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Comparative Analysis of Electric Vehicles and Internal Combustion Engine Vehicles in Urban Transport

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Abstract
Urban transportation systems are under increasing pressure to reduce greenhouse gas emissions, improve air quality, and enhance energy efficiency. In this context, electric vehicles (EVs) are frequently promoted as a sustainable alternative to internal combustion engine vehicles (ICEVs). This study presents a comparative analysis of EVs and ICEVs within urban transport environments, focusing on environmental performance, energy efficiency, operational costs, infrastructure requirements, and public health implications. evaluates direct and indirect emissions, including tailpipe pollutants, lifecycle greenhouse gas emissions, and noise pollution. While ICEVs generate significant carbon dioxide, nitrogen oxides, and particulate matter during operation, EVs eliminate tailpipe emissions and contribute to improved urban air quality. However, the overall environmental advantage of EVs depends on electricity generation sources and battery production impacts. In cities powered by cleaner energy grids, EVs demonstrate substantially lower lifecycle emissions compared to conventional vehicles.
Keywords: Electric Vehicles (EVs); Internal Combustion Engine Vehicles (ICEVs); Urban Transport

Introduction
Urban transport systems play a central role in economic activity, social mobility, and daily life. However, they are also major contributors to greenhouse gas emissions, air pollution, traffic congestion, and noise. Internal combustion engine vehicles (ICEVs) have historically dominated city transportation due to their convenience, established fueling infrastructure, and relatively low upfront costs. Yet their reliance on fossil fuels has resulted in significant environmental and public health concerns, particularly in densely populated urban areas. Electric vehicles (EVs) have emerged as a promising alternative aimed at reducing urban transport emissions and improving energy efficiency. Unlike ICEVs, EVs produce zero tailpipe emissions, which directly contributes to improved air quality in cities. Given that urban residents are exposed to high levels of pollutants such as nitrogen oxides and particulate matter, the shift toward electric mobility is often framed as both a climate strategy and a public health intervention. Beyond emissions, EVs differ fundamentally from ICEVs in terms of drivetrain efficiency. Electric motors convert a higher percentage of stored energy into motion compared to combustion engines, which lose a substantial portion of energy as heat. This efficiency

advantage suggests that EVs may be better suited for stop-and-go urban traffic conditions, where regenerative braking can further enhance performance.

However, the comparison between EVs and ICEVs extends beyond operational emissions and efficiency. Manufacturing processes, battery production, fuel extraction, electricity generation, maintenance costs, and infrastructure requirements all influence the overall sustainability of each vehicle type. While EVs typically have higher initial production emissions due to battery manufacturing, their operational emissions may be significantly lower over the vehicle's lifespan, depending on the electricity mix used for charging. Urban infrastructure readiness also plays a crucial role. ICEVs benefit from well-established fueling networks, whereas EV adoption depends on the availability of accessible and reliable charging stations. Grid capacity, energy demand management, and public policy incentives further shape the feasibility of large-scale electrification in cities. Given these multiple dimensions, a comparative analysis of electric vehicles and internal combustion engine vehicles in urban transport must consider environmental, economic, technical, and social factors. This study aims to evaluate these variables comprehensively, providing a balanced assessment of how each vehicle type performs within the unique context of urban mobility systems.

Technical Differences Between EVs and ICEVs

Electric vehicles (EVs) and internal combustion engine vehicles (ICEVs) differ fundamentally in their mechanical structure, energy conversion processes, and operational design. These technical differences directly influence performance, efficiency, maintenance requirements, and environmental impact, particularly in urban transport settings.

The most significant distinction lies in the powertrain. ICEVs rely on an internal combustion engine that burns fuel, typically petrol or diesel, to generate mechanical energy. This process involves controlled explosions within engine cylinders, converting chemical energy into motion. In contrast, EVs use electric motors powered by rechargeable battery packs. Instead of combustion, electricity stored in batteries drives the motor, producing motion through electromagnetic interaction. As a result, EVs operate without fuel combustion or tailpipe emissions.

