Light Duty Vehicle Greenhouse Gas Life Cycle Assessment

R&D GREET 2023 Annual Update

Argonne National Laboratory's Research & Development Greenhouse gases, Regulated Emissions, and Energy use in Technologies (R&D GREET®) model analyzes the life cycle impacts of vehicle, fuel, chemical, and material technologies. These analyses guide research and development and decision-making for current and future transportation and energy systems.

Comparing light duty vehicle-fuel combinations

R&D GREET can be used to compare and contrast the complete greenhouse gas (GHG) emission impacts for all components of a vehicle's life cycle. For instance, researchers can assess the GHG emission impacts between gasoline and electric vehicles (EVs), including emissions from vehicle production and end-of-life, fuel production and use, and facility construction (i.e., embodied emissions in fuel production facilities).

Figure 1 shows this comparison in action by calculating the life cycle GHG emissions of two representative 2024 light-duty sports utility vehicles: one a gasoline-powered internal combustion engine (ICE) vehicle and the other an EV. This comparison looks at the emissions produced per mile (g CO_2e/mile). Each vehicle is using a representative fuel: E10 gasoline for the ICE and the U.S. average electricity grid generation mix[1] for the EV. For the ICE, fuel use (i.e., gasoline combustion in the vehicle during use) is the greatest contributor to GHG emissions, while fuel production (i.e., generating electricity) is the biggest contributor for EVs. Overall, R&D GREET shows that the 2024 EV produces 52% less GHG emissions than a comparable ICE vehicle.

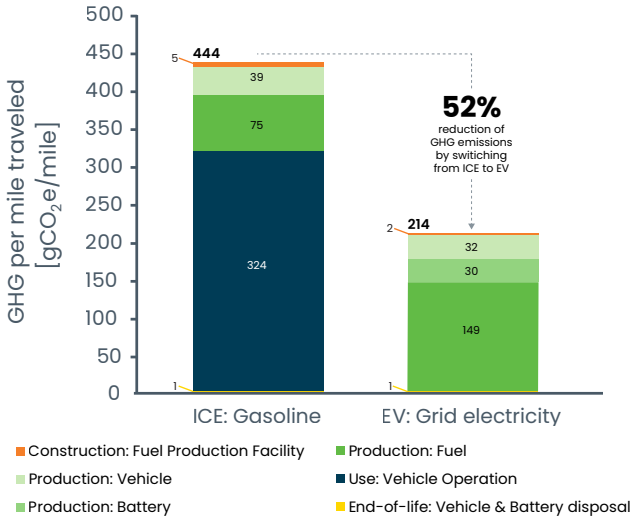

FIGURE 1: Electric vehicles today produce 52% fewer GHGs than their comparable gasoline vehicles on a life cycle basis.
The life cycle GHG emissions on a per-mile basis for representative electric and gasoline 2024 light-duty passenger vehicles (small, sports utility vehicles). Life cycle GHG emissions include those from construction of the fuel production facility, vehicle and battery production[2] and end-of-life, and production and use of fuel in the vehicle. Source: R&D GREET 2023; Simulation year: 2024.

Tracking Trends and Forecasting the Future: Fuels

R&D GREET can also track progress and projected changes over time—identifying where, for example, we can reduce emissions throughout technology development or deployment. By tracking these trends, R&D GREET can identify target areas for further research and help assess the impacts of technology options.

Figure 2 demonstrates this tracking over time for two fuels used in light-duty vehicles: gasoline and electricity. In contrast to Figure 1, when comparing fuels alone, a common metric for comparison is on a unit energy basis, as shown in megajoules (MJ)

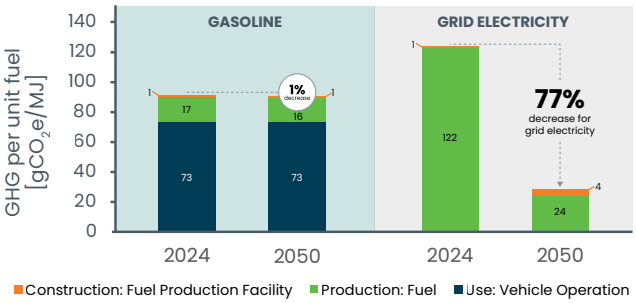

FIGURE 2: 77% GHG emissions reduction from grid electricity projected by 2050 outpaces reduction for gasoline fuel.
The life cycle GHG emissions of gasoline and electricity on a per-MJ fuel delivered basis today and in the future. Life cycle GHG emissions from a fuel perspective include those from construction of the fuel production facility, fuel production itself, and use of the fuel during vehicle operation. Source: R&D GREET 2023; Simulation years: 2024 and 2050. Year 2050 uses 2023 NREL Standard Scenarios Midcase for estimated electricity grid generation mix.

in Figure 2. While R&D GREET predicts relatively little change to gasoline fuel life cycle emissions by 2050, dramatic reductions are expected for electricity over the same time period. These GHG reductions seen in electricity stem from larger portions of the grid projected to be powered by renewables, such as solar and wind, in 2050.

