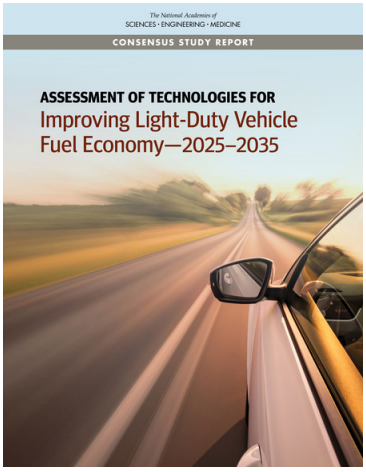
Consensus Study Report
HIGHLIGHTS
March 2021

Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy—2025-2035



The 2025-2035 timeframe will bring fundamental changes to the cars and trucks we drive, from the growing market share of electric vehicles, to the deployment of automated vehicle technologies, to increasingly globalized markets and a priority to reduce greenhouse gas (GHG) emissions. These developments will transform how automakers design, manufacture, and market vehicles; how businesses sell, service, and refuel them; how consumers buy and use their vehicles; and how federal, state, and local governments regulate and plan for future transportation infrastructure.

At the request of Congress and the Department of Transportation (DOT), the National Academies evaluated how internal combustion engine, hybrid, battery electric, fuel cell, nonpowertrain, and connected and automated vehicle technologies could contribute to vehicle efficiency in 2025-2035, and the impacts of these technologies for consumers, manufacturers, and vehicle regulations. The report provides cost and effectiveness estimates for future fuel efficiency technologies and recommends updates to the current Corporate Average Fuel Economy (CAFE) standards to reflect new technical, economic, and policy developments.

TECHNOLOGY FUTURES

Internal combustion engines vehicles (ICEVs) will continue to play a significant role in the new vehicle fleet in 2025-2035. Manufacturers will continue to develop and deploy technologies to further improve the efficiency of conventional powertrains, with the greatest potential coming from electric hybridization.

Battery electric vehicles (BEVs) with longer electric range (e.g., 300 miles) may reach cost parity with comparable ICEVs by 2030, primarily due to projected reductions in battery cost. In 2025-2035, lithium ion batteries will be the dominant battery technology, and wide bandgap devices (silicon carbide or gallium nitride) are expected to be used in power electronics.

Fuel cell electric vehicles (FCEVs) are being prioritized by a few major automakers in order to take advantage of their long ranges and short refueling times relative to battery electric vehicles. FCEVs could reach parity with ICEVs in total cost of ownership in 2025-2035 if aggressive efficiency and cost targets are met.

Nonpowertrain technologies will continue to improve fuel economy through further advances in mass reduction, aerodynamics, and reducing rolling resistance. In 2025-2035, automakers will implement mass reduction to improve driveability and reduce fuel consumption in all vehicles, and for increased driving range in BEVs and

FCEVs. Mass and geometric disparity in the fleet may increase or decrease due to electrified powertrains, new architectures, advanced driver assistance systems, and a shift from sedans to crossovers/SUVs/pickup trucks. Improvements in crash compatibility will reduce the adverse effect of mass and geometric disparity on crash safety for all road users.

Vehicle connectivity and automation technologies could improve the fuel efficiency of ICEVs by up to 9% in city driving and up to 5% on the highway by detecting upcoming conditions and adjusting acceleration and powertrain operation accordingly. Fully-automated light-duty vehicles (LDVs) will be deployed in some ride-hailing, delivery, and closed-campus fleets by 2025. More widespread adoption of automated technologies will require ensuring safety under all conditions, resolving cybersecurity issues, developing appropriate regulations, and gaining consumer acceptance of a radically different driving experience.

INCREASING DEPLOYMENT OF ZERO-EMISSION VEHICLES

The greatest opportunity and uncertainty for light-duty vehicle energy efficiency in 2025-2035 will be the increasing penetration of zero-emission vehicles (ZEVs). The price of the vehicles, fueling infrastructure, performance attributes, and consumer interest in and comfort with the technology will be major determinants in their uptake. Automakers are predicting deployment of tens of millions of ZEVs globally during 2025-2035, with leading jurisdictions (e.g., California, China, Europe) aiming to achieve 50%-100% ZEV sales by 2030-2035. High penetration of ZEVs will involve profound changes to the vehicle fleet, charging/fueling infrastructure, business models for dealers, driver behaviors, repairs, emergency response, materials, and battery recycling.

