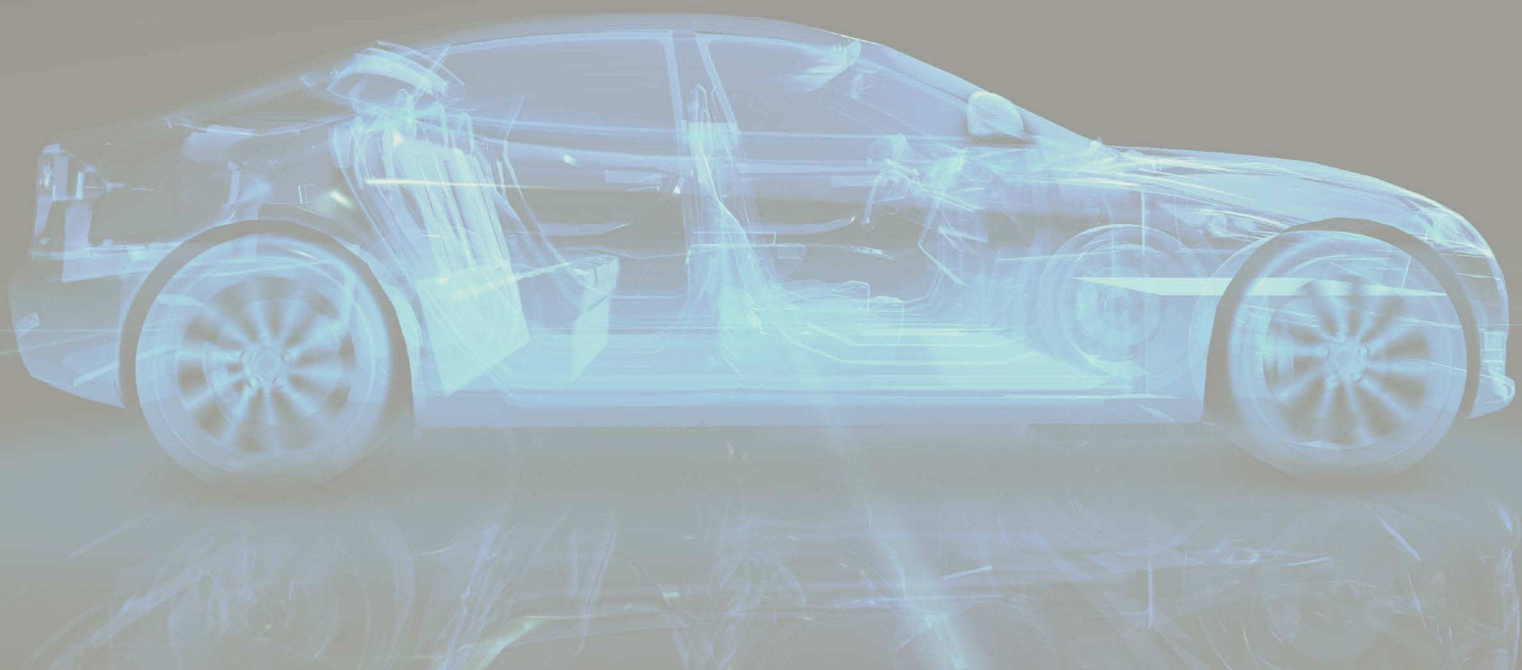
Fuels Institute

Life Cycle Analysis Comparison

JANUARY 2022

ELECTRIC AND INTERNAL COMBUSTION ENGINE VEHICLES

EXECUTIVE SUMMARY



Executive Summary

Life Cycle Analyses of Electric and Internal Combustion Vehicles

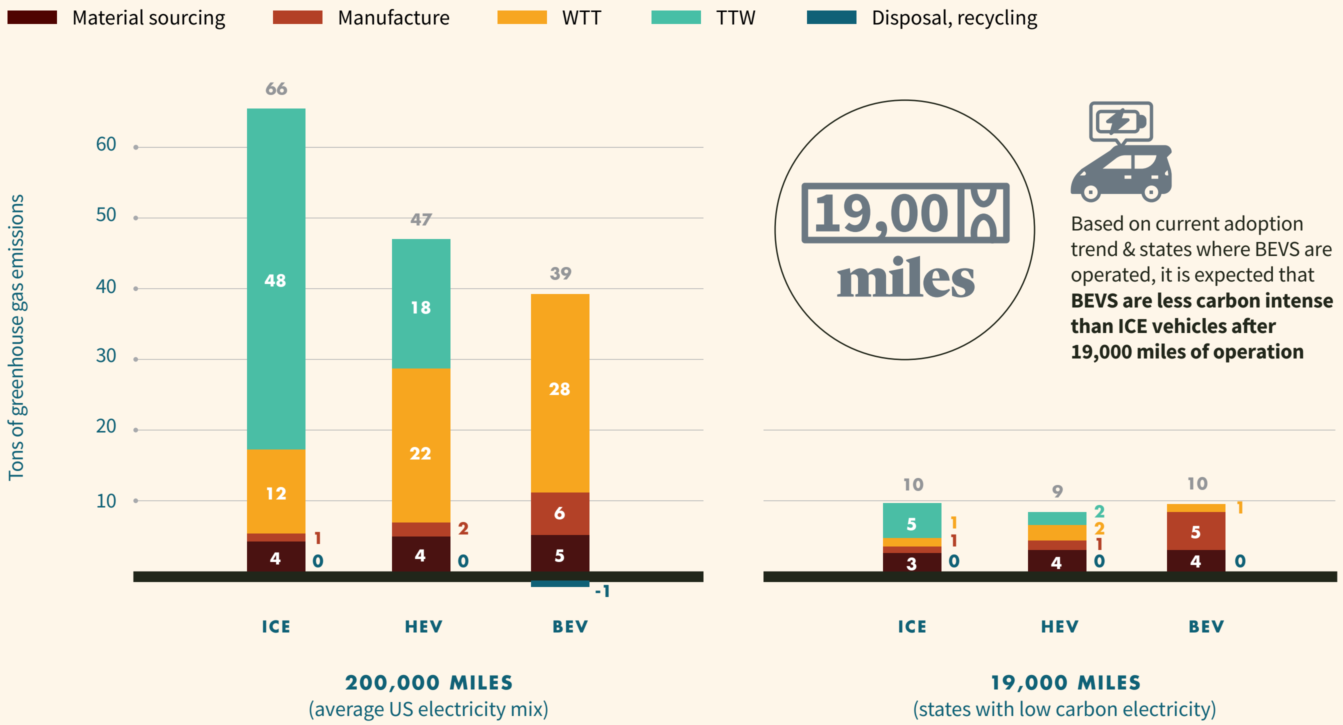
Ricardo Strategic Consulting conducted a life cycle assessment study for the Fuels Institute to study the life cycle emissions and total cost of ownership of internal combustion engine (ICE) vehicles and electric vehicles. The study involved an extensive literature review of the research work in this field and a customized life cycle analysis (LCA) model development by Ricardo.

During the literature review phase, Ricardo studied research material from government agencies, private corporations, and academic institutions for the approaches used and results published.

The firm developed a custom-made LCA model with an approach developed from the literature review and Ricardo internal expert consultations. The greenhouse gas (GHG) emissions from various stages in the life cycle from cradle to grave of the vehicle were studied.

The various stages in the life cycle include vehicle manufacturing, operation, and vehicle after-life management. Vehicle production involves the material procurement and processing phase. The operational cycle includes fuel production (petroleum or electricity based on the vehicle) and utilization of the fuel in the vehicle. Vehicle after-life management includes vehicle and powertrain disposal, material substitution through any remanufacturing, and recycling.

FIGURE 1: GHG EMISSIONS (IN TONS)



Argonne National Lab's 2020 Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model was used in conjunction with benchmarking databases to estimate the life cycle GHG emissions. Figure 1 presents a summary of the findings from the LCA modeling exercise with the reconciled emissions projected from individual stages.

The life cycle assessment is inclusive of a certain base set of assumptions with a plethora of factors, variances of which influence the total emissions from the vehicle throughout its lifetime. This report lists important factors that impact the emissions and varies corresponding input parameters to identify the variations in the GHG emissions results. Electricity makeup, fuel production chains, technological advancements, driving-style variations, and ambient temperature of vehicle operation are some identified key factors. The study included a sensitivity analysis to determine the effects of the variations. Figure 2

