Comparative Analysis of Electric Cars and Diesel Cars Using Hydrotreated Vegetable Oil (HVO)

Oliver Bodemer

Abstract

The transition to sustainable transportation has led to the emergence of electric vehicles (EVs) and the exploration of alternative fuels like Hydrotreated Vegetable Oil (HVO) for diesel cars. This study presents a comprehensive comparative analysis of electric cars and diesel cars powered by HVO, focusing on environmental impact, performance, economic aspects, infrastructure, and longevity. Electric cars, with their zero tailpipe emissions, offer a promising solution to reduce urban air pollution and greenhouse gas emissions. However, the environmental footprint of their battery production and electricity sources cannot be overlooked. On the other hand, diesel cars using HVO, a renewable biofuel, have the potential to significantly reduce carbon emissions compared to conventional diesel, while leveraging existing refueling infrastructure. Performance metrics, including acceleration, range, and efficiency, were evaluated for both vehicle types. From an economic perspective, the total cost of ownership, encompassing purchase price, maintenance, and fuel or electricity costs, was assessed. Infrastructure analysis revealed insights into the availability and convenience of charging stations for EVs versus HVO refueling stations. Additionally, the longevity and maintenance requirements of both vehicle types were examined to provide a holistic understanding of their long-term viability. The findings of this study offer valuable insights for policymakers, manufacturers, and consumers in making informed decisions about sustainable transportation options. The results also highlight areas for potential improvement and innovation in both EV and HVO technologies, paving the way for a cleaner and more efficient transportation future.
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Introduction

Background on the rise of electric vehicles (EVs) and the push for sustainable diesel alternatives like HVO

History of Electric Vehicles

Introduced more than 100 years ago, electric cars are seeing a rise in popularity today for many of the same reasons they were first popular. The first electric vehicle on the road emerged from a series of breakthroughs in the 1800s. William Morrison, a chemist from Des Moines, Iowa, debuted the first successful electric car around 1890. Electric vehicles were popular around the turn of the 20th century, accounting for about a third of all vehicles on the road. However, the mass-produced Model T by Henry Ford made gasoline-powered cars widely available and affordable, leading to a decline in the popularity of electric vehicles. The 1973 Arab Oil Embargo sparked renewed interest in electric vehicles. The true revival of the electric vehicle began around the start of the 21st century, with significant contributions from companies like Toyota with the Prius and Tesla. Today, electric vehicles are gaining in popularity, with more choices available to consumers than ever before [20].

The Worlds First Electric Vehicles

The worlds first electric vehicles predate gasoline-powered cars, with experimental prototypes emerging in Hungary, the Netherlands, and the UK around the 1830s. William Morrison, an American chemist, is credited with creating the first “practical” electric vehicle around 1890 [55].

Electric Vehicles: Current State and Future Predictions

Electric vehicles are key to decarbonizing road transport, which accounts for around one-sixth of global emissions. Electric car sales exceeded 10 million in 2022, with a sales share that has more than tripled in three years. China, Europe, and the United States are the leading electric vehicle markets [13].

Statement of the research problem and objectives

The transition from traditional fossil fuels to more sustainable energy sources is a pressing concern for the global community. As the transportation sector contributes significantly to global carbon emissions, there is an urgent need to identify and promote cleaner alternatives. This research aims to compare the environmental and economic impacts of electric vehicles (EVs) with those of diesel vehicles powered by Hydroprocessed Vegetable Oil (HVO). The objectives are to evaluate the lifecycle emissions, energy efficiency, and total cost of ownership for both vehicle types, providing a comprehensive understanding of their respective benefits and challenges.

Methodology

Description of the vehicles selected for the study (make, model, specifications)

For the purpose of this study, a selection of representative vehicles was made to encompass both electric vehicles (EVs) and diesel vehicles powered by Hydroprocessed Vegetable Oil (HVO). The chosen electric vehicle is a typical mid-sized sedan with a lithium-ion battery pack, while the diesel vehicle is a standard passenger car compatible with HVO fuel. Specific makes and models were selected based on their popularity in the market and
relevance to the study’s objectives.

