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Transitions to Alternative Vehicles and Fuels

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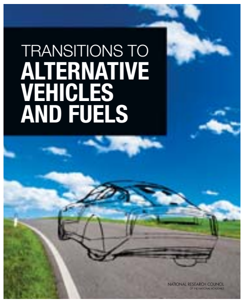


For a century, almost all light-duty vehicles (LDVs) have been powered by internal combustion engines (ICEs) operating on petroleum fuels. Energy security concerns over petroleum imports and the effect of greenhouse-gas (GHG) emissions on global climate are driving interest in alternatives. This report assesses the potential for reducing petroleum consumption and GHG emissions by 80% across the U.S. LDV fleet by 2050, relative to 2005. It examines the current capability and estimated future performance and costs for each vehicle type and non-petroleum-based fuel technology as options that could significantly contribute to these goals. By analyzing scenarios that combine various fuel and vehicle pathways, the report also identifies barriers to implementation of these technologies and suggests policies to achieve the desired reductions. Several scenarios are promising, but strong, effective, and sustained but adaptive policies such as research and development (R&D), subsidies, energy taxes, or regulations will be necessary to overcome barriers such as cost and consumer choice.

Study Goals and Analytical Approach

In response to a congressional mandate in the Senate's Fiscal Year 2010 Energy and Water Development Appropriations Bill for the U.S. Department of Energy, Energy Efficiency and Renewable Energy (DOE-EERE), the National Research Council (NRC) convened a committee to assess the potential for a 50% reduction in petroleum use by 2030, and 80% by 2050, as well as an 80% reduction in GHG emissions by 2050. The committee identified 4 general pathways that could contribute to both goals:

- Much more efficient conventional vehicles including internal combustion engine vehicles (ICEVs) and hybrid electric vehicles (HEVs);
- Vehicles with internal combustion engines operating on biofuels;
- Plug-in electric vehicles including hybrids (PHEVs) and battery electric vehicles (BEVs); and
- Fuel-cell electric vehicles (FCEVs) which are expected to be introduced commercially over the next several years.

In addition, several options can contribute to the petroleum reduction goal but little or none to the GHG reduction goal:

- Compressed natural gas vehicles (CNGVs); and
- Vehicles with internal combustion engines operating on liquid fuels produced from natural gas (GTL) or coal (CTL).

The study also considered crosscutting technologies and key federal R&D activities applicable to fuel and vehicle technologies. For vehicles, these include weight reduction (for example, light-weight but strong materials) and rolling and aerodynamic resistance improvements. For fuels, carbon capture and storage will be very important. In addition, the analysis took into account factors such as consumer preferences and decarbonization of the electric power sector.

As detailed in the full NRC report, there are great uncertainties regarding future vehicles and fuels; in particular, these include the costs, timing, commercialization, and market penetration associated with advances in each technology. As a result, the committee used two sets of assumptions for cost and performance for vehicle technologies: midrange estimates with ambitious but reasonable goals and optimistic estimates which, while potentially feasible, require greater successes in R&D and vehicle design.

The vehicle technology advances discussed in the report do not require unexpected breakthroughs such as in batteries, fuel cell systems, or lightweight materials. Dramatic advances can be made with technologies that exist now, but significant continuing research and development yielding sustained progress in cost reduction and performance enhancement is essential.

The vehicle and fuel options were modeled in a series of scenarios that also considered consumer choice and potential policy initiatives. These scenarios were not intended to be predictions of the future but rather to evaluate the relative potential impact of technology development and policy options on future petroleum use and GHG emissions.

Meeting the Goals of Reducing Petroleum Use and Greenhouse Gas Emissions

No one pathway is adequate to reach the goals. All the successful scenarios combine continued improvement in vehicle fuel economy with at least one other pathway.

All vehicles considered in the full NRC report are expected to be several thousand dollars more expensive than today's conventional vehicles, even by 2050. The near-term costs for battery and fuel cell vehicles will be considerably higher. Driving costs per mile will be lower, especially for natural gas and electricity, but vehicle cost is likely to be a significant issue for consumers for at least a decade. In addition to cost, some of the technology options will require substantial infrastructure changes and possibly consumer adaptation. However, the committee does not expect safety to be compromised by any of the vehicle or fuel technologies discussed here.

Reducing Petroleum Use 50% by 2030

It will be very difficult for the nation to meet the goal of a 50% reduction in annual petroleum use by 2030 relative to 2005; however, with additional policies, it might achieve a 40% reduction. Future petroleum use is likely to decline as more efficient vehicles enter the market in response to the Corporate Average Fuel Economy (CAFE) standards and GHG requirements for 2025, more than compensating for the increased number of vehicles on the road and the miles traveled.
In addition, biofuels mandated by the Renewable Fuel Standard could displace a significant amount of petroleum fuels by 2030, especially if coupled with advances in processes for producing "drop-in" cellulosic biofuels as direct substitutes for gasoline or diesel fuel.

