

In the future, connected autonomous vehicles could coordinate with each other by forming platoons and by creating gaps to allow for merging vehicles.

# What's Ahead for Light-Duty Motor Vehicle Emissions?

An overview of the projected trajectory for light-duty motor vehicle emissions, trends, and standards.

The global stock of on-road light-duty vehicles (LDVs) grew by nearly 32% from 2010 to 2018, reaching over 1.3 billion (see Figure 1), with increases to over 2.4 billion vehicles projected by 2050. Much of this growth will occur in Asia. Although market shares of alternative vehicles—including plug-in hybrid electric vehicles (PHEVs), battery-powered electric vehicles (BEVs), natural gas-fueled vehicles, and hydrogen fuel-cell vehicles (FCEVs)—are expected to increase, in the absence of policies to the contrary, the vehicle fleet is expected to be dominated by internal combustion engine (ICE) fossil-fueled vehicles for the next few decades.<sup>1</sup>

U.S. LDV greenhouse gas emissions increased by 13% from 1990 to 2018 to 1.09 billion metric tons of carbon dioxide (CO<sub>2</sub>)-equivalent.<sup>2</sup>

### Improvements in Conventional Vehicle Technology

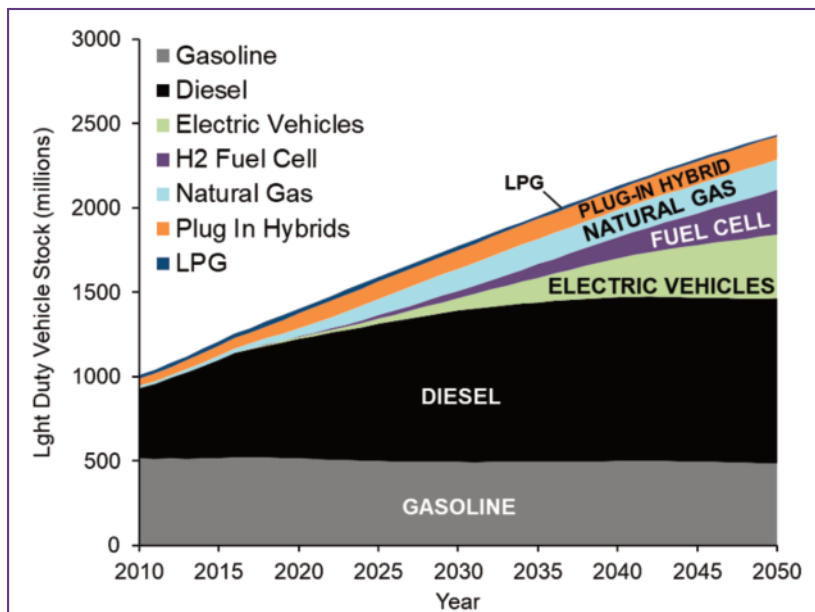
Conventional LDVs are becoming more energy efficient through the use of improved technologies (e.g., direct injection, more efficient transmissions, hybridization).<sup>3</sup> Although average vehicle weight is approximately the same, and although average engine horsepower is 70% greater, the

U.S. LDV fleet today is approximately twice as fuel efficient as it was in 1970. While fuel economy improvements could lead to net reductions in energy consumption in developed countries, growth in vehicle stock and vehicle miles traveled (VMT) elsewhere is likely to increase global energy consumption (see Figure 2).<sup>1,4</sup>

