THE TECHNOLOGY TO REACH 60 MPG BY 2025

Putting Fuel-Saving Technology to Work to Save Oil and Cut Pollution

Increasing the fuel efficiency of new cars and trucks is a critical step towards cutting America's oil dependence and reducing the carbon pollution that causes climate change. Fuel economy standards have been instrumental in increasing vehicle efficiency over the past four decades. The Obama administration is now developing new standards covering model years 2017 through 2025. Strong standards should be implemented to maximize the use of cost-effective, fuel-saving technology.

Known technologies can dramatically cut the fuel consumption and carbon pollution from passenger vehicles over the next fifteen years. By relying on technology and innovation, the auto industry can build a range of clean, fuel-efficient cars and light trucks—from conventional gasoline vehicles to hybrid-electrics to electric drive vehicles—that average 60 miles per gallon (mpg) and emit no more than 143 grams of CO_2 per mile by 2025. Expert assessments from the Massachusetts Institute of Technology (MIT), the University of Michigan (UM), the University of California, Davis (UC Davis), and the U.S. Environmental Protection Agency (EPA) show that we know how to put the needed clean vehicle technology to work and that it is poised for broad use across America's fleet of cars and trucks.

Vehicle Technologies

Conventional gasoline cars and trucks are already improving thanks to new standards from the Obama administration, hybrids are already on the road, and different kinds of electric-drive vehicles are expected on the market in 2010. All of these technologies have significant potential to grow, both in market share and their ability to save fuel and cut emissions, and each will have a key role in delivering a model year (MY) 2025 fleet that achieves 60 mpg.

Improving Gas Cars and Trucks

Studies by MIT and UC Davis show that conventional cars and trucks that rely completely on an internal combustion engine (ICE) could cut fuel use and greenhouse gas emissions by as much as 45% in the next 20 years compared to vehicles with the same size and performance (e.g. 0-60 miles-per-hour acceleration) on the market in recent years.[1]

[1] Kasseris, E.P. and J.B. Heywood. 2007. Comparative analysis of automotive powertrain choices for the next 25 years. SAE Paper No. 2007-01-1605. Warrendale, PA: Society of Automotive Engineers. Burke, A., and H. Zhao. Forthcoming in 2010. Projected fuel consumption characteristics of hybrid and fuel cell vehicles for 2015-2045. EVS-25, November 5-9.

These improvements come from optimizing gasoline spark-ignition engine platforms for fuel efficiency. Aerodynamic drag and rolling resistance are improved through better shapes and fuel-efficient tires. Overall weight of the vehicle is reduced by 10-20 percent through improved design and the application of stronger substitutes to today's steel. Engines are downsized to match the optimized platform while maintaining performance thanks to improved friction reduction, more efficient valve controls, better fuel-air mixing through gasoline direct-injection and turbocharging. Transmissions also evolve to reduce friction and optimize power application from the engine to the wheels through 6-speed dual-clutch transmissions with more automatic shift controls.

The U.S. Environmental Protection Agency (EPA) evaluated a more limited set of technologies for a nearer implementation. EPA found that, even with modest weight reduction and less opportunity for engine optimization, a 34 percent reduction in CO_2 emissions and fuel consumption is possible in large cars for 2016.[2] The gap between the EPA and MIT analyses highlights the opportunities that still remain for conventional gasoline vehicles to reach even greater reductions beyond 2016 as technologies have more time to penetrate the market and more advanced materials (enabling mass reductions of 20 percent vs. EPA's 10 percent) and added engine efficiency improvements become feasible with more lead time.

In our analysis, we are focused on 2025, or about half way between EPA's analysis and those of MIT and UC Davis. Given that, the potential is clearly higher than EPA's 2016 level, while some of the advancements from the other studies may not be ready yet. We therefore assume that internal combustion engines achieve a 40 percent reduction in fuel consumption and CO_2 emissions from MY 2008, to reach 46 mpg. The reduction is a fleet average based on a mix of 67 percent cars and 33 percent light trucks projected by EPA for MY 2016.

Hybridization

Hybrids can combine the significant efficiency improvements available to ICE vehicles with an electric motor and a small battery to go even farther on a gallon of gas. A variety of hybrid powertrains are already in the market with rated fuel efficiency far above their non-hybrid counterparts, as shown in Table 1.

