Reason Foundation

CAFE Standards in Plain English

by Baruch Feigenbaum and Julian Morris

In 1975, Congress enacted Corporate Average Fuel Economy (CAFE) standards as part of the implementation of the Energy Policy and Conservation Act. The intent was to reduce oil consumption in the wake of the Organization of Petroleum Exporting Countries (OPEC) oil embargo of 1973–1974 that had limited oil supplies and spiked prices. Since 1986, the National Highway Transportation Safety Administration (NHTSA) has been tasked with setting the actual standards. In 2010 NHTSA and the Environmental Protection Agency (EPA) jointly developed a new set of standards to meet the requirements of both the Energy Policy Conservation Act and the Clean Air Act.

This brief describes in plain English the development of the CAFE standards and how they function.

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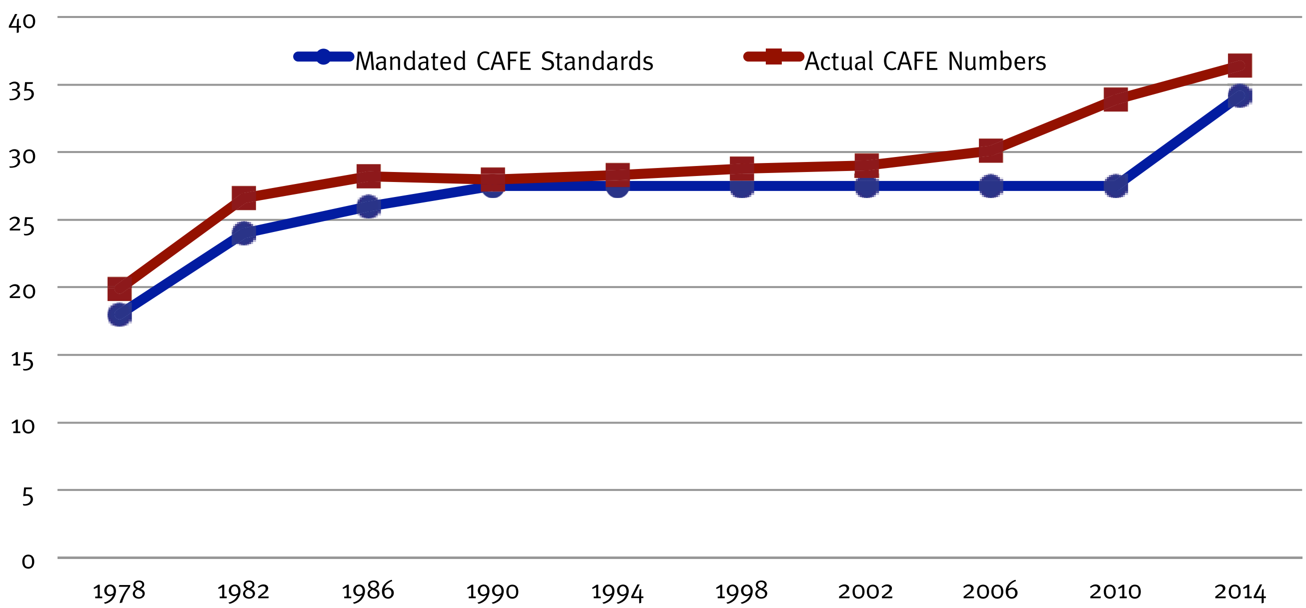
The Original CAFE Standards

The original CAFE standards set minimum average fuel consumption performance (average miles travelled per gallon of fuel used) for the fleets of new "passenger automobiles" (passenger cars) and "non-passenger automobiles" (light trucks, which includes many SUVs) produced by each manufacturer.[1] The standards for these two types of vehicles differed.