### Trends in Consumer Choices

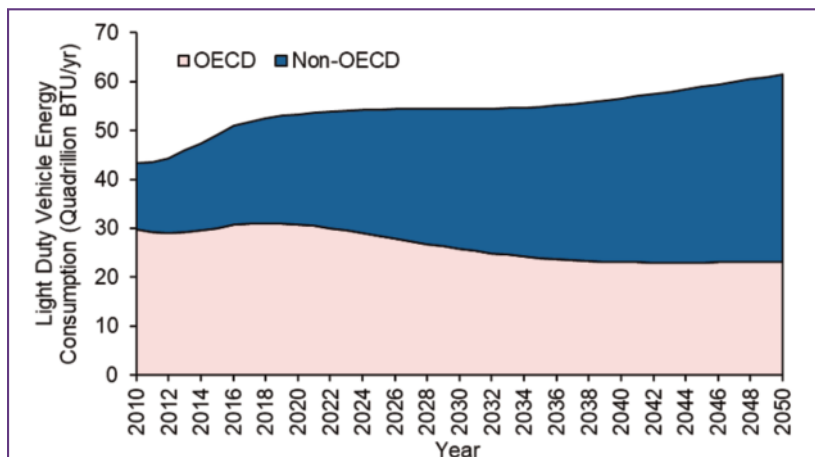
The rise of sport utility vehicles (SUVs) has been one of the major drivers of recent global CO<sub>2</sub> emissions growth, according to the International Energy Agency, putting increased pressure on advanced technologies for reducing CO<sub>2</sub> emissions from vehicles. The U.S. market share of light-duty trucks, including SUVs, has recently far outpaced that of sedans and wagons (see Figure 3). In 2018, the fuel economy of truck-based SUVs averaged only 22 miles per gallon (mpg), compared to 30 mpg for sedans.<sup>2</sup>

Social attitudes toward transport may be changing in ways that could increase energy consumption. For example, energy consumption for vehicles used in ridesourcing services (e.g., Uber, Lyft) may be substantially higher, by 40%–90%, compared to previous transport mode choices, because of miles accumulated to reach a service territory and during deadheading (driving without passengers) between rides.<sup>5</sup> However, although some ridesharing is replacing walking and mass transit use, much of it replaces private car or taxi usage; thus, the overall effect on vehicle miles traveled and greenhouse gas emissions is small.<sup>6</sup>



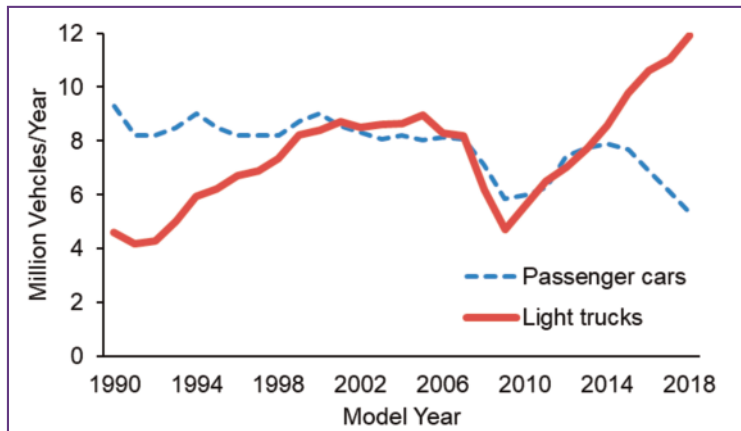
**Figure 1.** Global light-duty vehicle stock, projected to 2050.

Source: U.S. Energy Information Agency, **2019 International Energy Outlook** (<http://www.eia.gov/ieo>)



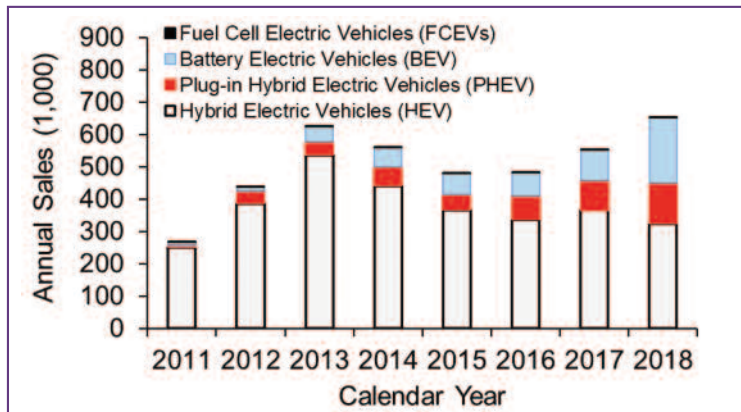
**Figure 2.** Global light-duty vehicle energy consumption for Organization of Economic Cooperation and Development (OECD) and non-OECD countries, projected to 2050.

