

# Effects of locations on the CO<sub>2</sub> Emissions of E-Cars Compared to Internal Combustion Engine Cars

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**Abstract.** This paper focuses on the effects of locations on the CO<sub>2</sub> emissions of electric cars compared to internal combustion engine cars. The transportation sector is a major contributor to CO<sub>2</sub> emissions, and the adoption of electric vehicles is seen as a potential solution. However, the environmental footprint of EVs needs to be assessed through Life Cycle Assessment (LCA), considering factors such as the energy mix, manufacturing processes, and end-of-life management. The geographical location plays a crucial role, as regions with different energy mixes have varying lifecycle CO<sub>2</sub> emissions for EVs. Additionally, temperature impacts the emissions of both ICEVs and EVs. In low-temperature environments, ICEVs' emissions increase significantly, while for EVs, temperature affects battery performance and energy consumption. Through a comparative analysis, it is found that although EVs may have higher emissions in some stages, their total carbon emissions are 22.4% less than that of ICEVs. Understanding these factors is essential for making informed decisions towards a greener transportation future, and further efforts are needed to reduce the environmental impact of both vehicle types through technological advancements and policy interventions.

**Keywords:** CO<sub>2</sub> Emissions; Electric Cars; Internal Combustion Engine Cars; Locations; Life Cycle Assessment.

## 1. Introduction

The transportation sector stands as a pivotal contributor to the escalating global climate crisis, with carbon dioxide (CO<sub>2</sub>) emissions constituting a substantial portion of total greenhouse gas emissions. In the United States, this sector alone accounted for nearly a third of all greenhouse gas emissions in 2022, underscoring the urgency to transition towards more sustainable modes of transportation [1]. Among the various strategies aimed at mitigating these emissions, the proliferation of electric vehicles (EVs) has emerged as a promising solution, fueled by technological breakthroughs and supportive government policies worldwide.

The widespread adoption of EVs is often hailed as a game-changer in the fight against climate change, as they eliminate tailpipe emissions, a significant source of air pollution and CO<sub>2</sub> emissions from internal combustion engine (ICE) cars. However, a nuanced understanding of EVs' environmental footprint necessitates a broader examination that transcends the mere absence of tailpipe emissions. Life Cycle Assessment (LCA), a comprehensive methodology that evaluates the environmental impacts of a product or service throughout its entire lifecycle, from raw material extraction to end-of-life disposal, has emerged as a vital tool in this regard [2].

While the operational phase of EVs, during which they run solely on electricity, indeed reduces direct emissions, the overall CO<sub>2</sub> emissions associated with their lifecycle are influenced by numerous factors, including the energy mix used for electricity generation, manufacturing processes, and end-of-life management. These factors vary significantly across different regions and over time, highlighting the complexity of assessing the true environmental benefits of EVs.

In particular, the geographical location of EV usage plays a pivotal role in determining their CO<sub>2</sub> emissions. For instance, regions heavily reliant on fossil fuels, particularly coal, for electricity generation, such as West Virginia in the United States, may experience higher lifecycle CO<sub>2</sub> emissions from EVs compared to regions with a more diversified and renewable-heavy energy mix, like California. This disparity underscores the importance of considering regional energy systems when evaluating the environmental performance of EVs.



**Table 1.** Raw material conversion to virgin inputs energy consumption [3]

Material	ICEV Energy (MJ)	EV Energy (MJ)
Glass	1050	1050
Ferrous	35400	17000
Lesd	400	0
Zinc	350	150
Rubber	3780	3500
Plastics	9000	7110
Copper	900	1300
Nickel	0	10230
Aluminum	17820	66880
Magnesium	2800	5600
Sum	122.2(GJ)	245.6(GJ)

Raw material to virgin input play the role for EV with 50.8% of the carbon emissions, which is 184.6 g/km. It is almost twice as much emissions as the ICEV. This could be attributed to the heavy use of rare metals such as nickel and other metals in lithium-ion batteries. However, the carbon emission of ICEV in the operation phase is 351.3g/km, which accounts for 74.9% of its total emissions, which is much higher than the carbon emissions of EV. Although the emissions of EV in other stages are higher than those of ICEV, they account for only a small portion of total emissions. For instance, in decommissioning stage, the emission of EV is much higher than that of ICEV, but that is because the figure of ICEV is so small. Totally, the carbon emissions of EV reach 363.2 gram per km, which is 22.4% less than that of ICEV.