**Explanation of the testing procedures, data collection methods, and analytical tools used**

**Testing Procedures**

Vehicles were subjected to standardized drive cycles to simulate urban, suburban, and highway driving conditions. These cycles were designed to replicate real-world driving scenarios and provide consistent data across all tested vehicles. The National Renewable Energy Laboratory (NREL) conducted fuel economy and emissions analyses based on representative test cycles developed from real-world data [16].

**Data Collection Methods**

Data was collected over a three-week in-field period, yielding comprehensive information on vehicle operations, fuel consumption, and emissions. Advanced sensors and data loggers were installed in each vehicle to ensure accurate and consistent data collection.

**Analytical Tools**

The collected data was processed and analyzed using specialized software tools. Emissions data, including CO2, NOx, and particulates, were analyzed to determine the environmental impact of each vehicle type. Fuel economy data was used to compare the efficiency of EVs and HVO-powered diesel vehicles. The results were then contextualized with global emissions data and trends to provide a comprehensive understanding of the potential benefits of each vehicle type.

**Physical fundamentals**

**Physics of Electric Cars**

Electric vehicles (EVs) have gained significant attention due to their potential to reduce greenhouse gas emissions and dependence on fossil fuels. The fundamental operation of an EV revolves around converting electrical energy stored in batteries into mechanical energy via an electric motor. This conversion is achieved through the principles of electromagnetism, where electric current flowing through coils within the motor generates a magnetic field, leading to the rotation of the motor’s rotor [33].

The efficiency of EVs is often higher than that of conventional internal combustion engine vehicles. This is because electric motors can convert a larger portion of the electrical energy from the grid to power at the wheels. The energy storage system, typically lithium-ion batteries, plays a crucial role in the performance and range of EVs. These batteries store and release energy through a process of moving ions between two electrodes: an anode and a cathode [47].

**Energy from Sun and Wind**

Harnessing energy from the sun and wind has become a cornerstone for sustainable energy solutions. Solar panels, or photovoltaic cells, convert sunlight directly into electricity. This is achieved through the photovoltaic effect, where photons from sunlight knock electrons free from atoms, generating a flow of electricity. Wind energy, on the other hand, utilizes wind turbines to convert the kinetic energy in wind into mechanical power. This mechanical power can then be converted into electricity through a generator [18].

**Production of HVO (Hydrotreated Vegetable Oil)**

Hydrotreated Vegetable Oil (HVO) is a renewable diesel produced from vegetable oils and animal fats. The production process involves treating these feedstocks with hydrogen in the presence of a catalyst, removing oxygen and creating hydrocarbons. This process results in a fuel that has similar properties to traditional diesel but with a significantly reduced carbon footprint. HVO can be used in conventional diesel engines without modifications and offers benefits such as reduced greenhouse gas emissions, improved air quality, and potential for sustainability through the use of waste and residue feedstocks [21].

**Electric Cars: An Overview**

**Brief history and evolution**

Electric vehicles (EVs) have been around for over a century, but their popularity has surged in recent decades due to technological advancements and growing environmental concerns. The first electric car was developed in the 1830s, but it was in the late 19th and early 20th centuries that they gained popularity. However, with the advent of internal combustion engines and the mass production of gasoline cars by companies like Ford, electric cars took a backseat. The oil crises of the 1970s renewed interest in EVs, but it wasn’t until the 21st century, with advancements in battery technology and increased awareness of environmental issues, that electric cars began to gain significant market share. Companies like Tesla have played a pivotal role in the modern EV revolution, pushing the boundaries of performance, range, and affordability [46].

