Research Brief

Meeting CAFE Standards by 2020 and Beyond

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November 2008

Introduction

New U.S. Corporate Average Fuel Economy (CAFE) standards currently proposed would force new passenger cars and light trucks to improve their fuel economy by about a third, to 35 mpg by 2020 from the current average of 26 mpg.

How auto manufacturers will meet this challenge is a key question. The mandate will require employing a combination of various vehicle technologies, like significantly improved naturally-aspirated spark-ignition (NA SI) engines, introducing many more turbocharged direct-injection SI (Turbo SI) engines, more diesels and hybrids, transmission improvements, and vehicle size and weight reduction. The mandate will also require moderation of our escalating vehicle power levels. These improved efficiency opportunities will need to be widely deployed within the next 12 years.

In this research brief, the magnitude of engine, transmission and vehicle improvements, and the needed sales mix of these improvements in 2020 will be explored to shed some light on the realities associated with this challenge. The possibility of doubling the current fuel economy to 52 mpg by year 2035 will also be analyzed. Aiming for this factor-of-two target continues the mandated rate of fuel economy improvement for another 15 years: see Figure 1.

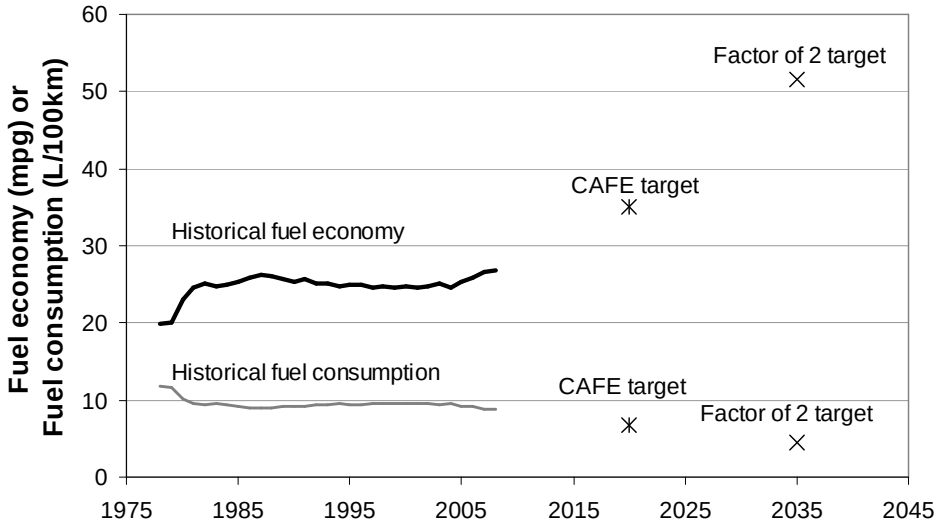

Figure 1. Historical fuel economy and fuel consumption, and future targets

Options to improve fuel economy

The fuel consumption of an average vehicle depends on the propulsion system used (e.g. NA SI or diesel engine), and can steadily decrease over time due to improvements in propulsion system efficiency, and reductions in vehicle weight, aerodynamic drag, and tire rolling resistance. Our assessments of the average relative fuel consumption of future cars, by powertrain, used in the scenarios are shown in Figure 2. The values in this figure can be realized if all future improvements in propulsion system efficiency over time are dedicated to reducing fuel consumption, while vehicle size

and performance attributes remain constant. This is defined this as 100% *Emphasis on Reducing Fuel Consumption* or ERFC. In contrast, without any emphasis on reducing actual fuel consumption (0% ERFC), the fuel consumption of new vehicles will remain at current values, and all of the efficiency gains from technology improvements are channeled to increase the horsepower and acceleration performance instead. So the ERFC parameter that we introduce quantifies an explicit design decision to dedicate future advances in vehicle efficiency into reducing fuel consumption, as opposed to improving performance, or increasing vehicle size.

