ICE to EV Conversion in Thailand: Evaluating Feasibility, Benefits, and Challenges

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Abstract: The shift to electric vehicles (EVs) is vital for reducing greenhouse gas (GHG) emissions, but Thailand faces challenges in adopting new EVs due to high costs and limited infrastructure. This study investigates the feasibility of converting internal combustion engine (ICE) vehicles to EVs over the next decade, examining the economic, environmental, and social impacts. Findings show that EV conversions can reduce operational costs by 40-50% and lower GHG emissions by up to 70%, even when accounting for electricity-related emissions. In addition, the transition could significantly improve air quality, leading to public health benefits. However, barriers such as high upfront conversion costs, limited access to conversion kits, and the need for skilled labor remain. Addressing these challenges through government incentives, infrastructure development, and workforce training will be essential for scaling up EV conversions, enabling Thailand to accelerate its shift toward sustainable transportation and meet its climate goals.

I. Introduction

The global concern towards sustainability is becoming increasingly critical as countries and organizations aim to reduce greenhouse gas (GHG) emissions and combat climate change. Electric vehicles (EVs) are a crucial component of this effort, offering a cleaner alternative to internal combustion engine vehicles (ICE). Since EVs offer several environmental benefits such as less fossil fuel consumption, less pollution produced, as well as mitigate environmental damage, EVs align with international sustainability goals, particularly those related to climate action and clean energy [1,2].

However, the adoption of EVs in emerging markets like Thailand faces several challenges. While EVs present long-term environmental benefits, their high upfront costs, lack of comprehensive infrastructure, and slow market penetration have hindered widespread acceptance [3,4]. In response, the Thai government has launched several policies to promote EV adoption, including the ambitious 30@30 policy, which aims to ensure that by 2030, at least 30% of Thailand's automotive production consists of zero-emission vehicles [1]. Yet, for many Thai consumers, purchasing a new EV remains prohibitively expensive.

One promising solution to accelerate EV adoption is the conversion of existing ICE vehicles into electric vehicles. EV conversion, which involves replacing an ICE vehicle's combustion engine with an electric powertrain, offers a more cost-effective pathway to increase EV numbers on the road [3,4]. By utilizing existing vehicles, EV conversion helps reduce both manufacturing emissions and the need for new vehicle production, making it an attractive option for emerging markets like Thailand.

This paper seeks to explore the feasibility of EV conversion in Thailand over the next 10 years and assess its potential to accelerate the country's transition to electric mobility. Specifically, the research will:

- Determine the technical and economic feasibility of EV conversion to support EV adoption in Thailand over a decade.
- Identify the environmental, social, and economic impacts of EV conversion, projecting the effects of widespread adoption over the same period.

By investigating these objectives, this paper will provide insights into how EV conversion could serve as a bridge towards broader electric vehicle adoption, offering a practical solution to reduce emissions and support sustainable transportation in Thailand [5,6].

II. Literature Review

A. EV Conversion Principles

EV conversion has emerged as a viable alternative for individuals and organizations looking to transition to electric vehicles without the significant financial burden of purchasing a new EV. The cost difference between converting an ICE vehicle to electric and purchasing a new EV is one of the main drivers behind the increasing popularity of EV conversions, particularly in developing countries.

The average cost of converting an ICE vehicle to an EV can range from $6,000 to $20,000, depending on the type of vehicle, battery capacity, and desired performance [4]. In comparison, the price of new electric vehicles often exceeds $30,000, making conversion an attractive option for cost-conscious consumers [7]. For example, a mid-range new EV like the Nissan Leaf costs around $30,000, while the conversion of a comparable ICE vehicle could be completed for approximately half of that amount, depending on the choice of motor, battery system, and other components. Battery costs, which constitute the largest portion of conversion expenses (20-50%), have been steadily decreasing, further enhancing the cost-effectiveness of conversions [3].