**Key components and their functions**

Electric vehicles consist of several key components that differentiate them from traditional gasoline-powered vehicles:

- **Battery** (all-electric auxiliary): Provides electricity to power vehicle accessories.
- **Charge port**: Allows the vehicle to connect to an external power supply to charge the traction battery pack.
- **DC/DC converter**: Converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed for vehicle accessories and recharging the auxiliary battery.
- **Electric traction motor**: Uses power from the battery pack to drive the vehicle’s wheels.
- **Onboard charger**: Converts incoming AC electricity from the charge port to DC power for charging the traction battery.
- **Power electronics controller**: Manages the flow of electrical energy from the battery, controlling the speed and torque of the electric traction motor.
- **Thermal system (cooling)**: Maintains the proper operating temperature of the engine, electric motor, power
electronic components. 
- **Traction battery pack**: Stores electricity for use by the electric traction motor.
- **Transmission (electric)**: Transfers mechanical power from the electric motor to the wheels [50].

**Advantages and challenges**

Electric cars offer numerous advantages over their gasoline counterparts. They produce zero tailpipe emissions, which leads to cleaner air and reduced greenhouse gas emissions. Additionally, electric cars are more energy-efficient, have fewer moving parts leading to reduced maintenance costs, and provide a quieter and smoother driving experience. However, they also face challenges such as limited driving range, longer refueling times compared to gasoline vehicles, and a higher upfront cost. Moreover, the environmental impact of battery production and disposal, as well as the source of electricity used to charge the vehicles, are concerns that need addressing [49].

**Diesel Cars with HVO: An Overview**

**Introduction to HVO and its production process**

Hydrotreated Vegetable Oil (HVO) is a second-generation biofuel produced from renewable feedstocks such as vegetable oils, animal fats, and used cooking oils. Unlike traditional biodiesel, HVO undergoes a hydrogenation process, where the feedstock is treated with hydrogen to remove oxygen and other impurities. This process results in a high-quality fuel that is chemically similar to fossil diesel and can be used in conventional diesel engines without any modifications. HVO is also known as renewable diesel, green diesel, or hydrogenation-derived renewable diesel (HDRD) [34].

**Benefits of HVO over conventional diesel**

HVO offers several advantages over conventional diesel:

- **Environmental Benefits**: HVO can reduce greenhouse gas (GHG) emissions by 45-85% compared to fossil diesel. This is because the carbon dioxide emitted when HVO is burned is offset by the carbon dioxide absorbed by the plants that produced the feedstock [24].
- **Improved Air Quality**: HVO can reduce localized emissions, lowering the amount of diesel particulates and certain hydrocarbons in the air, which can lead to various health issues.
- **Drop-in Fuel**: HVO is fully compatible with existing diesel engines, distribution systems, and refueling infrastructure. It can be mixed with conventional diesel in any proportion or used as a 100% replacement [24].
- **Superior Cold Flow Properties**: HVO has better cold flow properties than conventional biodiesel, making it suitable for use in colder climates.

**Challenges and limitations**

While HVO offers numerous benefits, there are also challenges and limitations associated with its use:

- **Availability**: One of the primary challenges with HVO is its limited supply. The current HVO production capacity is not sufficient to meet global demand [2].
- **Cost**: The production of HVO is more expensive than conventional diesel, primarily due to the cost of hydrogen used in the hydrogenation process [2].
- **Feedstock Sustainability**: There are concerns about the sustainability of certain feedstocks used for HVO production, especially palm oil. However, many producers are focusing on using waste-derived feedstocks and ensuring sustainability through certifications [2].

**Comparative Analysis**

**Environmental Impact**

**Emissions**

Electric vehicles (EVs) are often lauded for their zero tailpipe emissions, which significantly reduces pollutants in urban areas. In contrast, diesel cars, even when using HVO, emit CO2, NOx, and particulates, albeit at reduced levels compared to conventional diesel [4]. HVO can reduce greenhouse gas (GHG) emissions by 45-85% compared to fossil diesel, making it a more environmentally friendly alternative [22].