Tracking Trends and Forecasting the Future: Fuels and Vehicles

R&D GREET can further combine the results for fuels in Figure 2 with future projections of light-duty vehicle production, use, and disposal emissions. This comparison holistically integrates the full life cycle of light-duty vehicles in the future.

Figure 3 shows the trends in time for ICEs and EVs. From 2024 to 2050, ICEs are projected to reduce their life cycle GHG emissions by 28% down to 318 gCO_2e/mile, primarily through improving the vehicle's fuel economy (i.e., MPG). Only small improvements to gasoline fuel production or vehicle production technology are expected. In contrast, EVs sold in 2050 are expected to have life cycle GHG emissions of 73 gCO_2e/mile, a 66% reduction from 2024. While ICEs benefit from vehicle fuel economy improvement, EVs benefit from both fuel economy improvement and a cleaner fuel as clean electricity deployment increases. As a result, the GHG emission gap between EVs and ICEs is widened by 2050.

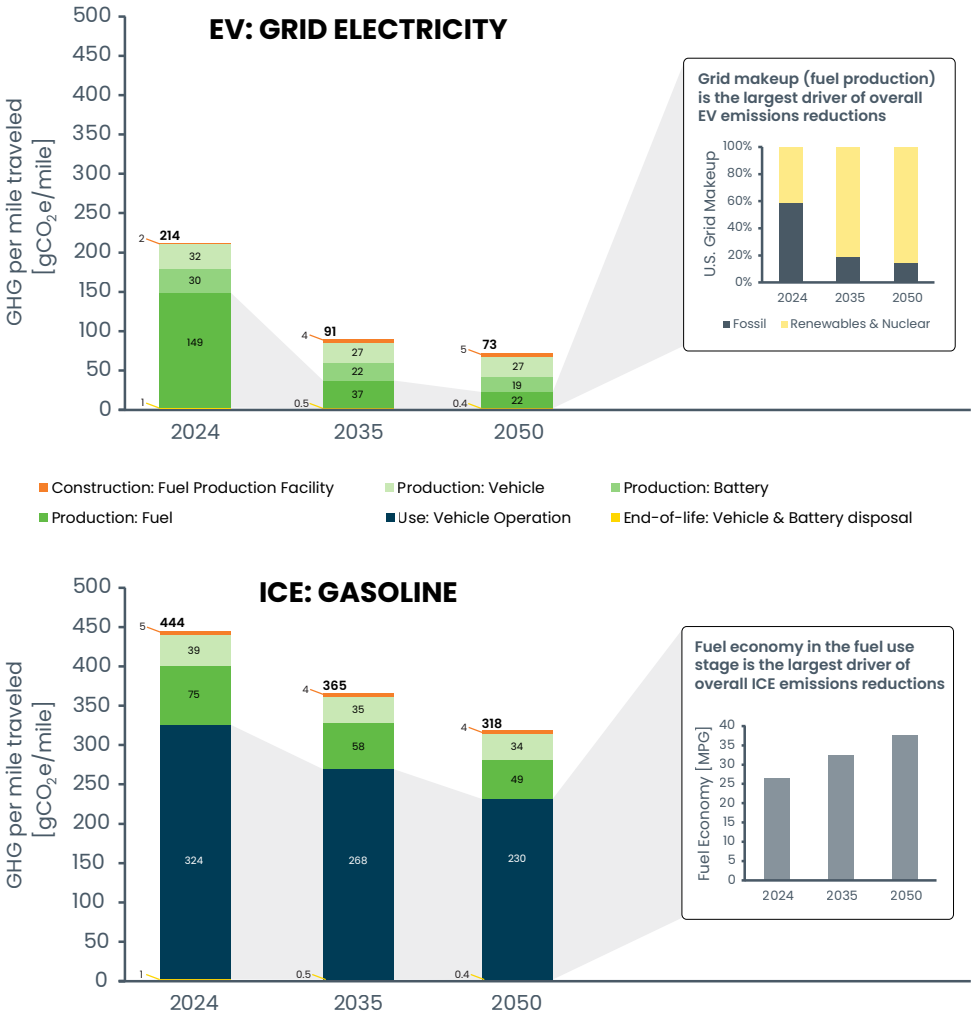

FIGURE 3: EVs projected to dramatically reduce GHG emissions as U.S. grid decarbonizes.
The GHG emissions per mile for 2024, 2035, and 2050 for light-duty sports utility vehicles. GHG emissions include those from construction of the fuel production facility, vehicle and battery production[2] and end-of-life, and production and use of fuel in vehicle. Source: R&D GREET 2023; Simulation years: 2024, 2035, and 2050. Years 2035 and 2050 use 2023 NREL Standard Scenarios Midcase for estimated electricity grid generation mix.

1 The U.S. grid is powered by a mix of power plants that use different fuel sources to generate electricity (e.g., coal, natural gas, wind, solar, nuclear, and others)
2 Lead-acid battery production emissions for ICE vehicles are included in the "Production: Battery" category, but they are negligible.