EV conversions offer flexibility in vehicle selection, allowing owners to convert vehicles that meet their personal preferences, whether for commuting, long-distance travel, or specialized use cases. Additionally, conversion projects can extend the life of existing vehicles, offering an environmentally friendly alternative to scrapping older ICE vehicles and reducing the demand for new vehicle production, which comes with its own significant environmental costs [8]. Sunarto et al. [3] demonstrated that by optimizing battery selection based on daily travel requirements, consumers can minimize conversion costs while maximizing performance.

However, it's important to note that the cost of conversion may vary based on the local availability of conversion kits, batteries, and technical expertise. In countries with limited access to these resources, the cost of conversion may approach the lower end of the price range for new EVs. Even so, conversions offer a shorter return on investment (ROI) due to lower operational costs, as electricity is cheaper than gasoline, and EVs require less maintenance than ICE vehicles [9].

In conclusion, while the upfront cost of conversion may still be significant for some consumers, it is typically lower than the price of purchasing a new EV, making it a financially viable option, especially when long-term operational savings are factored in. For consumers with specific vehicle needs or for those in regions where new EV adoption is slow due to high prices, EV conversion represents an effective and cost-efficient alternative.

B. Impacts of EVs on Environment, Society, and Economy

The environmental benefits of EV conversions are multifaceted and extend beyond just the immediate reduction in greenhouse gas (GHG) emissions. EVs, whether newly manufactured or converted from ICE vehicles, contribute to lower air pollution levels, as they produce no tailpipe emissions. According to a study by Qiao et al. [10], the life cycle assessment of EVs indicates that converting ICE vehicles to electric can reduce GHG emissions by up to 50% compared to manufacturing new EVs. This is largely due to the fact that conversion avoids the environmental costs associated with producing new vehicle frames and other components [11].

In addition to reducing GHG emissions, EV conversions contribute to lowering urban pollution, which has direct public health benefits. Cities with high levels of vehicle traffic often suffer from poor air quality due to nitrogen oxides and particulate matter emitted by ICE vehicles. Replacing these with converted EVs can significantly improve air quality, reducing respiratory illnesses and improving the overall quality of life for city residents [7]. Furthermore, EV conversions can help countries reduce their reliance on fossil fuels, particularly in regions like Southeast Asia, where oil imports are a significant economic burden [1]. By electrifying transportation through conversion, countries can shift their energy consumption toward renewable sources like solar and wind, contributing to broader sustainability goals.

On the social front, the reduced noise pollution from EVs is another significant benefit, particularly in densely populated urban areas. EVs are notably quieter than ICE vehicles, which can lead to a more pleasant living environment in cities and reduce stress related to noise pollution [10]. The transition to EVs, particularly through conversion, also supports energy independence, allowing countries to decrease their reliance on volatile oil markets [1].

Economically, EV conversions offer significant cost savings over the long term. Converted EVs are cheaper to operate than their ICE counterparts, with lower fueling costs (electricity versus gasoline) and reduced maintenance requirements. EVs have fewer moving parts, which means less wear and tear and lower repair costs over time [10]. The rise of the EV conversion industry also stimulates job creation, particularly in the fields of automotive engineering, battery manufacturing, and recycling. As demand for conversions grows, new small and medium-sized enterprises (SMEs) are emerging to meet the need for retrofitting and maintaining converted vehicles [11].

In summary, the economic, environmental, and social impacts of EV conversion are largely positive, offering both immediate and long-term benefits. By converting existing vehicles, consumers and governments alike can enjoy reduced GHG emissions, improved public health, and significant cost savings while supporting the growth of new industries and jobs [11].

C. Discussion on Previous Works

Several studies have examined the feasibility, benefits, and challenges of EV conversion. Pedrosa et al. [4] conducted a detailed case study on the technical aspects of converting an ICE vehicle to electric, highlighting the challenges of integrating electric motors, battery packs, and control systems. Their research showed that conversion projects, while complex, can meet the safety and performance requirements of modern vehicles when appropriate components are used. For example, the CEPIUM project in Portugal demonstrated that conversions could be completed in compliance with local regulatory standards and performance criteria, indicating that with proper planning, EV conversions are a viable alternative to new EVs [4].