Energy conversion efficiency represents another major technical difference. Combustion engines typically convert only a fraction of the fuel's energy into usable motion, with a significant portion lost as heat. Electric drivetrains, on the other hand, are considerably more efficient, converting a larger percentage of stored electrical energy into mechanical power. This higher efficiency is particularly advantageous in stop-and-go urban traffic, where EVs can also recover energy through regenerative braking systems. Regenerative braking captures kinetic energy during deceleration and feeds it back into the battery, improving overall efficiency.

Mechanical complexity also differs significantly between the two systems. ICEVs contain numerous moving components, including pistons, crankshafts, valves, exhaust systems, and transmission assemblies. These parts require regular lubrication, maintenance, and periodic replacement. EVs have fewer moving components in their drivetrain, which generally results in lower mechanical wear and reduced maintenance requirements. The absence of engine oil changes, exhaust systems, and complex gear transmissions simplifies long-term servicing.

Battery systems are central to EV operation. Lithium-ion battery packs store electrical energy and supply power to the motor through electronic control systems. Battery management systems regulate temperature, charging cycles, and performance to ensure safety and longevity. ICEVs, by contrast, use smaller batteries primarily for starting the engine and powering auxiliary systems, while energy storage for propulsion is maintained in liquid fuel tanks.

Refueling and charging processes further highlight technical differences. ICEVs can be refueled quickly at established fuel stations, while EVs require charging through electrical infrastructure. Charging speed depends on battery capacity, charging technology, and grid capacity. Although fast-charging systems are improving, charging typically takes longer than conventional refueling.

EVs and ICEVs differ not only in energy source but also in system architecture, efficiency, mechanical complexity, and energy management. These technical distinctions shape their environmental performance, operational costs, and suitability for urban transport environments. Understanding these differences is essential for evaluating the long-term transition toward sustainable mobility systems.

Energy Efficiency and Performance in Urban Driving Conditions

Urban driving conditions are characterized by frequent acceleration, deceleration, traffic congestion, short travel distances, and lower average speeds. These factors significantly influence how different vehicle technologies perform in terms of energy efficiency and operational effectiveness. Electric vehicles (EVs) and internal combustion engine vehicles (ICEVs) respond differently to such conditions due to their distinct drivetrain mechanisms.

Electric vehicles are generally more energy efficient in urban environments. Electric motors deliver instant torque, allowing smooth and rapid acceleration without the need for complex gear shifting. This characteristic is particularly advantageous in stop-and-go traffic, where frequent starts and stops are common. Moreover, EVs utilize regenerative braking systems that capture kinetic energy during deceleration and convert it back into stored electrical energy. This process improves overall efficiency by reducing energy loss, especially in congested city settings.

In contrast, internal combustion engine vehicles tend to perform less efficiently under similar conditions. Combustion engines operate most efficiently at steady speeds and optimal engine revolutions. In urban traffic, repeated idling and low-speed operation reduce fuel efficiency. Additionally, energy lost as heat during combustion further limits overall efficiency. Idling in traffic contributes to unnecessary fuel consumption and increased emissions without productive movement.

Energy conversion efficiency also differs substantially. Electric drivetrains convert a high proportion of electrical energy into mechanical motion, whereas combustion engines lose a significant share of energy through heat dissipation and friction. As a result, EVs typically consume less energy per kilometer traveled in city environments compared to ICEVs.

Performance characteristics further distinguish the two technologies. EVs provide immediate power delivery and quieter operation, enhancing driving comfort in urban areas. Reduced vibration and noise levels contribute to improved passenger experience and lower urban noise

pollution. ICEVs, while capable of high-speed performance, do not offer the same level of smooth acceleration and low-speed responsiveness.
However, factors such as battery range, temperature sensitivity, and charging accessibility can influence EV performance in certain urban contexts. Cold weather conditions may temporarily reduce battery efficiency, and limited charging infrastructure can affect operational convenience. Despite these considerations, EVs generally demonstrate superior energy efficiency and performance in urban driving scenarios.
urban transport environments highlight the inherent advantages of electric drivetrains. Higher energy efficiency, regenerative braking capabilities, and smoother acceleration make EVs particularly well-suited for city mobility, supporting their growing adoption in metropolitan transportation systems.