The on-road fleet in 2030 will still mostly consist of ICEVs with an increasing share of HEVs. Additional policy support may be required to promote increased sales of CNGVs, BEVs, and FCEVs. Even then the nation is unlikely to reach 50% petroleum use reduction by 2030 because that is very little time for achieving the required massive changes in the on-road LDV fleet and/or its fuel supply. Many of the vehicles on the road in 2030 will have been built by 2015 with lower fuel economy.

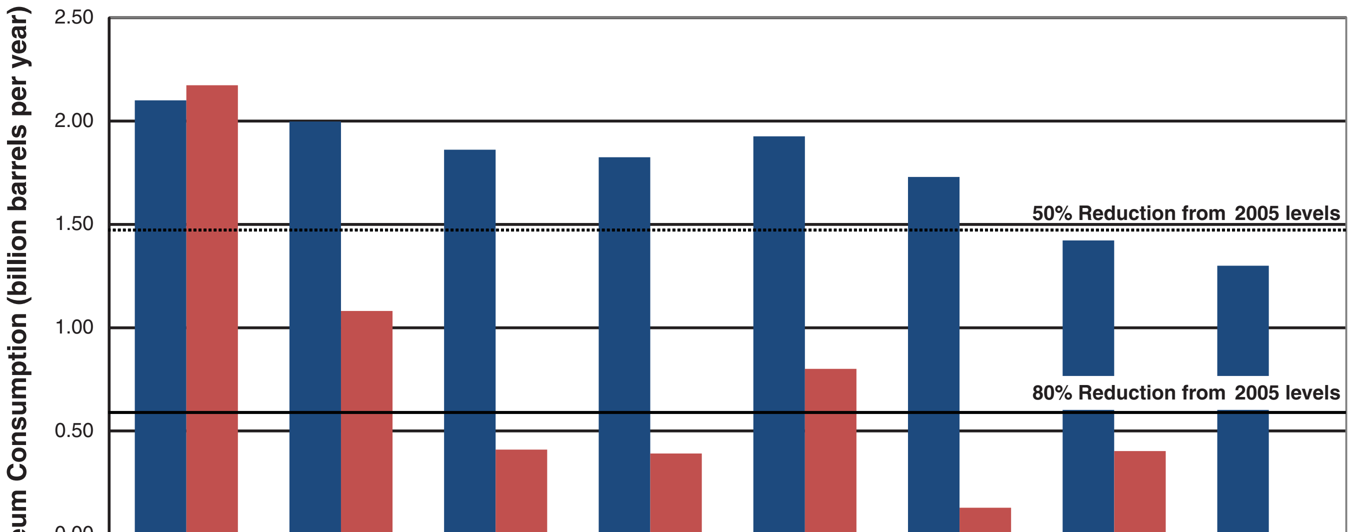
Reducing Petroleum Use 80% by 2050

The 80% reduction goal potentially could be met by several combinations of technologies that achieve at least the mid-range level of estimated success. Efficiency is an important part of each successful combination. Technologies will be available to continue to improve vehicle efficiency well beyond that required by the 2025 CAFE standards. By 2050, the average ICEV could achieve 74 mpg on the CAFE test cycle, and HEVs could reach 94 mpg.

In addition, a successful path to large petroleum-use reductions will require increased production and use of biofuels, and/or the successful introduction and large-scale deployment of CNGVs, BEVs with greatly improved batteries, or FCEVs. Extensive new fuel infrastructure would be needed for FCEVs, while CNGVs would require new supply lines in areas where natural gas is in limited supply, along with many filling stations. The infrastructure needed for BEVs would mostly be charging facilities, since electricity supply is already ubiquitous.