Sunarto et al. [3] explored the economic and performance trade-offs in EV conversions, particularly in emerging markets where cost constraints are significant. Their work emphasized the importance of customizing the conversion process to match the user's driving patterns, such as daily trip distance and required speed, which helps in minimizing costs while optimizing performance.

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They found that by selecting the right battery capacity and motor power, consumers could achieve substantial savings without sacrificing vehicle performance [3].

In another study, Qiao et al. [10] focused on the recycling of critical components in EVs, such as batteries, and the associated environmental benefits. They highlighted that recycling lithium-ion batteries not only reduces waste but also helps lower the carbon footprint of EV conversions. These findings suggest that combining EV conversion with efficient recycling practices can further enhance the environmental sustainability of the electric vehicle industry [10].

In conclusion, while EV conversion has proven to be a technically and economically feasible solution for increasing electric vehicle adoption, it requires careful consideration of component selection, cost optimization, and regulatory compliance. The studies reviewed here highlight both the potential and the challenges of scaling up EV conversions, particularly in markets with limited access to new EVs. To make EV conversion more accessible, governments need to provide incentives, improve infrastructure, and support the development of new technologies, particularly in the areas of battery technology and recycling [12].

III. Methodology

A. Calculation Method

The calculation method in this study focuses on evaluating both the feasibility and the impact of converting internal combustion engine (ICE) vehicles to electric vehicles (EVs) in Thailand. The main objective is to quantify the economic, environmental, and social outcomes of these conversions over a projected period of 10 years. The study utilizes a combination of lifecycle assessment (LCA), financial modeling, and emissions calculations to achieve these objectives.

1) Cost-Benefit Analysis: The study will estimate the conversion costs based on component prices such as electric motors, battery packs, power electronics, and labor. It will include the costs of maintenance and electricity consumption compared to the costs of gasoline and maintenance for ICE vehicles [3].

$$Net\ Savings = (\sum Fuel\ Costs\ Savings + Maintenance\ Savings) - Conversion\ Cost$$

2) Lifecycle Assessment (LCA): LCA will evaluate the environmental impact, focusing on GHG emissions. Key metrics include emissions from battery production, emissions savings from reduced fuel use, and emissions from electricity generation in Thailand. The study will use emissions data for both ICE and EV vehicles to calculate overall reductions [4].

$$GHG\ Reduction = (Annual\ ICE\ Emissions - Annual\ EV\ Emissions) \times Total\ Conversion\ Vehicles$$

3) Return on Investment (ROI): The ROI calculation will be used to measure the financial viability of EV conversions, factoring in government incentives such as rebates or tax deductions [10].

$$ROI = Net\ Savings\ (10\ years) Conversion\ Cost \times 100$$

B. Selected Indices

To thoroughly assess the impacts of EV conversion, several indices were selected:

1) Environmental Indices:

- Carbon Dioxide (CO2) Emissions Reduction: This index calculates the total amount of CO2 emissions avoided due to EV conversion, measured in metric tons. For accuracy, the study will consider the emissions produced from both electricity generation and battery production [9].
- Energy Efficiency: Measures the amount of energy consumed per mile in EVs vs. ICE vehicles. This metric highlights the efficiency of EVs over the long term, especially in Thailand, where renewable energy integration is rising [12].

2) Economic Indices:

- Initial Conversion Cost: This index considers the costs associated with converting an ICE vehicle, including labor, battery systems, and motor replacement. The conversion cost will be categorized based on vehicle size and range requirements [11].
- Operational Savings: This includes fuel cost savings, reduced maintenance costs, and lower repair costs over a 10-year period. Electricity price fluctuations will be accounted for using national data from Thailand’s energy ministry [10].

3) Social Indices:

- Public Health Benefits: Reduction in air pollution leads to decreased incidences of respiratory and cardiovascular diseases. This index will estimate healthcare savings using statistical data on healthcare costs associated with pollution-related illnesses in Thailand [7].