Source: U.S. Energy Information Agency, **2019 International Energy Outlook** (<http://www.eia.gov/ieo>)



**Figure 3.** U.S. annual new vehicle sales for passenger cars and trucks (SUVs, pickups, minivans), 1990–2018.

Source: Table I-17, **U.S. Bureau of Transportation Statistics** (<https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases>)



**Figure 4.** Annual U.S. sales of advanced technology vehicles, 2011–2018.

Source: **Auto Alliance Advanced Technology Vehicle Sales Dashboard** (<https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>)

### Adoption of New Technologies

The adoption of new energy vehicle technologies in the United States is relatively modest. New U.S. LDV sales in 2018 were over 17 million, of which only 654,000 were advanced technology vehicles, such as hybrid electric vehicles (HEVs), PHEVs, BEVs, or FCEVs (see Figure 4). Following a few years of rapid growth, U.S. new vehicle technology sales have been stagnant from 2013 to 2018. Plug-in electric vehicle sales in Europe increased from 407,000 in 2018 to 579,000 in 2019.<sup>7</sup> The electric vehicle market share in China is 4.7% with annual sales well over one million per year.<sup>8</sup>

BEVs are zero-emitting at the point of use, except for brake and tire wear, and therefore, can play an important role in achieving health-based air quality standards in urban areas. Even in countries that produce significant proportions of electric power from coal, such as the United States and China, BEVs already emit less CO<sub>2</sub> per mile driven than

equivalent ICE vehicles and, as coal gradually gets phased out, this CO<sub>2</sub> advantage will increase. The global share of power generation from renewables, such as wind and solar, is expected to increase, and the emissions intensity of power generation is expected to decrease.<sup>3</sup>

Emissions from battery manufacturing are roughly comparable to that for ICEs used in conventional vehicles, and will decrease as electric power is decarbonized.<sup>9</sup> There are unlikely to be raw resource constraints (e.g., rare earth metals) on battery production capacity.<sup>10</sup> EVs are also not likely to be constrained by power generation capacity, although there will be a growing need for home and public chargers. Public policies to promote new vehicle technologies tend to benefit disproportionately wealthy populations.<sup>11</sup> To address equity in BEV adoption, California has been piloting a Clean Vehicle Assistance Program aimed at low-income adopters.<sup>12</sup>