RECOMMENDATION: The agencies should use all their delegated authority to drive the development and deployment of ZEVs, because they represent the long-term future of energy efficiency, petroleum reduction, and GHG emissions reduction in the LDV fleet. Vehicle efficiency standards for 2035 should be set at a level consistent with market dominance of ZEVs at that time, unless consumer acceptance presents a barrier that cannot be overcome by public policy and private sector investment. At the same time, maximum feasible fuel economy of petroleum-fueled vehicles should be pursued, under NHTSA's interpretation of its existing authority, and as a portion of EPA's combined stringency assessment. The pathway to zero emissions should be pursued in a technology-neutral manner.

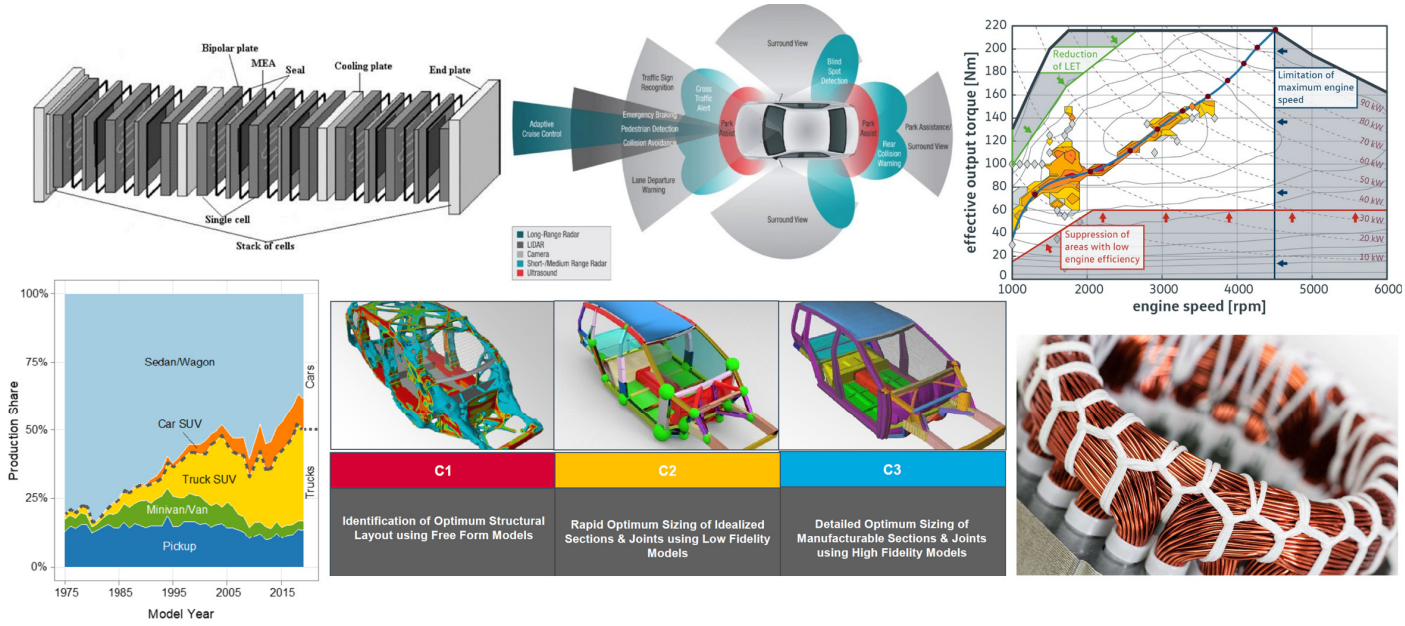
RECOMMENDATION: The U.S. federal purchase subsidies for BEVs, plug-in hybrid electric vehicles (PHEVs), and FCEVs should be continued until financial and psychological consumer barriers to purchasing such vehicles have been overcome. However, they should be changed to point-of-sale rebates to increase effectiveness and lower fiscal burdens. Income eligibility should be considered for both equity and effectiveness.

RECOMMENDATION: DOT, EPA and the Department of Energy (DOE) should coordinate to facilitate electric charging and hydrogen refueling infrastructure deployment with relevant stakeholders, including state and local government agencies, business associations and entities. Congress should appropriate funds for, and the agencies should create, a national public-private partnership to lead this coordinating effort.