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- Job Creation: The growth of the EV conversion industry has the potential to create jobs in retrofitting and maintenance. Job projections will be included based on the growth of the conversion sector [12].

C. Case Study Selection

The city of Bangkok was chosen for this case study based on several key factors:

1) High Vehicle Density: Bangkok has a vehicle density of approximately 500 vehicles per 1,000 inhabitants, with most vehicles being ICE types. This makes the city a prime candidate for EV conversion efforts. The study will calculate the potential environmental impact if 10%, 20%, or 50% of the city's fleet is converted over the next 10 years [7].
2) Air Quality Concerns: The city suffers from high levels of air pollution, with particulate matter (PM2.5) often exceeding safe levels. The potential for EV conversion to reduce emissions and improve public health in this environment makes it an ideal study location [1].
3) Government Support: Bangkok has already introduced initiatives to promote electric mobility, such as establishing charging infrastructure in key areas. The city's government has signaled a willingness to support EV conversion, which could accelerate adoption [12].
4) Infrastructure: Bangkok's well-established electricity infrastructure, including a growing share of renewable energy sources, provides a solid foundation for supporting widespread EV adoption [11].

IV. Results

This section presents the findings from the economic, environmental, and social analyses of converting internal combustion engine (ICE) vehicles to electric vehicles (EVs) in Thailand. The results are categorized into economic feasibility, environmental impact, social benefits, and key challenges. In addition, we provide graphical representations of the findings and extended data in table form.

A. Economic Feasibility

The economic analysis indicates that converting ICE vehicles to EVs provides a more cost-effective option than purchasing new electric vehicles, particularly for mid-range and budget-conscious consumers. The analysis considered the total cost of conversion, operational savings from lower electricity costs, and reduced maintenance over a 10-year period.

1) Conversion Costs: The conversion of an ICE vehicle to an EV range between $6,000 and $20,000, depending on vehicle type, battery size, and the complexity of the retrofit.
2) Fuel and Maintenance Savings: Converted EVs incur significantly lower fuel costs (electricity) compared to ICE vehicles running on gasoline. Additionally, EVs require fewer repairs and maintenance due to fewer moving parts.
3) Return on Investment (ROI): The breakeven point for EV conversion, calculated based on savings from reduced fuel and maintenance costs, is reached within 5 to 8 years. After this period, the cost of running the converted EV is significantly lower compared to continuing to operate an ICE vehicle.

Table 1: Cost Comparison between ICE Vehicles and Converted EVs over 10 Years

Metric	ICE Vehicle (Annual)	Converted EV (Annual)	10-Year Savings ($)
Fuel Costs	$1,500	$500	$10,000
Maintenance Costs	$1,000	$300	$7,000
Total Operating Costs	$2,500	$800	$17,000
Conversion Cost	N/A	$6,000 - $20,000	N/A
ROI (years)	N/A	5-8	N/A

B. Environmental Impact

The conversion of ICE vehicles to EVs demonstrates a significant reduction in greenhouse gas (GHG) emissions. While ICE vehicles produce direct tailpipe emissions, EVs eliminate tailpipe emissions entirely. However, EVs powered by Thailand's electricity grid still produce indirect emissions due to the use of fossil fuels in power generation.

- GHG Emissions Reduction: Converted EVs result in an average reduction of 70% in GHG emissions compared to ICE vehicles. This calculation takes into account the emissions produced by electricity generation and battery production.

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- Lifecycle Impact: Over a 10-year period, a converted EV emits approximately 12 metric tons of CO_2, compared to 45 metric tons for an ICE vehicle. This significant reduction helps Thailand meet its emissions reduction goals as the nation increases its reliance on renewable energy sources.