### Disruption from Autonomous Vehicles

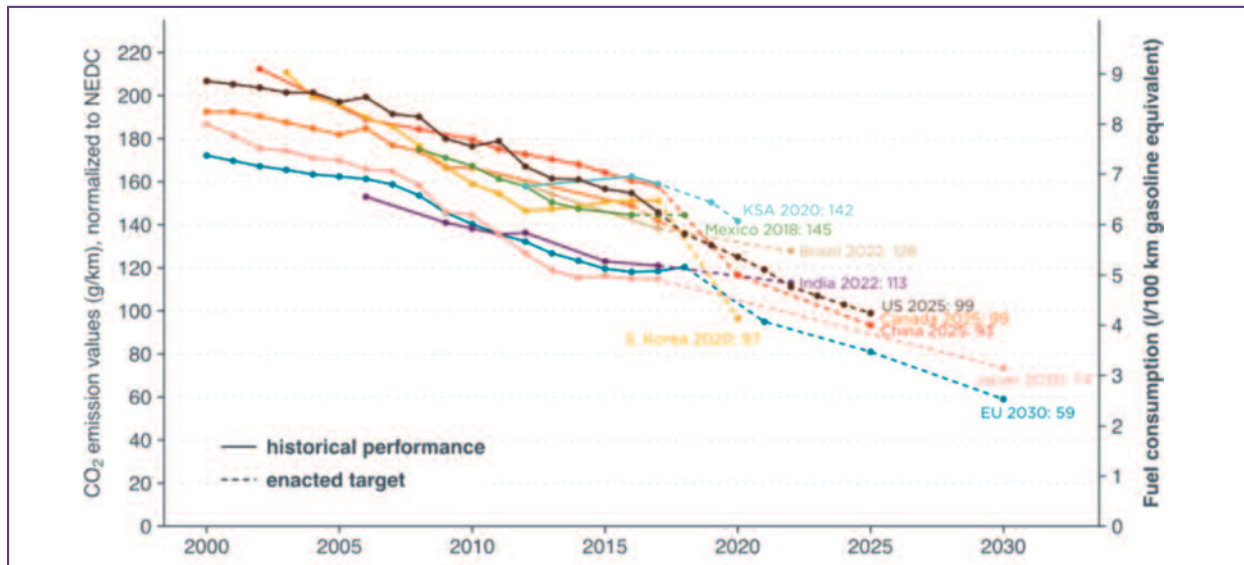
The emergence of autonomous vehicles (AVs) is likely to disrupt trends in LDV energy use and emissions. The effect of AVs will depend on many factors, such as levels of autonomy, vehicle connectivity, whether vehicles are shared, and the mix of AVs and traditional vehicles, as well as choices of fuels and powertrains. Broadly, AVs are likely to have two major impacts: at the individual vehicle level and at the macroscopic level.

At the individual vehicle level, AVs could be operated more efficiently by smoothing speed trajectories and coordinating with traffic and infrastructure. However, AV performance goals may differ by manufacturer and may not emphasize energy efficiency. Vehicles could be controlled, for example, to minimize travel time rather than energy use.

At the macroscopic level, such as for an urban region, AVs may dramatically change trip-taking activity. For example, children not old enough to drive a traditional vehicle may be allowed to use AVs. AVs could be used by elderly or disabled persons who are not easily able to drive a traditional vehicle. Furthermore, leisure time in an AV could lead to tolerance of longer commutes and increased sprawl in land-use patterns. Depending on these and other factors, AVs could substantially reduce or increase transport energy consumption, by roughly a factor of two.<sup>13,14</sup>

### International Policy and Regulation

Although light-duty diesel vehicles (LDDVs) are more fuel



**Figure 5.** Passenger car CO<sub>2</sub> emissions and fuel consumption values for selected countries, projected to 2030 and normalized to the New European Driving Cycle.

Source: International Council on Clean Transportation

efficient and lower CO<sub>2</sub>-emitting than equivalent gasoline vehicles, their future is uncertain. Markets that have historically had high shares of LDDVs, particularly the European Union (EU) and India, have promulgated more stringent tailpipe nitrogen oxides and particulate matter emission standards, which require expensive emission controls. Many European cities are restricting diesel cars in light of the VW diesel emissions scandal. The prospect of such restrictions leads to loss of consumer confidence that, if they buy a diesel car, they will be able to drive it as they normally have.

Numerous countries are adopting passenger car CO<sub>2</sub> emission and fuel consumption regulations (see Figure 5). The EU is currently the most aggressive with stringent requirements going into effect in 2020, 2025, and 2030. Meeting these standards in the future will be difficult without BEVs. BEVs are inherently clean and do not require large and ongoing investment in strong emissions compliance programs. To address climate change, many countries and cities are calling for the elimination of ICE vehicles. For example, the sale of petrol and diesel cars would be banned in Ireland from 2030 under draft proposals for a new climate law. The Irish proposal sees the country join Denmark, Sweden, and the Netherlands in targeting a 2030 deadline. France and Spain have announced similar plans with a 2040 date, while the United Kingdom and Norway plan to ban sales of petrol and diesel cars from 2035 and 2025, respectively.