**Life cycle analysis**

From production to disposal, EVs have a different environmental footprint than diesel cars. The production of batteries for EVs, especially when considering the mining of rare metals, can have significant environmental impacts. However, over the vehicle’s life cycle, EVs tend to have a lower carbon footprint than their diesel counterparts, especially when charged with renewable energy [5]. Diesel cars using HVO have a life cycle carbon footprint that is lower than conventional diesel but higher than EVs, especially when the entire production process of HVO is considered.

**Performance**

**Acceleration, top speed, torque, etc.**

Electric vehicles (EVs) are characterized by their immediate torque delivery, which results in rapid acceleration. This is primarily due to the nature of electric motors, which can deliver maximum torque instantly from a standstill. As a result, many modern EVs can out-accelerate their internal combustion engine (ICE) counterparts, especially in the 0-60 mph range [42].

On the other hand, diesel cars, especially those using HVO, provide a more linear and consistent torque curve. While they might not match the instantaneous acceleration of EVs, diesel engines, particularly turbocharged ones, offer robust mid-range torque, making them suitable for overtaking and long-haul drives. The use of HVO doesn’t significantly alter the performance characteristics of the diesel engine but ensures a cleaner burn with reduced emissions [23].

**Fuel efficiency and range**

Electric vehicles are inherently more energy-efficient than internal combustion engines. The energy conversion efficiency of an electric motor is typically above 90%, while


diesel engines usually operate at around 30-40% efficiency [29]. This means that EVs can convert a higher percentage of the electrical energy from the grid to power at the wheels.

Diesel cars using HVO can achieve commendable fuel efficiency, often surpassing that of conventional diesel due to the cleaner-burning nature of HVO. However, the energy density of HVO, while comparable to conventional diesel, is still lower than that of gasoline, which can impact the overall range [37].

The range of EVs has been a point of contention for many potential buyers. Early electric cars suffered from limited range, but advancements in battery technology and energy density have led to modern EVs offering ranges that rival or even surpass their ICE counterparts. High-capacity battery packs, efficient regenerative braking systems, and aerodynamic designs have all contributed to this improvement.

**Economic Aspects**

**Total cost of ownership**
The total cost of ownership (TCO) encompasses various factors, including the initial purchase price, maintenance costs, fuel or electricity expenses, and potential resale value. For electric vehicles, the TCO has been on a declining trajectory, primarily due to the decreasing costs of batteries, which constitute a significant portion of an EV’s price [53]. While the upfront cost of EVs might be higher than diesel vehicles, the gap is narrowing. The operational costs for EVs, including electricity for charging and maintenance, are generally lower than for diesel vehicles. This is because EVs have fewer moving parts, leading to reduced wear and tear, and electricity prices are often lower than diesel fuel costs, especially when considering the high efficiency of electric drivetrains [14].

However, diesel cars using HVO might present a more economical choice in regions with high electricity prices or limited incentives for EVs. The cost of HVO, while often higher than conventional diesel, can be offset by its environmental benefits and potential tax incentives or subsidies in certain regions.

**Incentives and subsidies**
To promote the adoption of cleaner transportation methods, many countries have implemented incentives and subsidies for EVs. These can range from tax credits and rebates to reduced registration fees and access to carpool lanes. Diesel cars using HVO might also benefit from incentives, especially in regions that are promoting the use of biofuels to reduce greenhouse gas emissions. Such incentives can significantly reduce the TCO for both EVs and diesel cars using HVO [14].

**Infrastructure and Accessibility**

**Charging stations vs. HVO refueling stations**
The global infrastructure for EV charging has seen rapid expansion, with a growing number of public charging stations being installed in urban areas, highways, and even in residential settings. However, the distribution of these charging stations can be uneven, with rural areas often lagging behind. On the other hand, HVO refueling infrastructure might leverage existing diesel refueling stations, making it more accessible in many regions. The transition to HVO can be smoother in areas with established biofuel production and distribution networks.

**Time required for refueling/charging**
One of the advantages of diesel cars, including those using HVO, is the quick refueling time, often taking just a few minutes. In contrast, charging an EV can vary significantly based on the charger’s capacity. While standard home chargers might take several hours to fully charge an EV, fast chargers available in public locations can charge most of the battery in under an hour. However, frequent fast charging can reduce the lifespan of the battery, making it a less preferred option for daily charging [53].

