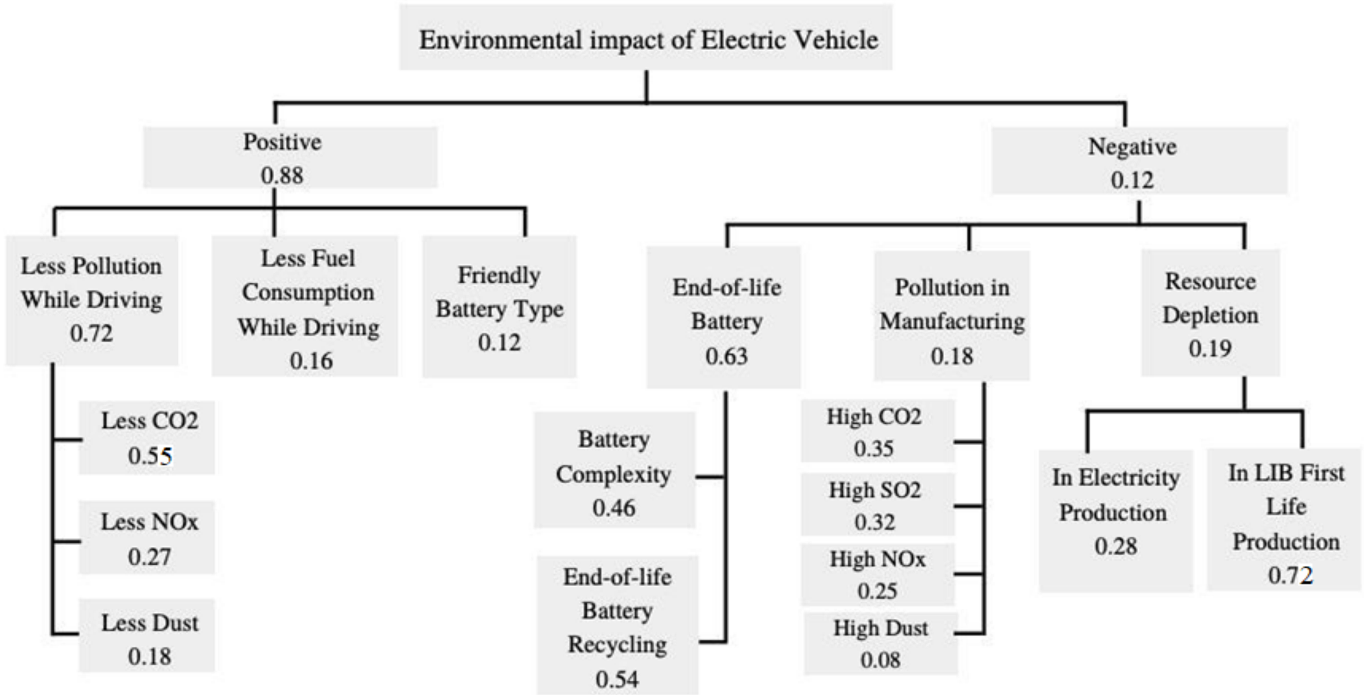

Fig. 4. Final hierarchy model of the environmental impact of electric vehicle.

The use of EVs also helps reduce the effects of hazardous exhaust gas emissions i.e., NO_x, on human health. Burchart-Koral et al. [31] explained that NO_x, one of the GHG emissions, is an irritating gas that causes inflammation of the respiratory system and increases allergic reactions if inhaled in high quantities. NO_x also plays a role in the growth of fine particles (PM) and ground-level ozone, most of which are related to health consequences. A 40% EV conversion could result in a NO_x reduction of more than 10%.

The results show that “less fuel consumption while driving” and “friendly battery type” receive less importance weights compared with “less pollution while driving”. This may be because the electricity production in Thailand, which is the main fuel used in EVs, still relies mainly on coal fired power plants [32].