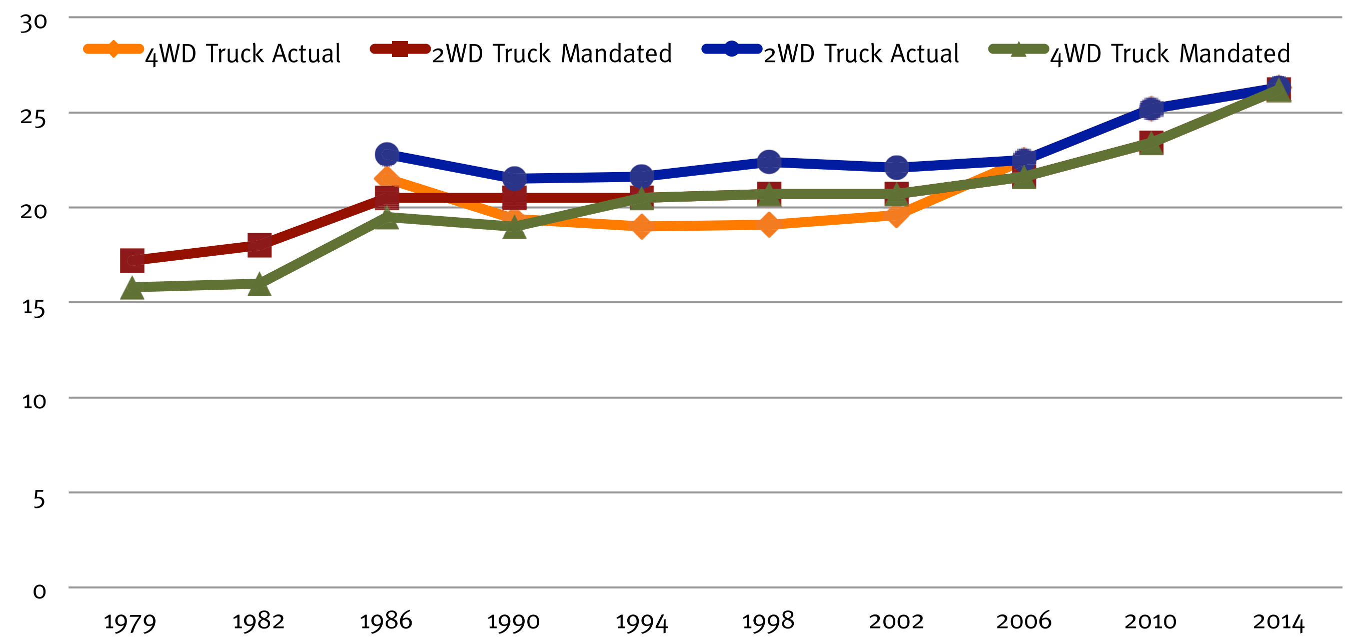
Before standards took effect, the average fuel efficiency for passenger cars was 15.2 miles per gallon (mpg). Congress required manufacturers to achieve a fleet average of 18 mpg by 1978, 19 mpg by 1979, and 20 mpg by 1980, rising to 27.5 mpg by 1985, with interim standards to be set by NHTSA. But by 1981 average fuel efficiency for passenger cars had risen to 28.4 mpg, exceeding the standards.

Figure 1: Automobile Fuel Efficiency, Mandated vs. Actual, 1978–2014 (Miles Per Gallon)



For light trucks, NHTSA set standards that required manufacturers to achieve a fleet average of 17.2 mpg for two-wheel drive vehicles and 15.8 mpg for four-wheel drive vehicles in 1979, rising to 21.5 mpg and 19 mpg respectively by 1989.[2] Over this time period, two-wheel drive vehicles increased from 13.4 to 16.9 mpg while four-wheel drive vehicles increased from 12.3 mpg to 14.4 mpg.

Figure 2: Light Truck Fuel Efficiency, Mandated vs. Actual, 1978–2014 (Miles Per Gallon)



Since these mandates aimed to reduce fuel consumption, these specific numbers reflect an anticipated amount of fuel savings, requiring a means for accurately calculating anticipated fuel consumption.

How Fuel Efficiency Is Calculated in CAFE Standards

To most of us, "average" refers to what mathematicians call the "arithmetic mean." For example, if we want to find the "average" weight of three people, we would first calculate their total weight and then divide by three to calculate the arithmetic mean. That is not how "average" fuel efficiency is calculated under the CAFE standards.