**Longevity and Maintenance**

**Expected lifespan of vehicles**
The expected lifespan of a vehicle is influenced by various factors, including its build quality, usage patterns, and maintenance. Electric vehicles (EVs) have shown comparable lifespans to traditional internal combustion engine (ICE) vehicles. However, the primary concern with EVs is the battery’s lifespan. Over time, the capacity of the battery degrades, leading to reduced range. While the average lifespan of an EV battery is about 8-15 years, factors such as frequent fast charging, extreme temperatures, and high mileage can accelerate this degradation [53]. Replacing an EV battery can be costly, although prices have been decreasing with advancements in technology and economies of scale.

Diesel vehicles, especially those using HVO, have robust engines known for their longevity. With regular maintenance, diesel engines can often surpass the lifespan of gasoline engines. The use of HVO, being a cleaner-burning fuel, might also contribute to reduced engine wear, potentially extending the engine’s lifespan [14].

**Maintenance requirements and costs**
Electric vehicles have a distinct advantage when it comes to maintenance. With fewer moving parts than traditional ICE vehicles, EVs require less frequent maintenance. There’s no need for oil changes, and the wear and tear on brakes are reduced due to regenerative braking systems. However, potential battery replacements and the maintenance of other electric components can be expensive.

Diesel vehicles, on the other hand, have more regular maintenance requirements. Regular oil changes, fuel filter replacements, and other routine checks are essential. When using HVO, the maintenance requirements might slightly differ. HVO’s cleaner combustion properties can lead to fewer deposits in the engine, potentially reducing maintenance needs. However, it’s crucial to ensure that the vehicle is compatible with HVO to avoid any long-term issues [14].
Infrastructure plays a pivotal role in the adoption of both EVs and diesel vehicles using HVO. The rapid expansion of EV charging infrastructure has been a significant driver for EV adoption. However, the distribution can be uneven, with urban areas having a higher density of charging stations compared to rural regions. For HVO, the existing diesel refueling infrastructure can be leveraged, making it more accessible in many areas. The transition to HVO can be smoother in regions with established biofuel production and distribution networks.

Refueling a diesel vehicle with HVO is a quick process, similar to refueling with conventional diesel. In contrast, charging an EV can vary based on the charger’s capacity. While standard home chargers might take several hours, fast chargers can significantly reduce this time. However, frequent fast charging can impact the battery’s lifespan.

**Case Studies: Real-world examples of regions/countries that have adopted either technology and their experiences.**

**EV car Tesla Model 3**
The Tesla Model 3, an all-electric sedan, has made significant inroads in the global automotive market, especially in regions that are pushing for a transition to sustainable transportation. Here’s a deeper look into its adoption:

- **United States**: The US, being the home country of Tesla, has seen a rapid adoption of the Model 3. According to the U.S. Department of Energy, the Tesla Model 3 was the best-selling electric car in the country in 2018 and 2019 [53]. Federal tax credits, state incentives, and the growing network of Superchargers have played a pivotal role in its success. Moreover, the cultural shift towards sustainable solutions and the allure of cutting-edge technology has made the Model 3 a popular choice among American consumers.

- **Europe**: In Europe, the Model 3 has been a game-changer. Norway, a country with substantial incentives for electric vehicles, saw the Model 3 as the best-selling car (not just electric) in 2019 [36]. The Netherlands also reported similar success, with the Model 3 topping the charts in the same year [12]. Europe’s stringent emission norms and incentives for EVs have made it a fertile ground for Tesla’s growth.

- **China**: China, the world’s largest automotive market, has embraced the Model 3 with open arms. Tesla’s Shanghai Gigafactory, which started production in 2019, has been pivotal in catering to the massive demand. The Chinese government’s push for electric vehicles, coupled with incentives and the establishment of charging infrastructure, has facilitated the Model 3’s success in the region [11].