Table 1: Hybrids Cut Fuel Consumption

Vehicles	Hybrid Reduction in Fuel Consumption
Toyota Prius vs. Matrix	44%
Ford Fusion Hybrid vs. Fusion	36%
Honda Civic Hybrid vs. Civic	29%
Ford Escape Hybrid vs. Escape	25%
Chevrolet Tahoe Hybrid vs. Tahoe	19%

The studies from MIT and UC Davis both indicate the potential for a 60 percent reduction in fuel use from hybrids. For our analysis we conservatively assume that hybrids in MY 2025 will cut fuel

[2] EPA and NHTSA. 2010. Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule. *Federal Register* 75(88): 25323-728, Friday, May 7.

consumption by an additional 25 percent on top of the fuel savings from the ICE vehicles discussed in the previous section. Hybrid fuel consumption and emissions are therefore 55 percent below a baseline MY 2008 vehicle, or 61 mpg.

As pointed out in a recent University of Michigan study[3], the MIT analysis simply confirms the potential already identified by the Detroit Three automakers over a decade ago. Under the U.S.-sponsored Partnership for a New Generation of Vehicles (PNGV), GM, Ford and Chrysler designed and built 5-passenger hybrid sedans that delivered reductions in fuel use on the order of 66 percent. The three PNGV concept vehicles were diesel-engine hybrids with curb weights about 30 percent below the baseline sedans.

Electrification

Electric vehicles, including pure battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell vehicles dramatically improve efficiency through greater (or complete) reliance an electric motor for propulsion. For this analysis, we focus on vehicles that use on-board batteries recharged from the grid. We assume these vehicles achieve an electric efficiency of 250 Wh/mi, which is about 10 percent less efficient than the expected performance in compliance testing of the upcoming Nissan LEAF.[4] For plug-in hybrid electric vehicles, we assume that by MY 2025, 50 percent of vehicle miles occur on electric drive with the remaining gasoline miles powered by a hybrid drivetrain that is about 15 percent more efficient than non-pluggable hybrids because the larger plug-in vehicle batteries allow for greater energy capture during regenerative braking.[5] These efficiency levels qualify battery electric and plug-in hybrid electric vehicles for fuel economy credit at 328 and 116 miles per gallon-equivalent, respectively, using the CAFE compliance calculation methodology.[6]

While they are very efficient, electric drive vehicles are still responsible for emissions of global warming pollution because the electricity they pull from the grid is produced at a power plant. We assume an upstream emissions factor of 125 gCO_2/mi, consistent with EPA's methodology used in the MY 2012-2016 final rule for the average American grid.[7]

Mass Adoption of Clean Vehicle Technologies

A 60 mpg fleet that emits no more than 143 gCO_2/mi can include a mix of the technologies discussed above. With the certainty of this 2025 requirement, automakers can plan strategically about the evolution of their vehicles platforms and the introduction of new vehicles to incorporate clean technologies. Automakers will pursue the mix of technologies that best fits their business goals, and each automaker may take a different path at any one time. For example, Toyota, Ford, and Honda have been well-recognized leaders in hybrid technology, while they are also aggressively implementing

[3] DeCicco, John M. 2010. "A Fuel Efficiency Horizon for U.S. Automobiles." University of Michigan. September 2010.
[4] We chose a less efficient value than the LEAF based on the potential availability of larger plug-in electric vehicles combined with in improvements in electric drive technology between now and 2030. Our assumption is consistent with EPA's 2030 estimate of 250 Wh/mi in EPA. 2010. EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios. Updated March 18, 2010.
[5] This assumption is used in EPA. 2010. EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios. Updated March 18.
[6] 10CFR 474.3 Petroleum-Equivalent Fuel Economy Calculation.
[7] This emission factor reflects an average vehicle efficiency of ~250 Wh/mi (covering both smaller and larger vehicles) and grid emissions of ~545 g/kWh (prior to transmission and charger efficiency corrections).

engine improvements from variable valve technologies to Eco-Boost with gasoline direct-injection and turbocharging. On the other hand, Nissan and GM are vying to be first in mass market electric vehicle offerings.

An example of a MY 2025 fleet that could reach 60 mpg would be one made up of 30 percent clean ICE vehicles, 55 percent hybrids and 15 percent electric-drive. Automakers can also improve their air conditioning systems to reduce global warming pollution by the equivalent of 15 gCO_2/mi. Combining the vehicle and air conditioning improvements, and including electricity upstream emissions, the fleet will average 143 gCO_2/mi.