In the original CAFE standards, the "average" used is what is known as the "harmonic mean." To understand what this is and its implications, it is helpful to use an example. Consider a car manufacturer that produces two types of passenger cars, a Big and a Small. Each year the manufacturer produces 300 Bigs, rated at 15 mpg, and 1000 Smalls, rated at 30 mpg.

If the arithmetic mean were used to calculate average fuel economy of this company's car fleet, the vehicles would average 26.5 mpg: ((300x15) + (1,000x30))/1,300=26.5. But using the arithmetic mean can result in an underestimate of total fuel used. For example, if every vehicle in the fleet were driven 10,000 miles per year, the total annual fuel usage implied by the arithmetic mean would be just under 500,000 gallons (13 million divided by 26.5 = 490,566). But the actual fuel used would be 533,333 gallons (300x10,000/15) + (1,000x10,000/30). Using the arithmetic mean, the greater number of Smalls drags the implied fuel use down, falsely boosting the average miles per gallon.[3]

Now, dividing the total number of miles travelled by all the cars (1,300 x 10,000 = 13 million) by the number of gallons used (533,333), we get an average fuel economy of 24.4 mpg.[4] If the number of miles travelled by each vehicle is approximately the same then this "average"—known as the "harmonic mean" [5]—is more accurate. Accordingly, NHTSA and the EPA use the harmonic mean to assess vehicle standards for compliance.

However, if less-fuel-efficient vehicles (generally larger ones) are driven more, then compliance with the standard will result in higher emissions than is implied. By contrast, if more-fuel-efficient vehicles (generally smaller ones) are driven more, then compliance with the standard will result in lower emissions than is implied.[6] To account for increasing complexity in determining emissions and fuel economy, starting in 2005, additional complexities were added to the calculation of fuel economy, as discussed in the "Details on the Standards" section of this brief, and in the endnotes.

Evolution of CAFE Standards

In 1975, when the original CAFE standards were developed, the U.S. was in the middle of an oil crisis, and curtailing fuel use was paramount. The original CAFE standards were predicated on the assumption that the vehicle fleet would use less fuel each year, and they were part of a package of other government mandates, including a 55-mile-per-hour (mph) national speed limit. The decrease from 75 mph in most states was expected to save hundreds of millions of barrels of oil a year.[7] As well, the economic consequences of fuel rationing sparked consumer demand for smaller, more-fuel-efficient vehicles, powered by 4-cylinder as opposed to 8-cyclinder engines. Emotional arguments that suggested patriotic Americans should drive more-fuel-efficient cars also increased demand for smaller vehicles. Finally, carpooling was increasing rapidly, in part due to incentives from both the government and private sector.

However, after the oil embargo, as gas prices dropped, vehicle purchasing patterns changed. In the 1980s and 1990s, Americans began buying larger cars and more light-duty trucks. The classification of SUVs as light-duty trucks, which allowed them to be subject to less-stringent fuel economy standards, also played a role. In 1987, the 55-mile-per-hour speed limit—always unpopular, challenging to enforce, and failing to meet its fuel-savings goal—was repealed. With America's population and job locations decentralizing, carpooling has decreased by more than 50% from its high in the 1990s,[8] resulting in an increase in the average number of miles driven per vehicle. With these changes, meeting CAFE standards is far more challenging.

The National Highway Traffic Safety Administration (NHTSA) kept CAFE standards for cars the same from 1985 to 2010, except for a slight decrease in required mpg from 1986 to 1989. Truck standards, initially set in 1976 for 1989 vehicles at 21.5 mpg for 2-wheel drive vehicles and 19 mpg for 4-wheel drive vehicles, were frozen by Congress in the mid-1990s at 20.7 mpg and were not increased until 2005.