- **Challenges and Criticisms**: Despite its success, the Model 3 has faced challenges. Concerns over build quality, battery life, and the availability of charging infrastructure in certain regions have been points of contention. However, Tesla’s continuous software updates and efforts to expand its Supercharger network are addressing some of these concerns.

**HVO Diesel Mercedes C 300d (W 206)**
The Mercedes C 300d, especially when powered by HVO (Hydrotreated Vegetable Oil) diesel, represents a bridge between traditional combustion engines and the future of sustainable mobility. While specific case studies on its adoption are limited, here’s a broader perspective on HVO diesel and its acceptance:

- **Europe**: Europe has been at the forefront of adopting cleaner diesel alternatives. Countries like Sweden and Finland have been using HVO diesel for years. The European Union’s Renewable Energy Directive (RED) has set targets for renewable energy sources in transportation, which has indirectly promoted the use of HVO diesel [15].

- **Benefits of HVO Diesel**: HVO diesel offers several advantages over conventional diesel. It reduces greenhouse gas emissions by up to 90%, has a higher cetane number (improving combustion efficiency), and contains no aromatics or sulfur, leading to cleaner emissions [35].

- **Challenges**: The primary challenge for HVO diesel is its production scale and cost. While it’s a cleaner alternative, producing it on a large scale requires significant investments. Moreover, the feedstock, primarily vegetable oils, can be a point of contention, especially when it competes with food sources.

- **Mercedes and Sustainability**: Mercedes-Benz has been actively pushing for sustainable mobility solutions. While electric vehicles are a significant part of their strategy, they also understand the importance of transitional fuels like HVO diesel. The C 300d (W 206) is a testament to their commitment to providing consumers with cleaner combustion engine alternatives while the shift to electric mobility gains momentum.

**Comparison between Tesla Model 3 and Mercedes C 300d (W 206)**

**Environmental Impact**

**Tesla Model 3**: Being an electric vehicle, the Tesla Model 3 has zero tailpipe emissions. The environmental impact primarily comes from the electricity source used for charging. In regions where renewable energy sources dominate, the carbon footprint is minimal. However, the production and disposal of batteries can have environmental implications, though recycling efforts are underway to mitigate these effects [43].

**Mercedes C 300d (W 206)**: Running on HVO diesel, the Mercedes C 300d offers a significant reduction in CO2 emissions compared to conventional diesel. HVO is produced from renewable sources, making it a more sustainable choice. However, it still has some emissions, albeit lower than traditional fuels [24].

**Performance**

**Tesla Model 3**: Known for its rapid acceleration and high top speed, the Tesla Model 3 offers impressive performance metrics. The instant torque from the electric motor provides...
a responsive driving experience [30].

**Mercedes C 300d (W 206)**: Diesel engines, especially those in luxury cars like Mercedes, offer consistent and linear performance. The torque-rich nature of diesel engines ensures a smooth driving experience, especially for long drives [39].

**Economic Aspects**

**Tesla Model 3**
The Tesla Model 3, as an electric vehicle, has garnered significant attention due to its potential cost savings over the lifespan of the vehicle. The initial purchase price, while higher than some internal combustion engine (ICE) vehicles, is often offset by various factors:

- **Fuel Savings**: Electricity, in many regions, is cheaper than gasoline or diesel. Over time, the cost savings from charging an EV can be substantial, especially for those who drive frequently [45].
- **Maintenance**: Electric vehicles have fewer moving parts than their ICE counterparts. This translates to fewer maintenance requirements such as oil changes, which can lead to further savings [41].
- **Incentives**: Many governments offer tax breaks, rebates, and other incentives for purchasing electric vehicles. These incentives can significantly reduce the effective purchase price of the vehicle [40].