Numerous manufacturers have announced investment of hundreds of billions of dollars for the production of BEVs and batteries, assuring an increasing variety of models and vehicle types and thereby increasing consumer options. As sales volumes climb, the cost of so-called zero-emissions

vehicles (ZEVs), including BEVs, is approaching that of ICE vehicles, with cost parity expected within five to seven years.<sup>15</sup> Increased affordability could enable more widespread adoption of BEVs.

### California's Unique Leadership Role

Because of historically uniquely severe air quality problems, California has the right under the U.S. Clean Air Act to request a waiver from the U.S. Environmental Protection Agency (EPA) to set its own state-level motor vehicle emission standards. For example, the California Air Resources Board (CARB) adopted the first ZEV mandate in 1990, primarily to address the serious ozone air pollution problem in the Los Angeles basin. As concerns regarding climate change increased, CARB viewed growth of ZEVs as critical to addressing that problem as well. Based on Section 177 of the Clean Air Act, other U.S. states can adopt either the federal or California standard. Thirteen states follow California's Low Emission Vehicle (LEV) standards of which nine also follow the ZEV mandate.

To place California's role in historical context, the state's technology-forcing regulations led to the introduction of three-way catalysts (TWC) to reduce carbon monoxide, hydrocarbon, and nitrogen oxides emissions from gasoline cars; advanced electronic controls and fuel-injection systems to assure proper air fuel mixture controls to optimize the performance of TWCs; onboard diagnostics to monitor emissions performance; and BEVs. These technologies have been adopted globally and have profoundly changed the global motor vehicle industry and its emissions footprint. For example, following California's technology and policy lead, China, which is the world's largest new car market, is now also the largest ZEV market.

## Reversal of U.S. Policy on Vehicle GHG Emissions

The recent U.S. trajectory toward more energy-efficient vehicles is being tempered by climate change deregulatory efforts of the current administration. In 2012, in an effort to assure a single national program, EPA, the U.S. National Highway Traffic Safety Administration (NHTSA), and CARB agreed to tighten greenhouse gas (GHG) and fuel economy standards through model-year 2025. To monitor progress, they provided for a mid-course review. In January 2017, EPA carried out an extensive review and concluded that the standards through model-year 2025 were feasible and more cost-effective than originally estimated. However, in April 2017, then-EPA Administrator Scott Pruitt reversed EPA's decision with the intent to freeze standards at 2020 or 2021 model-year levels.

In 2018, EPA and NHTSA issued a proposed regulation that would reverse California's waiver, at least with regard to GHG emissions and the ZEV mandate. The EPA/NHTSA proposal received strong criticism from the environmental and scientific communities, including EPA's own Science Advisory Board.<sup>16</sup> In particular, the modeling assumption that lowering the purchase price of new cars would result in overall VMT reductions was considered by many to be illogical. As of the time of writing, a final rule has not been promulgated, but is expected to require much more modest efficiency and CO<sub>2</sub> improvements annually from 2021 to

2025 than the 2012 rule. All parties expect the legal issues relating to California's authority to set standards for vehicle GHG emissions and to mandate ZEV sales to go to the U.S. Supreme Court for final resolution over the next year or so.

Looking to the future, if California is prevented from continuing its leadership role in reducing climate-related pollutants from vehicles, the likelihood of achieving the transportation emissions targets necessary to adequately address the climate crisis will be greatly diminished.

## Summary

Light-duty vehicle energy use and emissions are affected by a variety of trends, such as the current rollback of vehicle GHG emission standards in the United States, policies in other countries to promote cleaner vehicles, and manufacturer commitments to various technology options. Changing user needs for mobility and changing preferences for how mobility needs can be met will affect energy use and emissions. The anticipated emergence of autonomous vehicles may be highly beneficial or adverse with respect to energy use and emissions, depending on how technology adoption and deployment is managed. There is a growing need for research, demonstration, and implementation related to innovative technologies and policies to help manage these large changes. Technology-forcing regulation is an essential component of policies that can effectively reduce vehicle GHG emissions. **em**

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