FIGURE 2: SENSITIVITY ANALYSIS

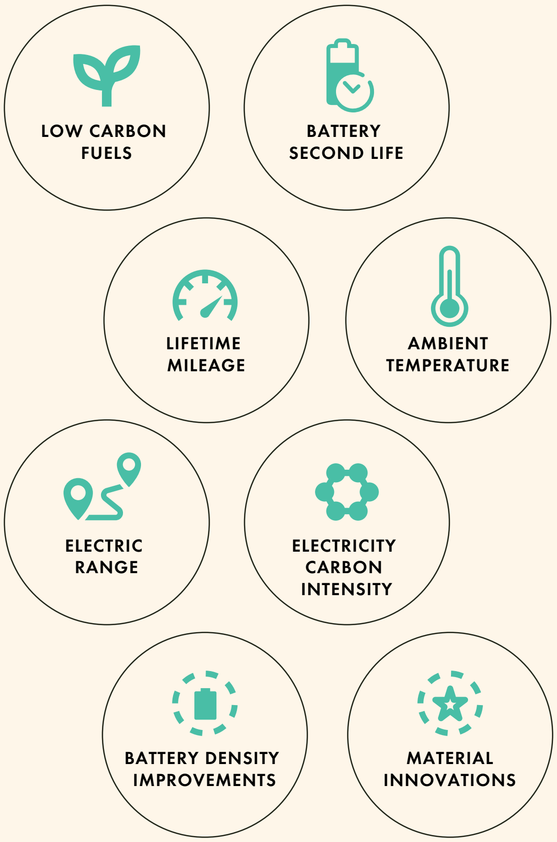
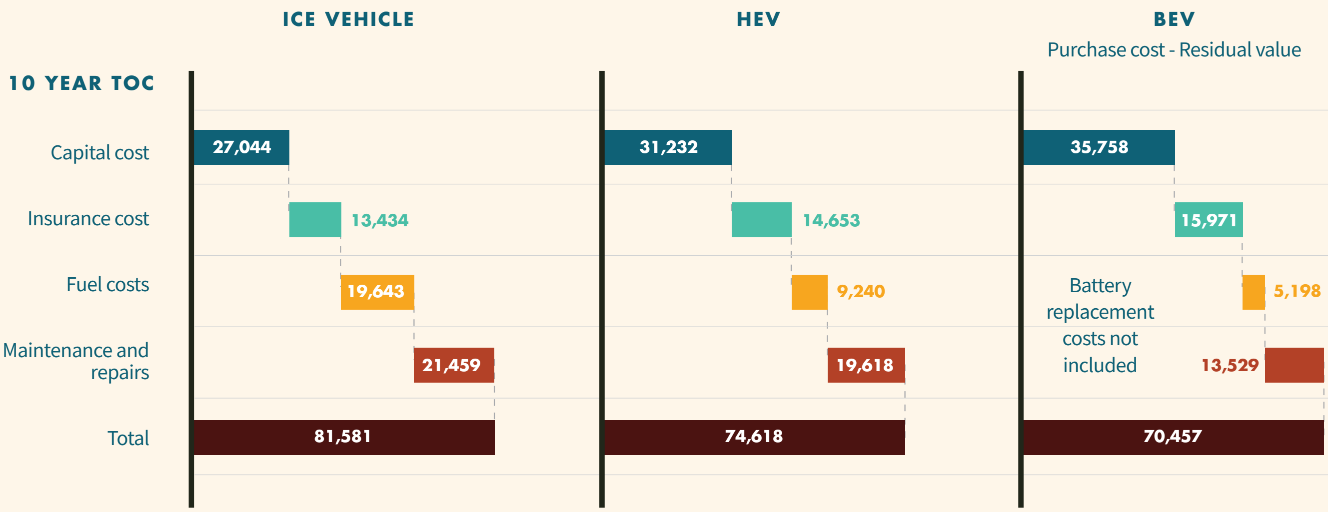


FIGURE 3: TOTAL COST OF OWNERSHIP (IN $)



Purchase cost - residual value
Battery replacement costs not included
Tax incentives not included

From a public policy perspective, the end consumers' total financial burden of owning and operating a vehicle also plays a vital role in operationalizing the GHG advantages from a given vehicle configuration. Total cost of ownership (TCO) is a means to estimate the total financial burden on the owner of the vehicle considering all associated costs with owning and operating a vehicle. Hence, vehicle TCO is a crucial component of life cycle assessments. It is a means to evaluate, from a cost perspective, the technological and sustainability impacts and a powerful tool for policy makers to design public policies and laws to influence transportation emissions strategies. Ricardo has developed a customized model for passenger vehicles that evaluates a 10-year TCO of vehicles with different powertrain configurations. The vehicle purchase and residual values (not including any government incentives such as tax credits) and its operating costs, such as insurance, fuel, maintenance, and repair, are all considered a part of the study, and these costs have been modeled using unique approaches. Figure 3 presents a summary of the results from the TCO model that predicts battery electric vehicles (BEVs) have a significant cost advantage in the long term compared to other vehicle configurations.

Although TCO plays a key role in customer adoption of vehicles and technologies, it is not the exclusive factor. Several other tangible and intangible factors, such as government incentives, infrastructure availability, proximity of refueling stations, customer perception on range anxiety, and vehicle brand perception, also play a key role in vehicle and technology penetration.

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