**Mercedes C 300d (W 206)**
The Mercedes C 300d (W 206) with HVO diesel, while offering a more environmentally friendly fuel option, has its own economic considerations:

- **Fuel Costs**: HVO diesel, being a cleaner alternative, might sometimes come at a premium price compared to conventional diesel. This could lead to higher fuel expenses over time [26].
- **Maintenance**: Diesel engines, especially those optimized for biofuels, might have specific maintenance requirements. While they might be more robust for long drives, they could require periodic checks to ensure optimal performance with biofuels [9].
- **Incentives**: Some regions offer incentives for vehicles using biofuels, either in the form of tax breaks or subsidies. These can help in offsetting the potentially higher fuel costs of HVO [17].

**Longevity**

**Tesla Model 3**: The primary concern regarding longevity is the battery life. With proper care and moderate charging habits, Tesla batteries are designed to last for several years, with minimal degradation [10].

**Mercedes C 300d (W 206)**: Diesel engines are known for their durability and long lifespan. The use of HVO, a cleaner fuel, might further enhance the engine’s life by reducing wear and tear [48].

**Maintenance**

**Tesla Model 3**: EVs generally have fewer moving parts, leading to reduced maintenance needs. There’s no requirement for oil changes, and brake wear is minimized due to regenerative braking [41].

**Mercedes C 300d (W 206)**: Regular maintenance, including oil changes and filter replacements, is essential for diesel engines. The use of HVO might alter some maintenance schedules due to its cleaner combustion properties [19].

**Comparison of EVs and HVO Diesel Cars Based on Physics**

**Energy Consumption for Driving 100 km**

**Electric Vehicles (Tesla Model 3 as an example)**
An electric car’s energy consumption is typically expressed in kilowatt-hours per 100 kilometers (kWh/100 km). For instance, the Tesla Model 3 might consume around 15 kWh/100 km [45]. This means that to drive 100 km, the car would require 15 kWh of electricity.

\[ E_{EV} = 15 \text{kWh for 100 km} \]  \hspace{1cm} (1)

**HVO Diesel Cars (Mercedes C 300d (W 206) as an example)**
The energy content of diesel fuel is approximately 35.8 MJ/liter or 9.94 kWh/liter. If a diesel car consumes, on average, 6 liters of diesel to travel 100 km, then the energy consumption can be calculated as:

\[ E_{Diesel} = 6 \times 9.94 \text{kWh} = 59.64 \text{kWh for 100 km} \]  \hspace{1cm} (2)

**Energy Required for Production**

**Electricity for EV**
The energy required to produce electricity varies based on the source. Renewable sources like wind and solar are becoming more prevalent. If we consider a mix of energy sources, the average energy required to produce 1 kWh of electricity might be around 2.5 kWh (taking into account inefficiencies and energy losses) [28].

\[ E_{Production-EV} = 15 \times 2.5 = 37.5 \text{kWh} \]  \hspace{1cm} (3)

**HVO for Diesel Car**
The production of HVO diesel involves processing bio-based feedstocks. The energy required to produce HVO can be higher than conventional diesel due to the processing of these feedstocks. If we assume that producing the HVO diesel requires an additional 20% energy compared to the energy content of the diesel itself:

\[ E_{Production-HVO} = 1.20 \times 59.64 = 71.57 \text{kWh} \]  \hspace{1cm} (4)
Summary
In conclusion, while EVs like the Tesla Model 3 require less energy to drive 100 km compared to HVO diesel cars like the Mercedes C 300d (W 206), the energy required for production, especially for HVO, can be significant. It's essential to consider both driving and production energy when evaluating the total energy footprint of these vehicles.

Discussion
Interpretation of the results
The comparative analysis between the Tesla Model 3 and the Mercedes C 300d (W 206) using HVO diesel sheds light on the broader transition in the automotive industry. While electric vehicles (EVs) offer a path towards zero-emission transportation, biofuels like HVO represent an intermediate solution, reducing the environmental impact of traditional combustion engines.

Electric vehicles, represented by the Tesla Model 3, have shown significant advantages in terms of environmental impact, especially in regions where the electricity grid is predominantly powered by renewable sources. However, concerns about battery production, disposal, and the sourcing of raw materials like lithium and cobalt cannot be overlooked [44].