However, starting in 2005, Washington policy makers ushered in a number of changes. Between 2005 and 2007, the Bush administration raised the truck fuel efficiency standard from 20.7 to 22.2 mpg. More significantly, in 2007, Congress passed the Energy Independence and Security Act (EISA), which requires model-year 2011 and later vehicles for sale in the U.S. that were manufactured outside the U.S. to achieve a fleetwide gas mileage of 35 mpg and requires vehicles for sale in the U.S. that were manufactured in the U.S. to achieve a fleetwide gas mileage of 27.5 mpg by 2020. In 2009, the Obama administration eliminated the default 27.5 mpg standard and established a new 27.3 mpg standard for 2011 model-year vehicles manufactured domestically and internationally. The new standard was scheduled to increase annually until it reached 35 mpg for 2020 model-year vehicles.

Starting in 2005 for trucks and 2011 for all vehicles, the standard is based on one specific attribute: a manufacturer's collective vehicle footprint. The formula multiplies every vehicle's wheelbase by its average track width for each manufacturer. This creates a relatively simple inverse-linear formula with cutoff values. The attribute-based formula produces one number for each automaker. So while each model sold does not have to achieve a specific target, the automaker's fleet on a whole must meet its target. This method helps balance earlier standards, which were biased against automakers whose overall vehicle lineup was fuel-efficient, but sold one or two models (typically work trucks) that were not fuel-efficient.

For example, the GM Sierra Denali, is a full-size work truck with an mpg range of 16 in the city and 23 on the highway.[9] The Honda Ridgeline is a mid-size truck with an mpg range of 19 in the city and 26 on the highway.[10] To balance the lower fuel efficiency of the Denali, GM also builds the hybrid Chevrolet Volt that gets 42 mpg. If the absolute standard was 20 miles per gallon, drivers would not be able to buy the Denali work truck, which averages 19. But because the standard is by manufacturer and not model, GM can use the Volt to help balance the Denali.

Current Standards

In 2012, NHTSA and the EPA issued joint standards for 2017–2025. While NHTSA's standards continued to focus on fuel efficiency, the EPA's more-stringent regulations targeted reductions in carbon dioxide emissions (greenhouse gas emissions) and not fuel efficiency. NHTSA increased the CAFE standards to 41 mpg by 2021 and 49.7 mpg by 2025. The EPA's standard of 163 g/mi of CO_2-equivalent emissions[11] effectively increased standards to 54.5 mpg by 2025. This 54.5 mpg 2025 standard is the first one benchmarked to emissions and not gasoline consumption.[12]

While NHTSA is required by law to consider “feasibility of available technology” for its fuel economy standards, the EPA has no such obligation for its standards. As a result, the EPA could mandate standards that are not technologically feasible using currently available technology. Some analysts argue the 54.5-mpg standards may not be technologically feasible while maintaining the current fleet mix (which is characterized by a high concentration of sport utility vehicles) and would necessitate a dramatic change in vehicle purchasing habits.[13]

Details on the Standards

Calculating emissions accurately is increasingly complex. Instead of two separate standards, as of 2005 a single “fleetwide” standard is used. Up until 2011, the measurements include three different fleets: “domestic passenger cars,” “imported passenger cars,” and “light-duty trucks.” Imported cars were calculated differently from domestic vehicles, since they started from a lower fuel-efficiency base when the CAFE standards were implemented in the 1970s.

As before, the standard is calculated using the harmonic mean, taking into account anticipated annual mileage of each of the three types of vehicle, as well as their “footprints.” The calculations are complex because the formula requires two different fuel economy targets (cars and light-trucks) and several adjustment factors.

For light duty trucks there is yet another factor to consider. The light duty standard provides for a floor term to prevent any footprint target from declining between model years. For example, without the floor term the target could actually decline from 40 mpg in 2027 to 38 mpg in 2028. The idea is to treat smaller and larger vehicles in an equivalent way since smaller vehicles would have an easier time meeting the standard.

Once these equivalencies are reconciled for each vehicle type, the number of vehicles produced for sale for each model is divided by the number of vehicles produced for sale per model as a percentage of the target. The result is the CAFE standard for each vehicle manufacturer.