Table 2: Hypothetical 60 mpg Fleet in MY 2025

Vehicle Type	CAFE (mpg)	Emissions (gCO_2/mi)	Market Share
ICE	46	195	30%
Hybrid Electric	61	146	55%
Plug-in Hybrid Electric	116[a]	125	10%
Pure Battery Electric	328[a]	125	5%
Fleet Average	**60**	**158**	n/a
Fleet Average with 15 gCO_2/mi AC credit[b]	n/a	**143**	n/a

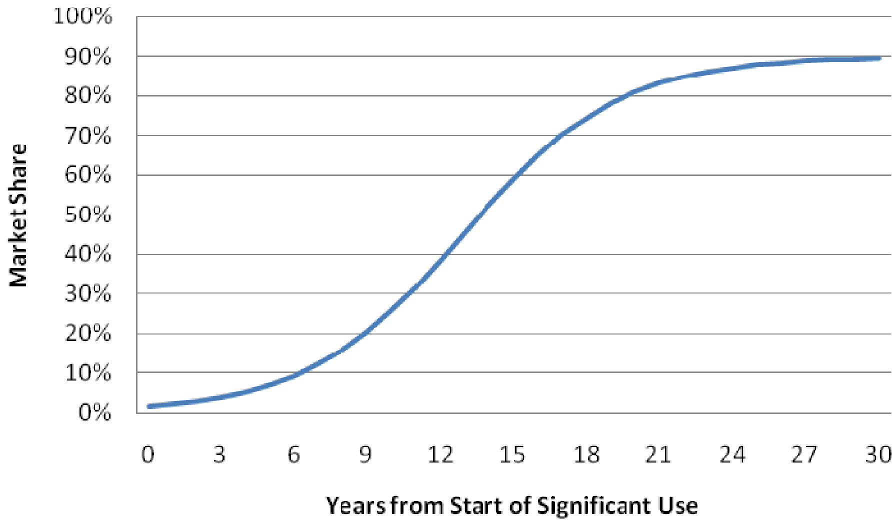
Notes:

[a]CAFE compliance values calculated using the electric-drive crediting of 10CFR 474.3 Petroleum-Equivalent Fuel Economy Calculation.

[b]One way manufacturers can reduce their fleet GHG emissions is through improvements to air conditioner efficiency and substitution of A/C refrigerants. Due to its cost effectiveness, we expect automakers will take full advantage of this approach. Consistent with recent EPA analysis and efforts in Europe on refrigerants, a reduction of 15 g/mi could be achieved through these measures.

Reaching the new fleet penetrations of 55 percent hybrids and 15 percent electric vehicles is a relatively modest goal. Hybrids would have to reach just over half the market more than 25 years after their introduction in the U.S., while electric vehicles would have to reach only 15 percent of the market about 15 years after their reintroduction. This potential is consistent with recent analysis by the University of Michigan. The University study analyzed the historic penetration of several technologies including a shift from rear- to front-wheel drive (now common in about 80% of new vehicles), use of fuel-injection (now ubiquitous), variable engine cylinder valve controls and multivalve engines. From these historic rates a hypothetical curve for hybrid penetration was developed by University of Michigan, as shown in Figure 1.

Figure 1: Hypothetical Hybrid Penetration



Source: Derived from DeCicco, John M. 2010. "A Fuel Efficiency Horizon for U.S. Automobiles." University of Michigan. September 2010.

Using the hypothetical curve, new technologies can reach 59 percent market share in 15 years after the start of significant use, or by 2025 if we make the very conservative assumption of 2010 as the first year of significant use for hybrids. The University of Michigan study noted, however, that some technologies have grown at much faster rates. Fuel injection and front-wheel drive reached 60 percent in just 6 years and 11 years, respectively. These technologies were adopted rapidly by automakers to meet improved standards for tailpipe pollution and efficiency. Fuel injection improved performance while also enabling 3-way exhaust catalysts. Front-wheel drive was driven by the oil crisis of the 1980's and rapidly improving fuel economy standards.