The most concerned negative environmental impact of EVs is “the management of end-of-life LIB”, especially in the complexity of LIB recycling processes, with the importance weight of 63%. According to Sonoc and Jeswiet [16], there is no standard method to deal with the end-of-life LIBs. There is no presence of a large-scale industry in the process of recycling LIBs. High acidification potential related to the smelting process during the recycling stage of LIBs causes toxic air that is harmful to humans [33]. Moreover, due to the lack of the economic influence, up to 97% of LIBs are not recycled [16]. Substitute chemistries used in the LIB are still not widely accepted and unavailable in the market. These materials usually end up in landfills which can take up to several centuries to decompose, and result in chronic problems for humans and aquatic animals, and cause water and soil contamination, and air pollution [34].

The production of LIBs also raises the concern in the “resource depletion” factor with the importance weight of 71%. Wangjiraniran et al. [32] mentioned that Thailand will need more primary fuels, such as natural gas and coal, to generate more electricity if the EVs are in use. This will lead to an increase in primary fuels usage and, consequently, result in increased GHG emissions.

High CO_2 and SO_2 emissions are major concerned pollutions in the manufacturing processes, with the importance weights of 35% and 32%, respectively. Helmers and Marx [33] stated that CO_2 and SO_2 are emitted during the electricity production from coal fired power plants. Pero et al. [35] added that the emissions in the raw material mining and chemicals and metals manufacturing (i.e., aluminum, copper, nickel, and platinum) used in the electric drivetrain of LIBs are mainly responsible for the toxicological effect.

5. Conclusions

This study identifies the environmental benefits and drawbacks of EVs supply chain to seek feasible solutions for long-term improvement. The AHP analysis results reveal that the dominant positive environmental impact of EVs is lesser to no GHG emission during the usage stage. Governments may launch campaigns, targeting to increase EV adoption, to control the CO_2 emission and support education related to EVs for long-term improvement. Manufacturers may also promote the benefits of EVs to persuade more customers and gain more attention. The Conference of the Parties (COP26), which includes Thailand and many other countries, announced the goal of being carbon neutral by 2050 and net-zero GHG emissions by 2065 to keep the global temperatures down by 1.5 degree Celsius [36]. To this end, the Thai government is moving towards a carbon neutrality economy, focusing on green manufacturing and targeting that 30% of total car production (i.e., 750000 cars) are ZEVs by 2030 [2]. Incentive packages are approved, including tax cuts and subsidies to promote the country as the Southeast Asia's major auto production base [37].

The analysis results, in contrast, reveal high concerns in the LIB production and end-of-life management. UNCTD [21] mentioned that in Chile, lithium mining uses almost 65% of the water in the Salar de Atamaca region, one of the driest desert areas in the world, to pump out brines from drilled wells. This has caused groundwater depletion and pollution, forcing local quinoa farmers and llama herders to migrate and abandon ancestral settlements. It has also contributed to environment degradation, landscape damage and soil contamination. The adverse environmental impacts could be reduced by increasing investment in technologies used to recycle rechargeable batteries. More R&D should be encouraged to improve the LIB recycling processes in terms of not only environmental reduction, but also economics. Alternative sources of electricity production, such as wind and water should also be encouraged to reduce the GHG emissions in the production stage. The advancement of electric battery recycling is necessary to economically recover battery-grade materials from end-of-life batteries [22].

This study contributes to the automobile industry, the LIB manufacturing, the government, and the related agencies. The government may use the study results to initiate various campaigns to promote the sustainable use of EVs. Supports could be provided to the EV and LIB manufacturers in terms of, for example, excise tax reduction, LIB end- of- life management training, provision of incentive packages of import parts, and partial support on charging infrastructure investment. The use of clean energy for electricity production, to replace coal- fired power plants, should also be encouraged to achieve the sustainability in the whole supply chain of EVs.

This study has a limitation. Limited experts from automobile manufacturers, academic, and consumers are used in the AHP analysis. An increase in the number of experts may enhance the analysis results.

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