Tailpipe Emissions and Urban Air Quality Impacts
Urban air quality is heavily influenced by road transport emissions, particularly in densely populated cities with high traffic volumes. Internal combustion engine vehicles (ICEVs) emit a range of pollutants directly from their exhaust systems, including carbon dioxide (CO_2), nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons, and particulate matter (PM). These pollutants contribute not only to climate change but also to smog formation, respiratory illnesses, cardiovascular diseases, and overall public health burdens.
Tailpipe emissions from ICEVs are especially problematic in urban environments where vehicles frequently idle in traffic or operate at low speeds. Incomplete combustion under such conditions increases pollutant output. Nitrogen oxides and volatile organic compounds react in sunlight to form ground-level ozone, a key component of urban smog. Fine particulate matter can penetrate deep into the lungs, leading to chronic respiratory conditions and increased hospital admissions.
Electric vehicles (EVs), by contrast, produce zero tailpipe emissions during operation. The absence of combustion eliminates direct emissions of NO_x, CO, and PM from the vehicle itself. This feature offers immediate local air quality benefits, particularly in cities struggling with pollution levels above recommended health standards. Reduced street-level emissions can significantly improve air quality in traffic-dense corridors, residential areas, and near schools or commercial districts.
However, the broader environmental impact of EVs depends on the source of electricity used for charging. If electricity generation relies heavily on fossil fuels, emissions may shift from urban centers to power generation sites rather than being entirely eliminated. Nevertheless, even in fossil-fuel-dependent grids, centralized power plants often operate with higher efficiency and stricter emission controls compared to dispersed vehicle exhaust systems. As electricity grids incorporate more renewable energy sources, the indirect emissions associated with EV operation continue to decline.
Noise pollution is another important dimension of urban environmental quality. ICEVs generate engine and exhaust noise, particularly during acceleration. EVs operate much more quietly at low speeds, reducing overall urban noise levels. Lower noise pollution contributes to improved living conditions and reduced stress in densely populated areas.

tailpipe emissions from ICEVs remain a major contributor to urban air pollution and associated health risks. Electric vehicles provide clear local air quality advantages by eliminating direct exhaust emissions. When combined with cleaner electricity generation, EV adoption can substantially improve urban environmental conditions and public health outcomes.

Conclusion

The comparative assessment of electric vehicles (EVs) and internal combustion engine vehicles (ICEVs) in urban transport highlights clear structural, environmental, and efficiency differences. EVs demonstrate superior energy conversion efficiency, smoother performance in stop-and-go traffic, and the ability to recover energy through regenerative braking. These characteristics make them particularly well suited to urban driving conditions, where congestion and short-distance travel dominate. From an environmental perspective, the elimination of tailpipe emissions gives EVs a significant advantage in improving urban air quality. Reduced emissions of nitrogen oxides, particulate matter, and carbon monoxide directly benefit public health and help cities address pollution-related challenges. However, the full climate advantage of EVs depends on electricity generation sources and sustainable battery production practices. Without parallel progress in clean energy transition and responsible manufacturing, some environmental benefits may be limited. Economic considerations further shape the comparison. While EVs typically involve higher upfront purchase costs, they often offer lower operational and maintenance expenses over time. Infrastructure readiness, including accessible charging networks and grid stability, remains a critical factor influencing large-scale adoption in cities. urban environments tend to amplify the strengths of electric vehicles. Higher efficiency in traffic conditions, lower noise levels, and improved air quality outcomes position EVs as a strong alternative to conventional combustion-based vehicles. Nevertheless, a successful transition requires coordinated policy support, clean energy integration, and strategic infrastructure planning. A balanced and context-specific approach will ensure that electrification of urban transport delivers sustainable, long-term environmental and social benefits.

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