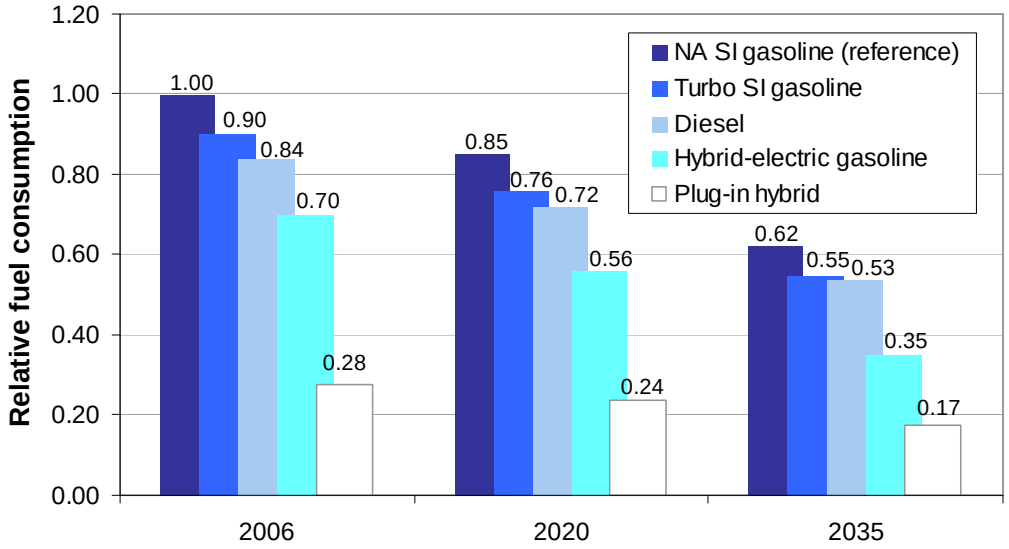

Figure 2. Relative fuel consumption of future cars, by powertrain (at 100% ERFC)

Future vehicle scenarios

Scenario analysis is used to explore how the deployment of the various propulsion systems and vehicle improvement options would reduce the petroleum consumption of the U.S. in-use light-duty vehicle fleet. Details on the methodology are available in Cheah et al. (2007). Two plausible vehicle sales mix scenarios are described below. Note that these scenarios are not predictions or forecasts of what the future vehicle fleet would be like in the future, but are intended as examples, to indicate the degree of changes that will be necessary to achieve better average vehicle fuel economy.

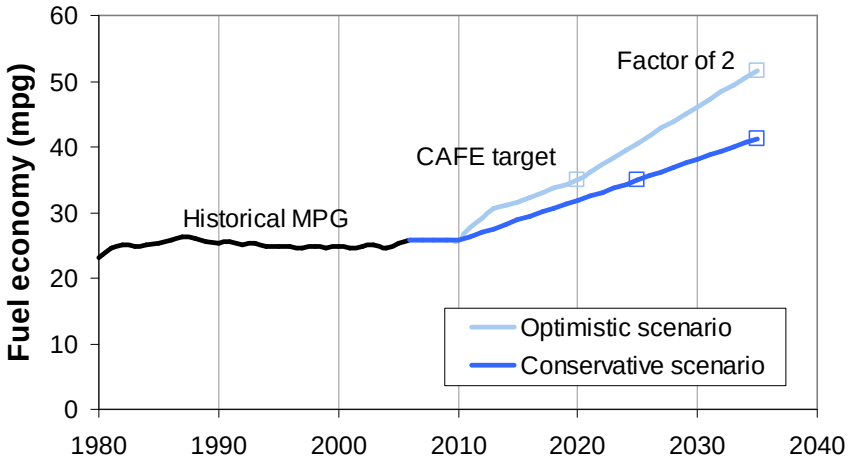

Figure 3. Sales-weighted average new vehicle fuel economy in two future scenarios

Scenarios	% ERFC	% Light trucks (vs. cars)	% Vehicle weight reduction	% Market share by powertrains					% FE increase from today
				NA SI	Turbo SI	Diesel	Hybrid	Plugin	
2006	-	55%	-	95%	1%	2%	2%	0%	-
Optimistic									
2020	75%	40%	17%	52%	26%	7%	15%	0%	+38%
2035	75%	30%	25%	36%	26%	9%	20%	9%	+100%
Conservative									
2025	50%	40%	17%	55%	24%	7%	14%	0%	+38%
2035	50%	40%	20%	49%	21%	7%	16%	7%	+62%

Table 1. Future vehicle scenarios

The first "optimistic" scenario meets both the CAFE and factor-of-two targets within the designated time frame. Table 1 shows the required sales mix indicating the percent of light trucks versus cars, the percent market share of the different powertrain options, as well as the percent average new vehicle weight reduction from today's average of 1,900 kg. Importantly, the efficiency improvements that these technology changes provide must be largely directed to decrease actual fuel consumption. To reiterate, the parameter ERFC—emphasis on reducing fuel consumption—indicates the tradeoff between improving vehicle performance or fuel consumption. This needs to be 75%, which allows only a modest average vehicle performance increase from today (i.e. a reduction of 0-60 mph acceleration time by about 1 second from its current average value of about 9 seconds). Thus, achieving these average mile per gallon targets in 2020 and 2035 requires substantial changes in engine and vehicle technology, and weight reduction.