### 3. CO<sub>2</sub> emissions sources in ICEVs

ICEVs are a major contributor to global carbon dioxide emissions, which are the primary driver of climate change. Understanding the sources of CO<sub>2</sub> emissions from these vehicles is crucial for developing effective strategies to mitigate their environmental impact.

The primary source of CO<sub>2</sub> emissions in ICEVs is the combustion of fossil fuels, primarily gasoline and diesel. During the combustion process, carbon-based fuels are burned with oxygen, releasing CO<sub>2</sub> as a byproduct into the atmosphere. This process occurs within the engine's cylinders, where a controlled explosion produces the power necessary to propel the vehicle [4]. The efficiency of the combustion process directly affects the amount of CO<sub>2</sub> emitted. Older and less efficient engines tend to emit higher levels of CO<sub>2</sub> compared to modern, high-efficiency engines. Factors such as engine design, fuel quality, and driving conditions can all influence combustion efficiency and, consequently, CO<sub>2</sub> emissions. The amount of fuel consumed by an ICEV is another significant factor determining its CO<sub>2</sub> emissions. Fuel consumption is influenced by factors such as vehicle weight, aerodynamics, engine size, and driving behavior. For example, a heavier vehicle or one with a larger engine will consume more fuel and emit more CO<sub>2</sub>, even when traveling at the same speed [5]. Similarly, aggressive driving behaviors like rapid acceleration and high speeds can increase fuel consumption and emissions.

It's essential to consider the life cycle emissions of ICEVs, which include not only tailpipe emissions but also emissions associated with the production and disposal of the vehicle. The production of fossil fuels, the manufacturing of vehicles, and the disposal of old vehicles all contribute to CO<sub>2</sub> emissions. Additionally, the electricity used to power factories and refineries involved in these processes also has a carbon footprint.

To reduce CO<sub>2</sub> emissions from ICEVs, policymakers and automakers have implemented various strategies. Governments have introduced stricter emissions standards, encouraging automakers to develop more efficient engines and technologies. These include advanced engine control systems, exhaust gas recirculation, and catalytic converters that reduce harmful emissions [6].

Furthermore, the transition to alternative fuel sources, such as biofuels and hydrogen, is being explored as a way to reduce the reliance on fossil fuels and their associated CO<sub>2</sub> emissions. However, the widespread adoption of these technologies faces challenges related to infrastructure, cost, and availability.

ICEVs are a significant source of CO<sub>2</sub> emissions, contributing to global climate change. Understanding the sources of these emissions and implementing effective strategies to reduce them is essential for mitigating their environmental impact. While technological advancements and policy interventions have made progress, further efforts are needed to achieve significant reductions in CO<sub>2</sub> emissions from ICEVs.

## 4. Temperature Impact

### 4.1. Impact of ICEVs

The CO<sub>2</sub> emissions of oil trucks will vary depending on the temperature, as shown in table 2. Studies such as Jacek Pielecha et al. have studied the difference in RDE cold-start emissions between gasoline vehicles at two ambient temperatures, and pointed out that the proportion of cold-start emissions of CO, CO<sub>2</sub> and PN in urban areas is less than 8 °C at ambient temperature of 25 °C [7]. Start-up stage: At low temperatures, the fluidity of oil, coolant, etc. inside the engine becomes poor, and the engine needs to overcome greater resistance when starting, and in order to allow the engine to reach the normal working temperature as soon as possible, the vehicle's electronic control unit (ECU) will automatically increase the fuel injection time and amount of fuel injection at the injector, which leads to a significant increase in fuel consumption and carbon dioxide emissions for a period of time after starting. For example, in an environment of minus 10 degrees Celsius, fuel consumption can increase by 30 to 50 percent in the first few minutes after starting the vehicle compared to normal temperatures, and CO<sub>2</sub> emissions will increase by a similar proportion.

Low temperatures make the engine less thermally efficient, as the engine constantly needs to consume more fuel to maintain operating temperatures. At the same time, in order to maintain the temperature in the car, the vehicle's heating system consumes part of the engine's energy, further increasing fuel consumption. During the cold winter months, the combined fuel consumption of the vehicle can be 10 - 20 percent higher than in the summer, and the corresponding CO<sub>2</sub> emissions will also increase.

In a high-temperature environment, the volatility of gasoline is enhanced, although this is conducive to the atomization and combustion of gasoline to a certain extent, but it is also easy to cause partial volatilization of gasoline before entering the engine, resulting in a certain amount of energy waste and increased emissions. However, this impact is relatively small during the start-up phase.