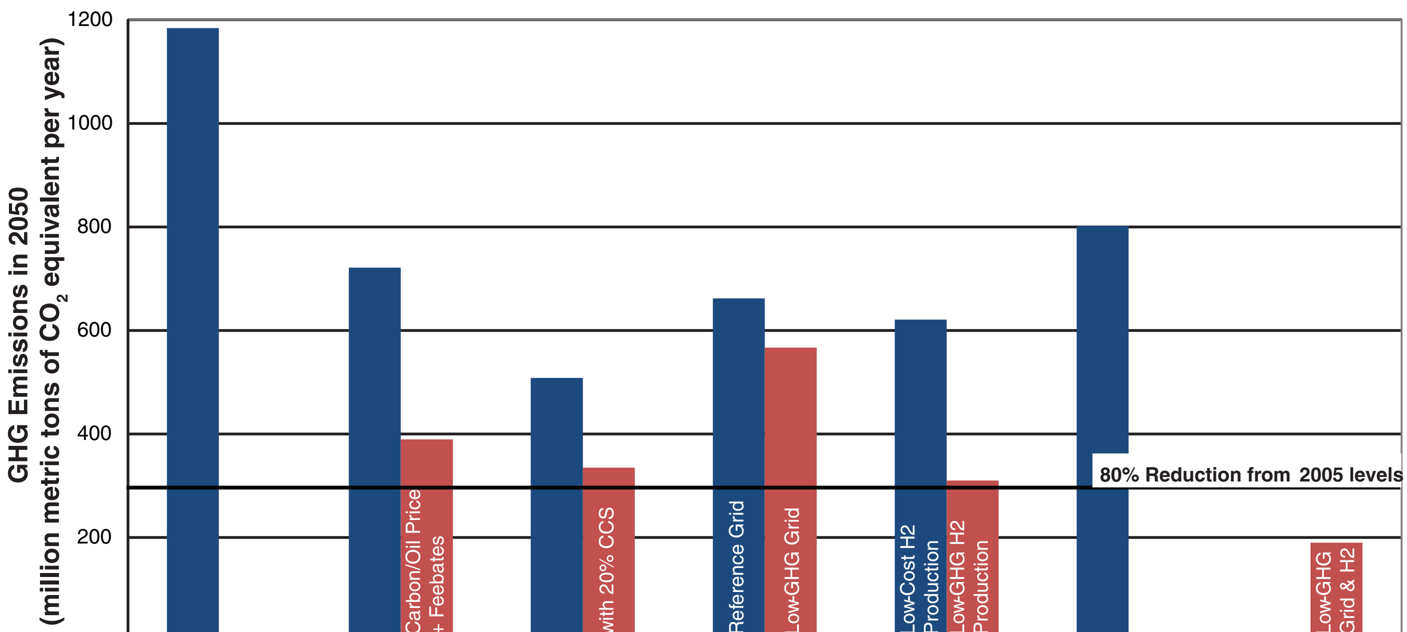
Reducing GHG Emissions

Reductions on the order of 60% to 70% relative to 2005 are potentially achievable in annual LDV GHG emissions by 2050. The goal of an 80% reduction in GHG emissions by 2050 may be achievable, but it will be more difficult than an 80% reduction in petroleum use. Petroleum-based fuels would have to be largely eliminated and at least two of four pathways would be required. Vehicles would have to be highly efficient and operate on biofuels, electricity, or hydrogen. Electricity and hydrogen would have to be produced with low net GHG emissions. This is a massive and expensive transition that would have to be part of an economy-wide transition away from GHG emissions to provide full GHG benefits.



	Committee Reference (Current Policies)	Efficiency	Efficiency + Biofuels	Efficiency + Carbon/Oil Price + Feebates	Plug-In Electric Vehicles (PEVs)	Fuel Cell Electric Vehicles (FCEVs)	Natural Gas Vehicles	PEVs + FCEVs + Biofuels
2030	2.10	2.00	1.86	1.82	1.93	1.73	1.42	1.30
2050	2.17	1.08	0.41	0.39	0.80	0.13	0.40	0.00

FIGURE S.1 Estimated U.S. LDV petroleum use in 2030 and 2050 under policies emphasizing specific technologies. Midrange values are the committee's best estimate of the progress of the technology if it is pursued vigorously. All scenarios except the Committee Reference Case (current policies, including the fuel economy standards for 2025) include midrange efficiency improvements. Controls for GHG emissions from hydrogen and electricity production are not assumed because the main objective is to reduce petroleum use.



	Committee Reference (Current Policies)	Efficiency	Efficiency + Biofuels	Plug-In Electric Vehicles (PEVs)	Fuel Cell Electric Vehicles (FCEVs)	Natural Gas Vehicles	PEVs + FCEVs + Biofuels
Reference Production	1184	721	508	662	621	801	
Low-GHG Production		389	335	567	310		190

FIGURE S.2 Estimated U.S. LDV GHG emissions in 2050 under policies emphasizing specific technologies. All scenarios except the Committee Reference Case (current policies, including the fuel economy standards for 2025) include midrange efficiency improvements. Fuel production for these scenarios is assumed to be constrained by policies controlling GHG emissions (low GHG production).

The benefits of biofuels depend on how they are produced and any direct or indirect land-use changes that could incur GHG emissions. While there are indications that sufficient biomass should be available to meet these objectives, the long-term costs and resource base for biofuels produced with low GHG emissions need to be demonstrated. Hydrogen and electricity will need to be produced in low net GHG fashions, and the costs of large-scale production are uncertain. If BEVs or FCEVs are to be a majority of the 2050 fleet, they would have to be a significant fraction of new car sales by 2035.

Policies for Meeting the Goals

None of the four pathways by itself is projected to be able to achieve sufficiently high reductions in LDV GHG emissions to meet the 2050 goal. Further, the cost, potential rate of implementation of each technology, and response of consumers and manufacturers to policies are uncertain. Therefore, an adaptive framework that modifies policies as technologies develop and as conditions change is needed to efficiently move toward the long-term policy goals.

Policies more stringent than the 2025 CAFE/GHG and Renewable Fuel Standards will be needed to continue raising fuel economy and reduce petroleum consumption. Additional measures, including policies to limit GHG emissions in energy sectors that supply fuels to LDVs, will be needed to meet a GHG reduction goal. Large capital investments would be required for both the fuel and vehicle manufacturing infrastructure. Further, because costs of alternative vehicles and some fuels will be very high during the transition, incentives may be required for more than a decade to ensure their penetration into the market is adequate to meet the goals.

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