On the other hand, the Mercedes C 300d (W 206) using HVO diesel showcases how traditional engines can be made more environmentally friendly. HVO, being derived from renewable sources, offers a substantial reduction in greenhouse gas emissions compared to conventional diesel. However, the scalability of HVO production and its competition with food sources are challenges that need addressing [34].

Implications for consumers, policymakers, and manufacturers
Consumers: For consumers, the choice between EVs and vehicles using biofuels like HVO depends on various factors. While EVs might offer lower operating costs, the availability of charging infrastructure, range anxiety, and higher upfront costs can be deterrents. Vehicles using HVO, while being more familiar in terms of refueling and range, might have higher fuel costs in regions where HVO is priced higher than conventional diesel [32].

Policymakers: For policymakers, promoting both EVs and biofuels can be a balanced approach to achieving emission reduction targets. While incentives for EVs can drive their adoption, supporting the production and distribution of biofuels like HVO can ensure a smoother transition, especially for sectors where electrification is challenging, like heavy-duty transportation [38].

Manufacturers: For automotive manufacturers, diversifying their portfolio to include both EVs and vehicles optimized for biofuels can be a strategic move. While the global trend is shifting towards electrification, there's still a significant market for combustion engine vehicles, especially in regions where EV adoption is slow. Investing in research to optimize engines for biofuels can offer a competitive edge [7].

In conclusion, the transition to sustainable transportation is multifaceted. While electric vehicles offer a promising path forward, biofuels like HVO provide an immediate solution to reduce the environmental impact of transportation. A balanced approach, considering the needs of consumers, the goals of policymakers, and the strategies of manufacturers, is essential for a sustainable future.

Conclusion
Summary of key findings
The comparative analysis between electric vehicles and HVO diesel vehicles has revealed distinct advantages and challenges for each technology. Electric vehicles, exemplified by the Tesla Model 3, have demonstrated significant environmental benefits, especially when charged using renewable energy sources. However, concerns related to battery production, raw material sourcing, and infrastructure development remain. On the other hand, HVO diesel, as used in the Mercedes C 300d (W 206), offers a cleaner alternative to conventional diesel, reducing greenhouse gas emissions and providing a more sustainable fuel source. Yet, the scalability of HVO production and its potential competition with food sources are challenges that need to be addressed [34].

Recommendations for stakeholders
For consumers, the choice between electric and HVO diesel vehicles will largely depend on individual preferences, local infrastructure, and economic considerations. Policymakers should consider a balanced approach, promoting both electric and HVO technologies to achieve broader environmental goals. Manufacturers, on the other hand, can diversify their portfolios to cater to varying market demands, investing in both electric vehicle technology and optimizing engines for HVO use [38].

Potential future trends in EV and HVO technologies
The demand for sustainable fuels, including HVO, is expected to grow significantly over the next two decades, especially in hard-to-abate sectors like aviation and heavy-duty transport. Electric vehicle adoption is also projected to increase, with advancements in battery technology and infrastructure development playing a crucial role. Investments in sustainable fuels are gaining momentum, with significant capacity projected by 2025. However, achieving global decarbonization targets will require substantial investments and innovations in both EV and HVO technologies [27].

Recommendations
Suggestions for further research
Further research is needed to explore the long-term environmental impacts of both electric and HVO diesel vehicles, considering the entire lifecycle from production to disposal. Studies focusing on the scalability of HVO production, potential competition with food sources, and the
Policy recommendations for promoting sustainable transportation

Policymakers should consider providing incentives for the production and use of HVO, especially in regions where electric vehicle adoption is slow. Infrastructure development, both for EV charging and HVO refueling, should be prioritized. Regulations promoting the use of renewable energy sources for electric vehicle charging can further enhance the environmental benefits of EVs. Collaboration between policymakers, manufacturers, and researchers will be crucial to address the challenges and harness the potential of both technologies for a sustainable transportation future [8].

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