Compliance Flexibilities and Strategies

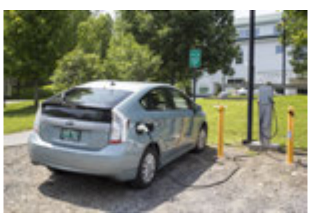
The original CAFE standards applied to the total fleet of vehicles in each class sold each year by each manufacturer. For manufacturers with multiple models, some of which had lower fuel economy than the relevant standard, the standard could only be met by ensuring that consumers purchase a large number of high-mpg models.

For example, Ford sells both the Focus, a mid-size car that gets 31 mpg on highways, and the F-150, a midsize truck that gets 25 mpg on highways. Several years ago with higher gas prices, Ford sold 246,000 Focus cars and 645,000 F Series trucks.[14] By 2015, Ford sold 202,000 Focus cars and 780,000 F series trucks. The decrease in car sales and the increase in truck sales likely take Ford out of compliance, if not today then by 2025. However, the changes are due almost entirely to lower gasoline prices. As a result automakers can be penalized for economic changes beyond their control.

Both the NHTSA and EPA standards offer certain flexibilities, termed "components," to help manufacturers comply with the standards. The first component is a credit trading system that allows manufacturers to carry efficiency and greenhouse gas credits forward by up to five years and backwards by up to three years to achieve compliance and avoid fines. Manufacturers can transfer credit between cars and trucks and trade credits with other manufacturers. Carbon dioxide credits generated for EPA compliance from model year 2016 and before can be carried forward up to model year 2021.

The second component is air conditioning efficiency improvements as compliance credits. For the NHTSA program, credits depend on fuel consumption reductions. The EPA allows credits for reductions in fuel use and refrigeration leakage and alternative refrigerants with lower global warming potential.

The third component is off-cycle credits, potentially including solar panels on hybrid vehicles, active aerodynamics or adaptive cruise control. Manufacturers can also apply for credits for newer technologies if they can provide sufficient greenhouse gas emission reduction data to the EPA.



The fourth component is for zero-emission, plug-in hybrid, and compressed natural gas vehicles. To encourage use of these vehicles, the EPA has included a credit multiple for model years 2017–2021. All-electric and fuel cell vehicles count as two vehicles in 2017 and phase down to 1.7 by 2021; plug-in hybrid electric vehicles begin with a multiplier of 1.6 in 2017 and phase down to 1.3 by 2021. Electric vehicles sold during this time period will be credited with emitting no carbon dioxide. After 2021 the multiplier disappears and a cap on the number of vehicles that qualify is applied. For manufacturers that sell 600,000 vehicles between 2019 and 2021, the cap is 300,000. For manufacturers that sell fewer than 600,000 vehicles, the cap is 200,000. For electric and fuel cell vehicles over the cap, manufacturers need to account for upstream emissions such as electricity used to generate hydrogen production. This cap only applies to EPA calculations, as NHTSA has legal concerns about credit multipliers.

The fifth component is for "truck hybridization." Hybrid pickup trucks that capture 15% to 65% of "braking energy" (recover energy loss through friction in braking and apply it to power the vehicle), are eligible for a per-vehicle credit of 10 g/CO_2 per mile, per model years 2017–2025, if the technology is included in 20% of the company's model year 2017 full-size pickups and 80% of model year 2021 vehicles. Pickup trucks in which at least 65% of braking energy is recaptured would be eligible for a credit of 20g/CO_2 per mile, assuming the technology is used in 20% or more of a company's full-size pickup trucks.

What Happens When CAFE Standards Are Not Met

Automakers who do not meet the CAFE standards can be fined. Currently, automakers that do not meet the standards are allowed to buy offsetting credits from automakers who meet the standards. NHTSA fined five automakers between 2010 and 2014. Jaguar-Land Rover paid $46.2M in fines followed by Daimler that paid $28.2M, Volvo that paid $17.4M, Porsche $4.8M and Fiat $3.6M.

In 2016, with little notice and no public hearing, NHTSA announced plans to double the fines for failing to meet CAFE standards from $5.50 per 0.1 mpg to $14.00. The fine is applied to each 0.1 mpg the automaker falls short and multiplied by the number of vehicles sold in a model year. Companies must satisfy both EPA and NHTSA standards. Manufacturers passing EPA's greenhouse gas emissions standards that fail NHTSA's CAFE standards still pay the fine.