ENCOURAGING CONSUMER ACCEPTANCE

New vehicle purchasers select vehicles with a variety of factors in mind, including fuel economy. Many consumers initially resist new technologies that disrupt current practices and lifestyles, or create novel risks or uncertainties, even if the technology provides net benefits to them.

RECOMMENDATION: Because consumer resistance to novel technology is a significant issue in market penetration and acceptance of new technologies, policy interventions beyond purchase subsidies may be needed to address these barriers. Such policies may include investment in charging and refueling infrastructure, or consumer education and exposure to the new technology and its benefits.



The report evaluates internal combustion, battery electric, fuel cell, connected/automated, and nonpowertrain technologies that are expected to impact vehicle efficiency in 2025-2035, including related consumer and regulatory considerations.

TEST CYCLES AND LIFECYCLE EMISSIONS

The current test procedures to determine CAFE fuel economy compliance are insufficient to test electric vehicle range and connected and automated vehicle operation, and they do not adequately reflect modern driving patterns of light-duty vehicles. Furthermore, there is no representatively sampled, empirical measure of on-road fuel consumption or GHG emissions for the U.S. light-duty fleet, but such a statistically valid and relevant dataset is increasingly possible to assemble using onboard diagnostics and available customer data.

RECOMMENDATION: The agencies (DOT, EPA, and DOE) should conduct a study on how well current driving patterns and new vehicle technology impacts are reflected by current vehicle certification test cycles. The results of this study should then be used to propose new LDV test cycles, or to re-adopt or revise the weighting of the existing 5-cycle test.

RECOMMENDATION: The agencies should implement a program that measures fuel consumption and GHG emissions from the LDV fleet in use. The purpose of the in-use program should be to evaluate and improve the effectiveness of the CAFE program, not for year-by-year enforcement against individual manufacturers.

Currently, vehicle manufacturers are responsible for meeting onboard per-mile fuel efficiency and emissions requirements. Neither NHTSA nor EPA account for full-fuel-cycle emissions or energy use in order to incentivize ZEVs, which have no GHG emissions at the tailpipe but some upstream emissions and energy use associated with generating electricity, hydrogen, or other zero-emissions fuels. Lifecycle assessments would more fully capture total GHG emissions and energy consumption and enable easier comparison between vehicles using different fuels.

RECOMMENDATION: In the longer term, it makes sense to address the full fuel cycle emissions of all vehicles, including ZEVs, especially as ZEVs become a progressively larger portion of the LDV fleet.

AGENCY COORDINATION AND CAFE STANDARDS

The efforts of NHTSA and EPA to coordinate their fuel economy and GHG emission standards since 2010 have been beneficial and should be continued to the extent feasible. However, the separate agency standards may

now diverge because of the growing availability and benefits from ZEVs and the agencies' different statutory authorities.

RECOMMENDATION: To fulfill its statutory mandate of obtaining the maximum feasible improvements in fuel economy, NHTSA should consider the fuel economy benefits of ZEVs in setting future CAFE standards. The simplest way to accomplish that would be for Congress to amend the statute by deleting the prohibition (42 U.S.C. § 32902(h)(1)) against considering the fuel economy of dedicated alternative fueled vehicles when setting CAFE standards.

RETHINKING FUEL ECONOMY REGULATIONS IN 2025-2035 AND BEYOND

Given the projected changes to vehicle technology, national goals for vehicle efficiency and emissions, and other changes to the LDV transportation system in 2025-2035, the existing CAFE program is quickly becoming outdated. It will need to be updated between 2025 and 2035 for legal, scientific, policy, technological, and economic reasons. When the CAFE program was adopted, its primary objective was to enhance energy security by reducing reliance on petroleum imports. Today, while energy security concerns remain relevant, addressing climate change has risen in importance, and this should now be expressly recognized in the CAFE program. It is increasingly likely that the United States will and must adopt an economy-wide national program to reduce GHG emissions across all sectors before or during 2025-2035.

Thus, the most important large-scale and longer-term issue is how the CAFE program, and GHG emissions from LDVs generally, fit within a broader national strategy to combat climate change. Regardless of the structure of any such strategy, it will almost certainly intersect with the CAFE program, given the significant contributions from the transportation sector to overall U.S. GHG emissions. Furthermore, the breadth of expected changes in mobility and transportation over the coming decades suggests that interagency coordination will be required to adequately address the many facets of sustainable transportation, from new vehicle technologies and ownership models, to fuel supply and infrastructure needs, to justice and fairness impacts.

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