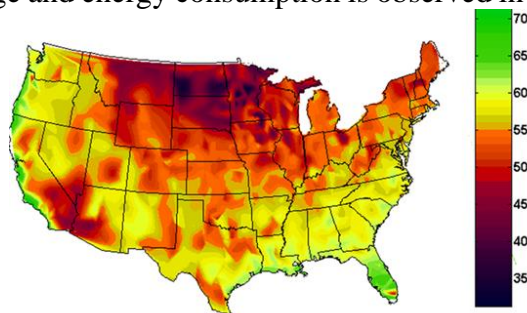
High temperatures can burden the engine with heat dissipation, and in order to prevent the engine from overheating, the cooling system needs to work more frequently, which consumes a certain amount of energy [8]. At the same time, the high temperature will also increase the air pressure of the tires, and the rolling resistance of the vehicle when driving will be reduced, which can reduce fuel consumption to a certain extent. Overall, however, the impact of high temperatures on fuel consumption and CO<sub>2</sub> emissions is relatively small, and a vehicle's fuel consumption and CO<sub>2</sub> emissions can increase by around 5% to 10% in the hot summer months compared to normal temperatures.

**Table 2** Effect of different temperatures on ICEVs

Temperature range (°C)	Approximate change in carbon dioxide emissions
	Compared with normal temperature (around 20°C), during cold start, fuel consumption increases significantly and carbon dioxide emissions may increase by 30% - 50% or even more. During driving, the engine thermal efficiency decreases, and the comprehensive carbon dioxide emissions may increase by 20% - 30%.
0 to 10	During cold start, fuel consumption increases obviously, and carbon dioxide emissions increase by about 20% - 30% compared with normal temperature. During driving, the impact is relatively small, and the overall carbon dioxide emissions increase by 15% - 20%. During cold start, there is still a certain impact. Carbon dioxide emissions increase by about 10% - 15% compared with normal temperature. During driving, the impact is relatively small, and the comprehensive emissions increase by 5% - 10%.
10 to 20 (normal temperature)	As a reference temperature range, the vehicle is in normal working condition and carbon dioxide emissions are at a normal level.
20 to 30	Under high temperature, the volatility of gasoline increases, but the impact during startup is small. During driving, due to factors such as increased heat dissipation burden, carbon dioxide emissions increase by about 5% - 10% compared with normal temperature.
30 and above	Under extreme high temperature, although the rolling resistance of tires may decrease, the cooling system works frequently. Carbon dioxide emissions may increase by about 10% compared with normal temperature, but the increase is usually smaller than the impact in low temperature environments.

**4.2. Impact of EVs**

Temperature has a certain impact on the battery performance, motor efficiency and overall energy consumption of e-cars, and these effects are related to the emissions of e-cars. Fig.2 and Fig.3 show the expected vehicle range on an average day across the fleet in each region. The plot uses bounded extrapolation, but results with full extrapolation are comparable. Expected range can drop to 64 miles in cold regions like the Upper Midwest and in hot regions like Southeast California and Southern Arizona. Therefore, the expected range in those regions is 11 miles less than the Environmental Protection Agency (EPA) rated 2013 Nissan Leaf range of 75 miles. In addition, the most dramatic effect of temperature on range and energy consumption is observed in Alaska due to the cold climate.



**Fig.2.** Average range across the fleet on the worst day of the year using full extrapolation [9]



**Fig.3.** Expected range on an average day across the fleet (miles) [9]

## 5. Conclusion

This study reveals that the CO<sub>2</sub> emissions of electric cars and ICE cars are influenced by multiple factors, including the life cycle assessment, geographical location, and temperature. In the LCA perspective, although the emissions of EVs in other states are higher than those of ICEVs, the total carbon emissions of EVs are 22.4% less than that of ICEVs. The primary source of CO<sub>2</sub> emissions in ICEVs is the combustion of fossil fuels, and factors such as engine efficiency, fuel consumption, and driving conditions all affect the emissions. Temperature has different impacts on the emissions of ICEVs and EVs. In low-temperature environments, the emissions of ICEVs increase significantly, while for EVs, temperature affects battery performance and energy consumption. Overall, understanding these factors is crucial for policymakers, industry stakeholders, and the public to make informed decisions towards a greener transportation future. Further efforts are needed to reduce the environmental impact of both ICEVs and EVs through technological advancements and policy interventions.

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