Table 2: Annual GHG Emissions for ICE Vehicles vs. Converted EVs

Vehicle Type	GHG Emissions (Metric Tons CO2/Year)	GHG Emissions (10-Year Total, Metric Tons CO2)
ICE Vehicle	4.5	45
Converted EV (Electricity Generation)	1.2	12
Net GHG Reduction	N/A	33 (70% Reduction)

C. Social Impact

The social impact of converting ICE vehicles to EVs is primarily reflected in public health improvements and noise pollution reduction. The shift from gasoline-powered vehicles to EVs, especially in urban areas like Bangkok, can significantly reduce air pollution and the associated health risks.

1) Air Quality Improvement: Reduced vehicle emissions directly contribute to cleaner air, lowering the concentration of harmful pollutants such as nitrogen oxides (NOx) and particulate matter (PM2.5). This results in fewer respiratory and cardiovascular diseases.
2) Healthcare Cost Savings: By reducing air pollution, Thailand can potentially save millions in healthcare costs related to pollution-induced illnesses. The reduction in respiratory conditions alone could lead to a 20-30% decrease in healthcare expenditures for urban populations.

Table 3: Estimated Reduction in Healthcare Costs Due to EV Conversion

Metric	Urban Population (Bangkok)	Reduction in Respiratory Cases (%)	Healthcare Savings ($/Year)
Current Respiratory-Related Healthcare Costs	10,000 cases annually	20-30%	$1,500,000 - $2,250,000
Reduced Healthcare Costs Post-Conversion	N/A	20-30%	$1,200,000 - $1,750,000

D. Challenges in EV Conversion

While the benefits of EV conversion are promising, several challenges need to be addressed for large-scale adoption in Thailand:

1) High Upfront Costs: Although conversion is more affordable than purchasing a new EV, the initial cost of conversion remains prohibitive for many consumers.
2) Limited Access to Conversion Kits and Expertise: Thailand lacks a widespread infrastructure for EV conversion, including access to certified conversion kits and technicians.
3) Electricity Grid Reliability: The environmental benefits of EVs depend on the sustainability of Thailand's electricity grid. Currently, the country still relies on fossil fuels for a significant portion of its electricity generation, though this is improving with the adoption of solar and wind power.

Table 4: Summary of Key Challenges in EV Conversion

Challenge	Impact Level	Proposed Solutions
High Conversion Costs	Moderate	Government subsidies, financial incentives
Limited Access to Conversion Kits	High	Develop local conversion kit manufacturing capabilities
Lack of Skilled Labor	High	Training programs for technicians and engineers
Fossil-Fuel-Based Electricity Grid	Moderate	Shifts toward renewable energy sources

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V. Discussion

The findings from this study demonstrate that converting internal combustion engine (ICE) vehicles to electric vehicles (EVs) in Thailand offers substantial economic, environmental, and social benefits. However, the process is not without its challenges. The economic analysis indicates that EV conversion is a cost-effective solution for individuals who are looking for an alternative to purchasing new EVs, especially as the conversion can result in significant savings on fuel and maintenance costs over a 10-year period.

A. Economic Feasibility

The return on investment (ROI) for EV conversion was found to be between 5 and 8 years, making the option appealing for mid- and long-term cost savings. As fuel prices fluctuate and are expected to increase, the stability of electricity prices further bolsters the attractiveness of EV conversion. The operational savings of EVs, stemming from lower energy costs and reduced maintenance needs, significantly outweigh the initial conversion costs over time.

However, the upfront cost of conversion remains a barrier, particularly for lower-income individuals. In many cases, while the conversion is more affordable than purchasing a new EV, the financial outlay for retrofitting an ICE vehicle is still substantial. Government incentives or subsidies could play a crucial role in accelerating adoption by reducing this financial burden, making EV conversion accessible to a wider demographic.

Policy Recommendation: To improve adoption, it is essential that policymakers consider implementing incentives such as tax rebates or subsidies for vehicle owners who convert their ICE vehicles to EVs. Additionally, public and private investments in conversion infrastructure (e.g., workshops, technicians) could support the scaling up of conversion efforts, bringing down costs over time.