The rapid technology adoption demonstrates automakers' ability to develop and deploy cleaner technologies faster when a clear signal is provided. Over the last two decades, the pressure for improvements in vehicle efficiency has been limited. Typical lead times have been estimated at 10-15 years.[8] However, volatile oil prices, recession and auto company bailouts during the past few years are focusing efforts. The shift of global vehicle platforms enables round-the-clock engineering and manufacturing processes are continually improved. According to University of Michigan, "standard product development times are now 2-3 years and typical product cycles are 5-6 years…, suggesting that fleetwide changes can be made in less than a decade."[9]

Together, the technology and market share assessments demonstrate a clear pathway to 60 mpg. In Table 2, we summarize the assumptions of our analysis showing one potential make-up of the MY 2025 fleet that reaches 60 mpg and emits no more than 143 gCO_2/mi.

[8] DeCicco. Op cit.
[9] Ibid.

Clean Vehicle Costs

With vehicle fuel economy and greenhouse gas emissions standards set out to MY 2016, we considered the incremental cost of technology from MY 2016 to cleaner MY 2025 vehicles. We considered cost assumptions from MIT, University of Michigan and Consumer Federation of America (CFA). We estimate an average incremental cost of about $2,740 to reach a 60 mpg fleet with the mix of ICE, hybrid and plug-in electric vehicles described above.

Our estimate lies between cost estimates derived from recent assessments by the CFA and University of Michigan. The 60 mpg standard would cost approximately $2625 using the CFA methodology and approximately $3125 using the University of Michigan methodology.

For our assessment, we start with cost analysis by MIT for each vehicle technology category (ICE, hybrids and plug-in vehicles).[10, 11] We rely on the MIT "optimistic" case assumptions but make an adjustment to battery size for pure electric vehicles. Instead of assuming that electric vehicles require 200 mile-range batteries, we use MIT projections to estimate the cost 100 mile range batteries in electric vehicles. We also assume that a 20 percent mass reduction is achievable at no net cost increase. This is more conservative than a recent study by Lotus Engineering that found mass could be reduced by 21 percent with a 2 percent cost decrease.[12]

Retail costs of technology are typically derived by summing the cost of materials and manufacturing and then applying a multiplier that reflects the cost of integration, marketing and distribution to bring the technology to market. We use multipliers of 1.13 for ICE vehicles, 1.26 for hybrids, and 1.39 for electric vehicles. These indirect cost multipliers are consistent with what EPA and NHTSA provided in the MY 2012-2016 final rule.[13]

The battery costs that we use from the MIT research are aggressive, but realistic when considering the large investments made recently in U.S. battery manufacturing and electric vehicle deployment. The Administration has pledged over $2.4 billion from the American Recovery and Reinvestment Act for electric vehicle technologies and the Department of Energy has been providing significant research funding for batteries for decades. According to a recent report from the White House, the U.S. had only 2 percent of advanced vehicle manufacturing in 2009 but by 2012, U.S. production capacity will account for over 20 percent of global capacity.[14] Projects funded by the Recovery Act are also actively pursuing improvements in battery energy density and extensions of battery life that will lower costs and enhance vehicle marketability.

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[10] MIT. 2008. On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions. Report No. LFEE 2008-05. Cambridge, MA: Massachusetts Institute of Technology Laboratory for Energy and the Environment, July.

[11] Kromer, M.A., and J.B. Heywood. 2007. Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet. Report LFEE 2007-03 RP. Cambridge, MA: Massachusetts Institute of Technology, May.

[12] Lotus. 2010. An Assessment of Mass Reduction Opportunities for a 2017–2020 Model Year Vehicle Program. Report prepared for The International Council on Clean Transportation. March. Available at http://www.theicct.org/2010/03/lightweight-future/.

[13] EPA and NHTSA, Joint Technical Support Document: Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards. April 2010.

[14] Executive Office of the President of the United States and Vice President of the United States. The Recovery Act: Transforming the American Economy through Innovation. August 2010.

Conclusion

Using well known clean car technologies, we can achieve a fleet average of 60 mpg and no more than 143 gCO_2/mi by model year 2025. The evaluation of product cycles and historical technology adoption demonstrates that there is ample time over the next 15 years for mass adoption of the needed clean vehicle technologies. Setting a 60 mpg standard will unleash American automotive ingenuity to perfect the technologies, drive down costs and put the U.S. on a path to save at least 44 billion gallons of oil annually by 2030.

For Further Information:

Jim Kliesch, Senior Engineer, Union of Concerned Scientists, jkliesch@ucsusa.org, 202.223.6133
Luke Tonachel, Senior Analyst, Natural Resources Defense Council, ltonachel@nrdc.org, 212.727.2700