A second, more "conservative" scenario achieves the CAFE target of 35 mpg, but does so later in year 2025. In this scenario, the average new vehicle fuel economy continues to improve, and eventually reaches 41 mpg by 2035 (a 60% increase above today's value) rather than doubling in the more "optimistic" scenario. Only half of the possible gains by years 2035 are realized in improved vehicle fuel economy, which is an ERFC of 50%. The rest of the efficiency improvements are used to offset additional increases in vehicle power, weight and size.

Both scenarios suggest it will take sales fractions of advanced technology vehicles at the high end of the ranges shown in Table 1, along with substantial vehicle weight reduction and some size reduction, to achieve the proposed CAFE target. As a point of reference, a 25% vehicle weight reduction from today's value entails a removal of 475 kg, or 1,050 lb from the average new vehicle.

Effect on overall fleet fuel use

The corresponding U.S. in-use light-duty vehicle fleet annual gasoline consumption from the present out to 2035 for the two scenarios is depicted in Figure 4, and the cumulative fuel savings from a no change baseline are given in Table 2. Note that this baseline includes some growth in overall fleet size and miles driven, but vehicle fuel consumption does not change: this baseline extrapolates the history of the past 20 years where powertrain efficiency improvements essentially offset the negative impacts on fuel consumption of increasing vehicle performance, size and weight.

For the "optimistic" scenario, the cumulative fuel savings from today to 2035 will be around 3,400 billion liters, while that in the "conservative" scenario will be 2,580 billion liters.

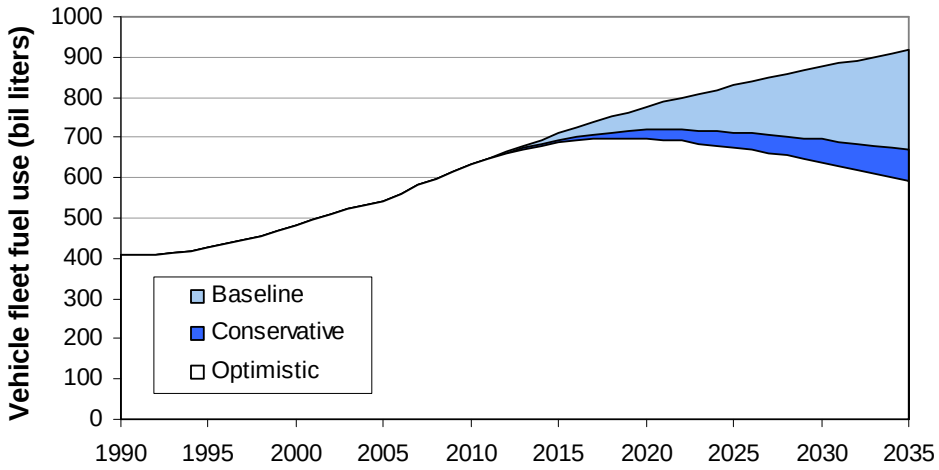

Figure 4. Corresponding U.S. in-use light-duty vehicle fleet annual fuel use

Cumulative fuel savings from baseline, billion liters	From today to 2020	From 2020 to 2035
Optimistic	326	3,159
Conservative	241	2,393

Table 2. Corresponding cumulative fleet fuel savings

Discussion

What insights can one obtain from exploring these scenarios? Firstly, the scenarios indicate that significant changes are needed to achieve the 35 mpg CAFE target as well as the factor-of-two target. Sales must shift towards smaller and lighter-weight cars, as opposed to large SUVs, minivans or pickups. Advanced technology vehicles with improved gasoline or diesel engines, and hybrid-electric vehicles must garner sizeable market shares. Meeting CAFE will require that all these technologies will necessarily be deployed together.

Secondly, the scenarios demonstrate that there are vehicle performance trade-offs associated with meeting the proposed targets. Future vehicle performance improvements will need to be moderated in the interest of advancing vehicle fuel economy instead. This requires commitment from automakers to market less powerful vehicles, and for consumers to curb their demand for them.

Finally, achieving these fuel economy targets will be effective in reducing the amount of fuel consumed by passenger vehicles. The cumulative fuel savings fleet-wide are substantial, as long as the proposed fuel economy standards are met and the rate of improvement sustained. The challenge now is to begin implementing the changes necessary to meet the CAFE standards by 2020 and beyond.

References

Cheah, L.; Evans, C.; Bandivadekar, A.; Heywood, J. B. (2007) Factor of Two: Halving the Fuel Consumption of New U.S. Automobiles by 2035, MIT Laboratory for Energy and the Environment, Cambridge, Massachusetts.