Discussion

While the original CAFE standards sought to drive automotive innovation to curtail fuel consumption, the purview of current standards has been expanded to address emissions of greenhouse gases. In the process, the standards have become increasingly complex. Future versions of CAFE standards may also seek to take into account other factors such as the environmental impact of electric vehicles' battery disposal, or of hydrogen vehicles' fuel transport effects. As the standards become more complex and administratively burdensome, legitimate questions arise as to their suitability for achieving fuel efficiency and environmental objectives. Additionally, CAFE standards are increasingly at odds with Americans' preference for larger vehicles, including trucks and SUVs, which are generally less fuel efficient, calling into question their feasibility. Other briefs in this series will consider the implications of CAFE standards in more detail.

About the Authors

Julian Morris is vice-president of research at Reason Foundation. He has written extensively on the law and economics of innovation, risk regulation, and environmental protection. He is the author, most recently, of *The WHO's Opposition to Tobacco Harm Reduction: A Threat to Public Health?* and *The Paris Agreement: An Assessment*.

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Prior to joining Reason, Baruch handled transportation issues on Capitol Hill for Representative Lynn Westmoreland. He earned his master's degree in Transportation from the Georgia Institute of Technology.

Endnotes

1 Public Law 94-163 Dec. 22, 1975, 89 Stat 901: Title III – Improving Energy Efficiency (Amending 15 U.S.C 1901 et seq.) at Sec. 501. https://www.gpo.gov/fdsys/pkg/STATUTE-89/pdf/STATUTE-89-Pg871.pdf

2 U.S. Department of Transportation, Summary of Fuel Economy Performance, June 26, 2014. https://www.nhtsa.gov/staticfiles/rulemaking/pdf/.../June_2014_Summary_Report.pdf

3 See http://www.c2es.org/federal/executive/vehicle-standards for more information on the difference between the arithmetic and harmonic mean.

4 13,000,000/533,333 = 24.4 mpg

5 The harmonic mean of a set of n numbers is found by adding the reciprocals of the numbers in the set, dividing the sum by n, then taking the reciprocal of the result. For example, the harmonic mean of 1, 2 and 3 is: 1/(1/3(1/1 +1/2 + ¼))= 3/(1/1+1/2+1/4) = 12/7. (By contrast, the arithmetic mean of 1, 2 and 3 is 1/3(1+2+3) = 2.)

6 For example, if on average the 300 Bigs are driven 10,000 miles and the 1,000 Smalls are driven 40,000 miles, then the total fuel used would be (300 x 10,000)/15 + (1,000 x 40,000)/30 = 1.53 million gallons, with an average fuel economy of 28.1 mpg.

7 http://www.c2es.org/federal/executive/vehicle-standards

8 http://www.nytimes.com/2011/01/29/us/29carpool.html

9 http://www.gmc.com/trucks/sierra-denali-pickup-truck/build-and-price.html#/config

10 http://www.autoblog.com/2016/04/29/2017-honda-ridgeline-fuel-economy-ratings/

11 To measure fuel economy, the U.S. now uses "grams of Carbon Dioxide equivalent (CO_2e)". CO_2e units are used because different greenhouse gases have different "global warming potentials." For example, a single molecule of nitrous oxide (N_2O) results in about 300 times the amount of warming as a single molecule of CO_2.[11] So, simply adding emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O) would produce an inaccurate measure of warming potential.

12 The EPA's power to regulate greenhouse gas emissions (and thus fuel economy standards) was challenged, but the Supreme Court upheld the decision to regulate GHGs, citing an earlier Supreme Court decision that determined carbon dioxide and other greenhouse gases to be pollutants that can be regulated. While these decisions did not change the standards, they set the legal basis for the EPA's regulation of CO_2 emissions from cars.

13 http://autoweek.com/article/car-news/buyer-appetite-takes-545-mpg-target-table-us-regulators-say

14 https://corporate.ford.com/content/dam/corporate/en/investors/investor-events/Sales%20Calls/2012/2012-december-sales-press-release-20130103.pdf