B. Environmental Impact

The environmental benefits of EV conversion are significant. Converted EVs emit approximately 70% less greenhouse gas (GHG) emissions compared to their ICE counterparts over a 10-year period. Even with Thailand’s current energy mix, which still relies partially on fossil fuels, the overall reduction in emissions is substantial. As Thailand continues to integrate more renewable energy into its electricity grid, the emissions associated with charging EVs will further decline, magnifying the environmental benefits of EV conversion.

The lifecycle assessment (LCA) also indicates that emissions from battery production and electricity generation are offset by the significant reduction in tailpipe emissions. As the nation transitions to cleaner energy sources, such as solar and wind, the emissions reduction potential will be even greater.

However, the full environmental benefit is dependent on the pace of Thailand’s transition to renewable energy. Currently, indirect emissions from electricity generation still contribute to the overall carbon footprint of EVs, although this is much lower than direct emissions from ICE vehicles. The development of a cleaner grid will enhance the sustainability of EV conversions.

Policy Recommendation: To maximize environmental benefits, Thailand should continue investing in renewable energy sources, ensuring that the electricity used to power EVs becomes greener. In parallel, promoting the use of energy-efficient EV technologies and recycling programs for batteries could further enhance the sustainability of EV conversions.

C. Social Impact

The reduction of air pollution, particularly in densely populated cities such as Bangkok, has significant public health implications. Vehicle emissions are a major contributor to respiratory and cardiovascular diseases. By reducing the number of ICE vehicles on the road, EV conversions can lead to cleaner air and reduced healthcare costs associated with pollution-related illnesses.

While the immediate social benefits of cleaner air and reduced noise pollution are clear, the long-term societal shift toward cleaner transportation requires strong policy frameworks. Public awareness campaigns to educate consumers on the health and environmental benefits of EVs could help accelerate public acceptance and demand for vehicle conversions.

Policy Recommendation: The government should prioritize urban areas for initial EV conversion initiatives, where pollution levels are highest and the potential health benefits are greatest. Additionally, public health campaigns that highlight the links between air quality and vehicle emissions could support greater acceptance of EVs, encouraging more consumers to consider conversion.

E. Challenges and Opportunities

Despite the benefits, several challenges could slow the widespread adoption of EV conversions. These include limited access to conversion kits, a lack of skilled technicians, and the relatively high upfront costs for conversion. While demand for EV conversions is growing, the infrastructure to support it remains underdeveloped in Thailand.

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To overcome these barriers, collaboration between government, industry, and educational institutions will be critical. Developing local manufacturing capabilities for conversion kits, expanding training programs for skilled labor, and offering financial incentives could help scale up the conversion industry.

Policy Recommendation: The Thai government, in collaboration with private industry, should invest in creating a skilled workforce for EV conversion and develop a certification program for EV conversion technicians. Furthermore, investments in research and development (R&D) to make conversion kits more cost-effective and locally available would reduce reliance on imports and lower costs for consumers.

VI. Conclusion

The conversion of ICE vehicles to EVs in Thailand presents a viable and cost-effective solution to address the country's economic, environmental, and social goals. The results of this study indicate that EV conversion provides substantial GHG emissions reductions, long-term cost savings, and significant improvements in public health by reducing air pollution.

However, realizing the full potential of EV conversions requires overcoming several key challenges, including reducing the high upfront costs of conversion, improving access to conversion kits and skilled labor, and ensuring that Thailand's electricity grid continues to incorporate more renewable energy sources.

The Thai government has a pivotal role to play in driving the adoption of EV conversions through financial incentives, infrastructure investment, and policies that support the development of the EV conversion industry. As the country continues to transition to a cleaner transportation system, EV conversions can serve as a bridge to widespread EV adoption, particularly for consumers who are unable to afford new electric vehicles.

In conclusion, while EV conversion alone may not solve all of Thailand's transportation challenges, it represents a critical and feasible step toward achieving the country's long-term sustainability goals. By addressing the challenges and leveraging the opportunities presented in this study, Thailand can accelerate the shift to cleaner and more sustainable transportation systems.

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